
Clinocardium nuttallii

Basket of heart cockle

Phylum: Mollusca

Class: Bivalvia, Heterodonta, Euheterodonta

Order: Cardiida

Family: Cardioidea, Cardiidae, Clinocardiinae

Taxonomy: This species was originally described as *Cardium nuttallii* (named after the zoologist, Thomas Nuttall) by Conrad in 1837. *Cardium* was later split into several groups and *C. nuttallii* was moved to the genus *Clinocardium*, which was designated by Keen in 1936 (Kafanov 1980; Schneider 2002). Other known synonyms include *Cardium californianum* and *Cardium corbis* (e.g. Fraser 1931; Weymouth and Thompson 1931). The distinctive shell morphology of *Clinocardium* (with some associated subgenera, see Kafanov 1980) is distinct within the subfamily Clinocardiinae (Karanov 1980). Taxonomy of the group is based largely on stomach and shell morphology (Schneider 1994, 1995).

Description

Size: Individuals up to 72 mm (Packard 1918), but often grows to greater size, particularly on northern beaches (Fraser 1931), where they can be up to 100 mm (Kozloff 1993).

Color: Warm brown when young and mottled. Adults are light brown (Kozloff 1993).

General Morphology: Bivalve mollusks are bilaterally symmetrical with two lateral valves or **shells** that are hinged dorsally and surround a mantle, head, **foot** and viscera (see Plate 393B, Coan and Valentich-Scott 2007). Cariids have distinctly inflated shells and central beaks, which is not seen in any other bivalve family (Kozloff 1993; Coan and Valentich-Scott 2007).

Body: (see Fig. 298, Kozloff 1993)

Color:

Interior: Ligament is entirely dorsal, and not internal. Labial palps are triangular

and consist of 30 ridges. The complex intestine is with 11 loops and the total length (from crystalline style to exit from visceral mass) is 300 mm (Schneider 1994). For diagram of internal anatomy see Schneider 1994.

Exterior:

Byssus:

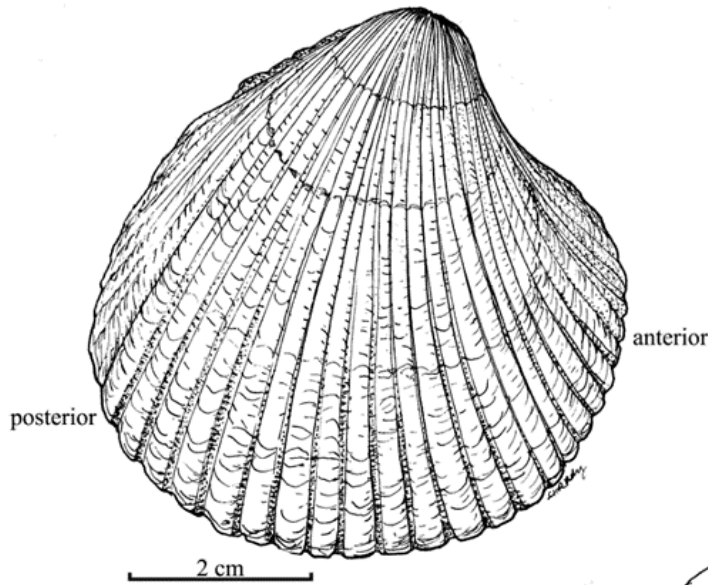
Gills: Gills are filibranch type, and are strongly plicated and fused to a siphonal septum posteriorly (Bernard and Noakes 1990; Schneider 1994). The outer demibranch bears 53–120 plicae (each plica comprises 40 filaments), while the inner has 75–110 (Schneider 1994). The gills in many suspension feeding bivalves are elongated and folded to increase filtering surface area (Barnard and Noakes 1990).

Shell: When viewed from the side (left or right valve), the shell is triangular, but when viewed from either end it is heart-shaped (Fig. 3) (hence “heart cockle”, Kozloff 1993). Usually approximately 34 ribs radiate outward from the shell umbo (fig. 1) and are crossed with concentric growth lines (Haderlie and Abbott 1980).

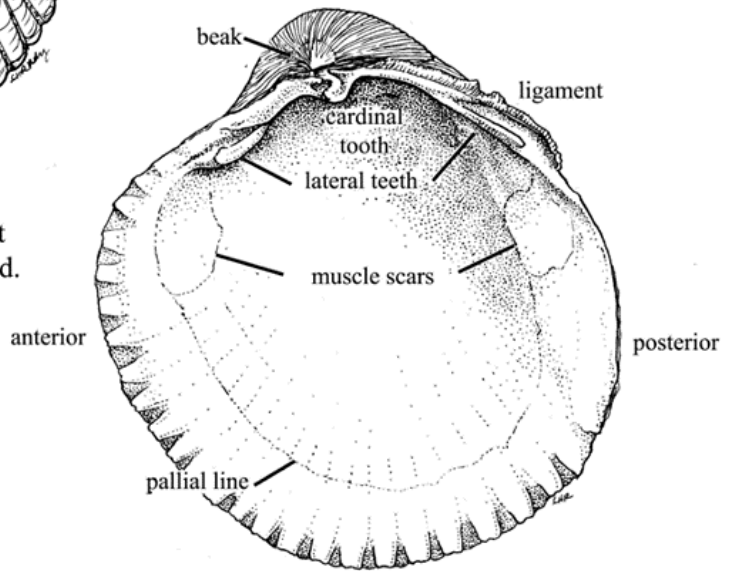
Interior: White, but not pearly. The anterior and posterior muscle scars equal in area (compare to *Adula californiensis*, this guide) and pallial line is simple. Known for its large foot and short siphon. Shell of *C. californiense* is composed of three layers including an inner layer that is cross-laminar, middle complex cross laminar, and outer that is prismatic in structure (Zhang et al. 2014).

Exterior: Shell as high as long (Kozloff 1974), or higher with individuals generally longer than wide during first year (Length: anterior to posterior) (Fraser 1931). Valves are

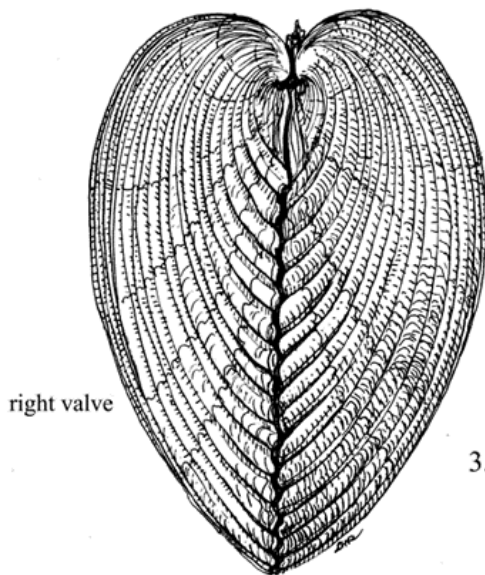
Clinocardium nuttallii



1. *Clinocardium nuttallii*, right valve 1.5x: 5.8cm, about 35 strong radial ribs; height greater than width; shell inflated, rounded.



2. Interior, right valve: beaks nearly central, directed anteriorly; surface white; scars equal, pallial line simple; one cardinal, two lateral teeth; ligament external.



3. Profile (anterior end): heart-shaped.

alike, and shell is inflated, triangular, and with rounded corners (Kozloff 1974). Shell thick, but rather brittle (Keep and Longstreth 1935). The posterior end is evenly rounded and smooth. The umbones are prominent (Abbott 1968), beaks nearly central and directed anteriorly (Keen and Coan 1974) (Fig. 2).

Hinge: Hinge is central, with one strong cardinal tooth, and an anterior and posterior lateral tooth in each valve (Fig. 2).

Eyes: Bears numerous, tiny eyes on optical tentacles on mantle margin (Haderlie and Abbott 1980).

Foot: Foot enables excellent digging (Ricketts and Calvin 1952; Coan and Valentich-Scott 2007). The large and strong foot can be used to push and flip the entire body (e.g., to escape predation from *Pycnopodia helianthoides*, Kozloff 1993; *Pisaster brevispinus*, Haderlie and Abbott 1980).

Siphons: No siphon tubes. Instead, siphons are simply holes in the mantle margin that allow for only a shallow burrow (Ricketts and Calvin 1952). *Clinocardium nuttallii* has 60 mantle tentacles, which are largely present dorsal to the excurrent siphon opening and extend to top of posterior adductor muscles (Schneider 1994).

Burrow: Shallow burrow is within 1 mm of surface (Ricketts and Calvin 1952; Chang and Levings 1989), so that the posterior end of the individual is situated just below the sediment (Kozloff 1993). Burrowing time is slowed (up to two-fold) in sediments bearing seagrass roots and/or invertebrate tubes (Brenchley 1982), however, a greater density of *C. nuttallii* was observed in mudflats that had eelgrass (*Zostera marina*) than those that did not (Galleher et al. 2012). If buried less than 50 mm (e.g., by dredging), *C. nuttallii* can open its siphon to filter feed after 24 hrs (Chang and Levings 1989).

Possible Misidentifications

The taxonomy (especially among higher-level taxa) of family Cardiidae, or cockles, has been thoroughly studied due to the diverse morphology and good fossil record (see Schneider 1992, 1994, 1995, 2002). It contains one to four species locally and *C. nuttallii* is the only species included in most recent keys (Coan and Valentich-Scott 2007). The family is within the Hederodonta and, as such, possesses few hinge teeth and is characterized by ovate and inflated shells with central beaks, hinges with lateral teeth, shell sculpture that is with radial ribs, a hinge ligament that is entirely external (see Plate 397B, Coan and Valentich-Scott 2007). They have shells that are generally not cemented to the substratum and a dorsal margin that is without ears (Coan and Valentich-Scott 2007). No other bivalve family has such an inflated shell and central beaks.

Clinocardium blandum is an offshore species, with distribution from Sonoma county, California northward, *Nemocardium centifoliosum* is also an offshore species and *Trachycardium quadragenarium* is a southern species, known from southern California to Monterey, California (Coan and Valentich-Scott 2007). *Nemocardium*, with few extant species, has a prominent shell sculpture, with posterior ribs only and an otherwise smooth surface (see Fig. 5, ter Poorten 2013).

Ecological Information

Range: Type locality is the Columbia River estuary in Oregon. Japan, Alaska and south along Pacific coast to San Diego (Weymouth and Thompson 1931; Haderlie and Abbott 1980). Fossils from the family Cardiidae are found along the north Pacific and European subarctic, and date to the Cenozoic (Kafanov 1980).

Local Distribution: Local distribution near bay mouths on tideflats in most Oregon estuaries as well as on exposed beaches south of

Oregon (Weymouth and Thompson 1931).

Habitat: Beaches of uniform, but not very coarse sand (Fraser 1931; "corn meal sand", Packard 1918; Ricketts and Calvin 1952). Often found in exposed beaches.

Clinocardium nuttallii occur in diverse habitats from exposed sandy beaches to fine bay sand (Fraser 1931), and large populations can be found in eelgrass/mud areas (Kozloff 1993).

Salinity: Not found in upper bays where salinities vary greatly.

Temperature:

Tidal Level: High and mid intertidal to deep waters, up to 200 m offshore in sandy areas or bays (Haderlie and Abbott 1980; Coan and Valentich-Scott 2007).

Associates: Small specimens are often host to young *Pinnixa faba* or *P. littoralis* (pea crabs) (Ricketts and Calvin 1971; Haderlie and Abbott 1980). Mantle, siphon, and foot tissue of individuals older than two years, found to house the green endosymbiotic alga, zoochlorellae (e.g. *Chlorella*), with a commensal or parasitic relationship suggested (Cooke 1975; Hartman and Pratt 1976; Jones and Jacobs 1992; Soo and Todd 2014).

Abundance: Not as abundant as other mollusks (e.g., *Saxidomus*, *Protothaca*, British Columbia, Canada, Fraser 1931). This species is the most abundant of its family on the west coast (Keep and Longstreth 1935). Abundant at Garrison Bay, Washington from -0.61 to +0.92 meters, with approximately 5–13 cockles per square meter (Gallucci and Gallucci 1982). In a comparison of abundance relative to other bay clams in two Oregon estuaries, *C. nuttallii* was found to be twice as abundant (Netarts Bay) and 7–9 times more abundant (Tillamook Bay) in subtidal than intertidal habitats (D'Andrea et al. 2015).

Life-History Information

Reproduction: Simultaneous hermaphroditism has been observed in this species (Edmondson 1920; Fraser 1931; Gallucci and Gallucci 1982). Spawning occurs annually from June–Oct in Oregon, April–Nov in San Juan Island (Haderlie and Abbott 1980; Garrison Bay, Gallucci and Gallucci 1982; Yaquina and Tillamook Bays, Oregon, Robinson and Breese 1982; Kabat and O'Foighil 1987), and June and July in British Columbia, Canada (Fraser 1931). Oocytes are 80 µm in diameter and are surrounded by a jelly layer that is 50 µm thick. Sperm are motile for up to 2 hours (at 4°C, Liu et al. 2008). Complete description of gametogenesis see Gallucci and Gallucci 1982.

Larva: Bivalve development generally proceeds from external fertilization via broadcast spawning through a ciliated trochophore stage to a veliger larva. Bivalve veligers are characterized by a ciliated velum that is used for swimming, feeding and respiration. The veliger larva is also found in many gastropod larvae, but the larvae in the two groups can be recognized by shell morphology (i.e. snail-like versus clam-like). In bivalves, the initial shelled-larva is called a D-stage or straight-hinge veliger due to the "D" shaped shell. This initial shell is called a prodissoconch I and is followed by a prodissoconch II, or shell that is subsequently added to the initial shell zone. Finally, shell secreted following metamorphosis is simply referred to as the dissoconch (see Fig. 2, Brink 2001). Once the larva develops a foot, usually just before metamorphosis and loss of the velum, it is called a pediveliger (see Fig. 1, Kabat and O'Foighil 1987; Brink 2001). (For generalized life cycle see Fig. 1, Brink 2001). At 15°C in the laboratory, development proceeds as follows: first cleavage after 1 hour, ciliated blastula at 10 hours, and early free-swimming veliger larvae after 18 hours (Kabat and O'Foighil 1987; Brink 2001). Early embryonic development stops at temperatures below 2.8°C (Liu et al.

2008). Larval growth increases with increasing temperature, but temperatures above 26.3°C are lethal (Liu et al. 2010).

Juvenile: Sexual maturity reached at 2 years (Haderlie and Abbott 1980; Gallucci and Gallucci 1982).

Longevity: 7 to 16 years (Fraser 1931; Weymouth and Thompson 1931; Haderlie and Abbott 1980).

Growth Rate: Northern populations, in contrast to southern, show a slower initial but more sustained growth, and reach the greater age and larger size (Weymouth and Thompson 1931). Annual growth rings are obvious, especially in northern specimens with cold winters, when growth is very slow. Shells may also show a growth pattern that correlates with tidal cycles. Bands or rings that are widely spaced are developed after spring tides and dense bands during neap times, when cockles experience more aerial exposure (Evans 1972; Haderlie and Abbott 1980). Shell growth lines (which are visible internally and externally) are added annually, beginning in later summer to early fall, with more faster growth occurring with warmer water temperature and more food (Svalbard, Ambrose et al. 2012). Growth is effected by several biotic and abiotic factors (e.g., ice cover in Svalbard, Tallqvist and Sundet 2000). First year cockles were approximately 34–50 mm in length, second year were 54–70, and third year 65–77 in Garrison Bay, San Juan Island, Washington (Gallucci and Gallucci 1982; Liu et al. 2010).

Food: Suspension feeders, *C. nuttallii* strain material through their gills, by pumping water through the pallial cavity using cilia that covers gill surfaces (Bernard and Noakes 1990). *Clinocardium nuttallii* can pump a volume of 2.51 liters per hour per gram body weight (Bernard and Noakes 1990). Although suspension and filter feeding can have a negative effect on larval settlement, settlement was not impeded by the siphonal

current of *C. nuttallii* (Ertman and Jumars 1988). Ingests larvae of other marine invertebrates (e.g., *Lepeophtheirus salmonis*, Webb et al. 2013). Pumping rates measured by Meyhofer (1985) were approximately 0.14 cubic centimeters per second per square centimeter unit gill area.

Predators: Known predators include sea otters (*Enhydra lutris nereis*, Kannan et al. 2004), sea stars (*Pycnopodia helianthoides*), birds, humans (e.g., First Nations, Liu et al. 2004; Lui et al. 2008), octopus, (*Octopus dofleini*, Hartwick et al. 1981). *Clinocardium nuttallii* tend to be “easy” prey, as they are often found on the surface of tide flats. As planktonic larvae, *C. nuttallii* are preyed upon by planktonic predators and suspension feeders. The life-history of *Clinocardium nuttallii* has undergone recent investigation into aquaculture potential in the northeast Pacific (e.g., Liu et al. 2010; Epelbaum et al. 2011; Dunham et al. 2013a, b).

Behavior: Can be very active, flipping to avoid predation with their large muscular foot and digging quickly. However, individuals do not burrow deeply or laterally.

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