Upogebia pugettensis

The blue mud shrimp

Phylum: Arthropoda, Crustacea
Class: Malacostraca
Order: Decapoda
Section: Anomura, Paguroidea
Family: Upogebiidae

Taxonomy: Dana described *Gebia pugettensis* in 1852 and this species was later redescribed as *Upogebia pugettensis* (Stevens 1928; Williams 1986).

Description

Size: The type specimen was 50.8 mm in length and the illustrated specimen (ovigerous female from Coos Bay, Fig. 1) was 90 mm in length. Individuals are often larger and reach sizes to 100 mm (range 75–112 mm) and northern specimens are larger than those in southern California (MacGinitie and MacGinitie 1949; Wicksten 2011).

Color: Light blue green to deep olive brown with brown fringes on pleopods and pleon. Individual color variable and may depend on feeding habits (see Fig. 321, Kozloff 1993; Wicksten 2011).

General Morphology: The body of decapod crustaceans can be divided into the **cephalothorax** (fused head and thorax) and **abdomen**. They have a large plate-like carapace dorsally, beneath which are five pairs of thoracic appendages (see **chelipeds** and **pereopods**) and three pairs of maxillipeds (see **mouthparts**). The abdomen and associated appendages are outstretched and shrimp-like in Upogebiidae (Kuris et al. 2007). For morphology of *Upogebia* (see Fig. 2, Williams 1986) and *U. pugettensis* see Williams (see Fig. 13, 1986).

Cephalothorax:

Eyes: Peduncle cylindrical (Schmitt 1921), eyestalks short but exceeding lateral rostral process. Corneas terminal and directed antero-laterally (Williams 1986).

Antennae: First segment of antennular peduncle has a sharp tooth at ventral border and second segment of flagellum has small, round disto-ventral spine (Wicksten 2011).

Mouthparts: The mouth of decapod crustaceans comprises six pairs of appendages including one pair of mandibles (on either side of the mouth), two pairs of maxillae and three pairs of maxillipeds. The maxillae and maxillipeds attach posterior to the mouth and extend to cover the mandibles (Ruppert et al. 2004).

Carapace: Bears two rows of 11–12 teeth laterally (Fig. 1) in addition to a small distal spines (13 distal spines, 20 lateral teeth on carapace shoulder, see Wicksten 2011). Carapace with thalassinidean line extending from anterior to posterior margin (Wicksten 2011).

Rostrum: Large, tridentate, obtuse, rough and hairy (Schmitt 1921), the sides bear 3–5 short conical teeth (Wicksten 2011). Rostral tip shorter than antennular peduncle. Two short processes extending on either side each with 0–2 dorsal teeth (Wicksten 2011).

Teeth:

Pereopods: Two to five simple walking legs. Second pereopod is not chelate and bears setae on lower segment margins. Carpus has small spines and merus has a single small spine. Pereopods 3–5 setose, decrease progressively in size and have dactyls with spinules (Wicksten 2011).

Chelipeds: First chelipeds approximately equal and subchelate (Fig. 1). Dactyls curved, with ridged upper surface and lateral surface with many tubercles (Wicksten 2011). Fixed finger slender (Williams 1986), with one conical tooth. Palm with setose lines, bearing setae and small teeth, as well as a sharp spine at dactyl base. Carpus with lateral and longitudinal furrow and spine with small teeth (4–10), two distal spines and, a larger marginal spine. The upper margin of the merus is curved and bears spines and small teeth (5–6). Ischium bears a single small spine (Wicksten 2011).

Abdomen (Pleon): Abdomen elongate and broad, not reflexed, extended, symmetrical and externally segmented. Bears four pairs of fan-like pleopods (Fig. 1).

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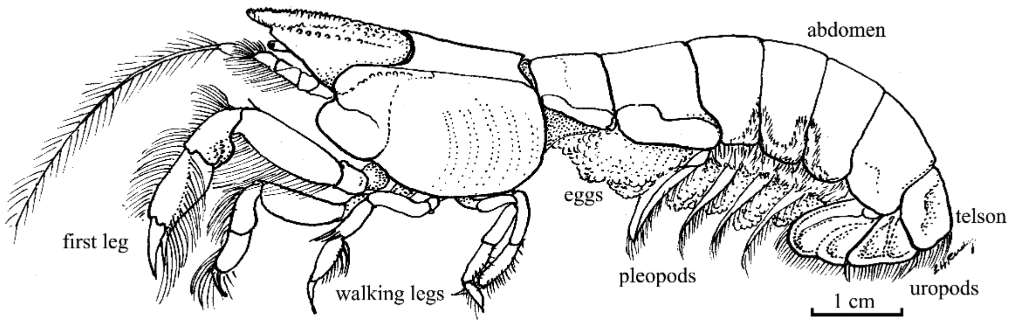
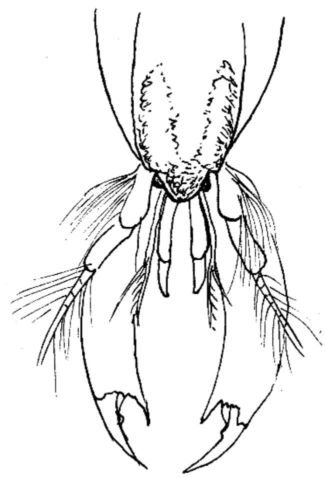
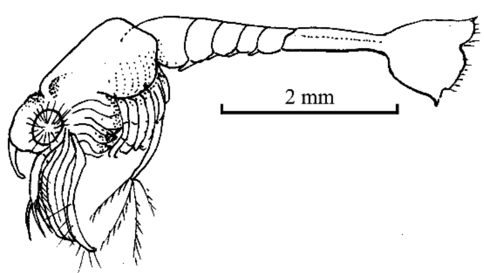
Upogebia pugettensis



1. *Upogebia pugettensis*, ovigerous ♀ x1 1/2: actual size: 9 cm; first legs equal and subchelate; legs 2,3,4,5 simple; four pairs of fan-like pleopods.



2. Head (dorsal view): hairy surface; rostrum: three teeth, eyestalks cylindrical, short; corneas terminal.



3. A larval form x15: first stage, about 5 mm.

Telson & Uropods: Telson wide anteriorly and uropod length exceeds that of the telson. Uropods bear dorsal ribs and marginal spines (Wicksten 2011). Fan-like tail formed by telson, uropods adapted for swimming.
Sexual Dimorphism: The first pleopod is absent in males and is slender, bi-articulating and simple in female *U. pugettensis* (Williams 1986).

Upogebiidae-specific Character

Burrow: *Upogebia pugettensis* builds U or Y-shaped burrows that are firm, permanent and simple with little branching (unlike *Neotrypaea californiensis*). Burrows extend vertically about 46 cm, then horizontally 0.6–1.2 m and up to the surface (MacGinitie 1930; Ricketts and Calvin 1971). Often, the entrance will have a gravel plug if the tide is out (Stevens 1928). The walls are smooth and mucus lined (MacGinitie and MacGinitie 1949). For figure see MacGinitie (1930).

Possible Misidentifications

Upogebiidae is described by Williams (1986) and Campos et al. (2009) and the single local species, *Upogebia pugettensis* (the blue mud shrimp) often co-occurs with *N. californiensis*. *Upogebia pugettensis* is easy to recognize because it is larger and its color (bluish and never red or pink) is strikingly different. Its burrows are also more firm and substantial. The most noticeable morphological difference between these species is the first pair of legs: both of which are small, sub-chelate and equal in *U. pugettensis*. Furthermore, its rostrum is hairy and has a laterally compressed and slender tip of the short fixed finger of the chela (Wicksten 2011).

Characteristics defining the Callianassidae are described by Sakai (1999) and Campos et al. (2009). There are three species locally, *Neotrypaea californiensis*, *N. gigas* and *N. biffari* (Kuris et al. 2007). *Neotrypaea californiensis* can be distinguished from the other two species by the lack of a prominent rostrum (present in *N. gigas*) and eyestalks that are acute and diverging tips of the eyestalks (rather than short, blunt and not diverging in *N. biffari*) (see Campos et al. 2009). *Neotrypaea gigas* is larger (to 125–150 mm) than the other two, and relatively rare in sandy sublittoral habitats. Its rostrum is sharp, with prominent medial tooth (not found in *N. californiensis*), and its first chela closes without a gap. It is more common in its southern distribution, south of Point Conception (Barnard et al. 1980; Kuris et al. 2007; Wicksten 2011). *Neotrypaea gigas* and *N. californiensis* also differ in the morphology of the second pereopod: In *N. californiensis* the propodus and dactyl are of equal length and in *N. gigas*, the propodus is curved and wider than the dactyl (Kuris et al. 2007). Recent examination of these two species using morphological and molecular data suggests that the key characters for differentiating species is the length of eyestalks and shape of the distal outer edges (Pernet et al. 2010).

Ecological Information

Range: Type locality is Puget Sound, Washington. Known range includes Alaska to Morrow Bay, California (see Fig. 1, Williams 1986; Wicksten 2011). Southern populations of *U. pugettensis* become replaced by the congener, *U. macginitieorum* (Kuris et al. 2007).
Local Distribution: Oregon estuaries and sloughs including Alsea, Nestucca, Netarts, Yaquina, Coos Bay.
Habitat: Estuarine mudflats (in areas without *Zostera*, Stevens 1928), in mud or sandy mud, often with some gravel. In adaptation to living in an environment that is relatively low in oxygen, *N. californiensis* and *U. pugettensis* exhibit low metabolic rates and can both survive periods of anoxia. *Upogebia pugettensis* has a higher metabolic rate and cannot survive periods of anoxia as well as *N. californiensis* (Thompson and Pritchard 1969a; Barnard et al. 1980; Zebe 1982).
Salinity: Collected at salinities of 30. A strong hyperosmotic regulator, their lower lethal limit is 3.5 (Thompson and Pritchard 1969b; Barnard et al. 1980).
Temperature:
Tidal Level: Intertidal to shallow subtidal, near shore (Wicksten 2011). Mid to lower intertidal of bays (Stevens 1928; Kuris et al. 2007) and usually lower than *N. californiensis.* Occasionally small individuals occur quite high in the intertidal (Ricketts and Calvin 1971).

Associates: The blue mud shrimp, *Upogebia pugettensis*, is found overlapping the range of *N. californiensis*, though it is generally found in lower intertidal burrows and in muddier sediments. Common commensals in ghost shrimp burrows include a polynoid worm *Hesperonoe*, pinnotherid crabs (*Scleroplax glanulata*), copepods (*Hemicyclops, Clausidium*), the shrimp *Betaeus harrimani*, the bopyrid isopod *Ione cornuta*, the goby *Clevelandia*, the echiuroid worm *Urechis caupo*, and the clam *Cryptomya californica* (MacGinitie 1934; Kuris et al. 2007; Campos et al. 2009; Wicksten 2011). The parasitic bopyrid isopod, *Orthione griffenis*, was introduced to the Pacific coast from Asia in the 1980s and is thought to have caused the 2002 collapse of *U. pugettensis* on the Pacific coast (e.g. Willapa Bay, Washington, see Fig. 1, Dumbauld et al. 2011; Williams and Boyko 2012). This parasite was discovered in Yaquina Bay, Oregon in 1999 and was the first parasite known from the gills of *Upogebia* in western North America (Markham 2004; Chapman et al. 2012). Larvae of the commensal phoronid, *Phoronis pallida*, exhibit increased swimming speed and settlement behavior in the presence of *Upogebia*-conditioned seawater (Santagata 2004).

Abundance: Can be locally common (Kuris et al. 2007). In Willapa Bay, Washington, the density of *N. californiensis* (up to 450 shrimp per m^2) was always higher than that of the other locally occurring ghost shrimp, *U. pugettensis* (up to 100 shrimp per m^2) Dumbauld et al. 1996).

Life-History Information

Reproduction: Each burrow inhabited by one pair (Barnard et al. 1980). Ovigerous females found December and February (Elkhorn Slough California, MacGinitie and MacGinitie 1949), October through May (Willapa Bay, Washington, Dumbauld et al. 1996) and early April (South Slough, Coos Bay, Oregon). Eggs carried under abdomen on pleopods (Fig. 2). *Neotrypaea californiensis* reach sexual maturity at 2 years and produce 3,900 eggs while *U. pugettensis* produces 7,100 (Dumbauld et al. 1996).

Larva: The larvae of *U. pugettensis* are found in plankton samples from February to June and their morphology was described by Hart (1937). Larval development in *U. pugettensis* proceeds via three zoea stages and, a final megalopa stage, each marked by a molt (Hart 1937; Puls 2001). *Upogebia pugettensis* zoea have rostrum shorter than antennules (1/3 antennule length, compare to Callianassidae), five abdominal segments, swimming setae on exopods and maxillipeds, and triangular telson with indentation at posterior margin with five setae, unlike *N. californiensis*, which have a medial tooth at telson posterior (see paguroid zoeae Fig. 53.2, Harvey et al. 2014: Hart 1937; Puls 2001). Larval size (measured from tip of rostrum to tip of telson) proceeds from 3.7 mm (Zoea I, Fig. 3), to 4.4 mm (Zoea II), to 5.4 mm (Zoea III) (Puls 2001). Megalopae are shrimp-like in morphology with blunt rostrum, pereopods and maxillipeds resembling adults. The telson becomes rectangular and has rounded uropods laterally. Pleopods on abdominal segments 2–5 have setae (Puls 2001). *Upogebia pugettensis* larvae recruit in spring (April-June) (Willapa Bay, Washington, Dumbauld et al. 1996).

Juvenile: Sexual dimorphism occurs before maturation in *U. pugettensis* (unlike *N. californiensis*), where claw size occurs almost immediately (<1 year old), when individuals are 4–5 mm in (carapace) length (Dumbauld et al. 1996).

Longevity: Moderately long lived (Ricketts and Calvin 1971).

Growth Rate: Growth occurs in conjunction with molting. In pre-molting periods the epidermis separates from the old cuticle and a dramatic increase in epidermal cell growth occurs. Post-molt individuals will have soft shells until a thin membranous layer is deposited and the cuticle gradually hardens. During a molt decapods have the ability to regenerate limbs that were previously autotomized (Kuris et al. 2007). The growth rate for U. pugettensis is approximately 4–5 mm (carapace length) per year (Dumbauld et al. 1996).

Food: Detritivore, obtaining food by filtering water through the burrow as it sits near the entrance. Individuals make a “basket" (MacGinitie 1930) with its first and second pereopods, which have long setae. Griffen et al. (2004) estimated filtration rates for *U.*

pugettensis and its commensal bivalve *Cryptomya californica* at three phytoplankton densities (low, medium and high).. They found that *U. pugettensis* removed 57, 53 and 40% of phytoplankton drawn into the burrow, while *C. californica* removed 12, 19 and 39%, respectively.

Predators: Adults are used by humans for fish bait, individuals avoid predation by retreating to burrow. Juveniles and larvae are eaten in the plankton (e.g. fish).

Behavior: Ghost shrimp species (*Neotrypaea*, *Upogebia*) are known to be ecosystem engineers with the ability to regulate and change community (macro and microbial communities) structure by burrowing and deposit feeding (Dumbauld and Wyllie-Echeverria 2003; Bertics and Ziebis 2009). Their presence and behavior effects biogeochemical composition including sediment grain size, nutrient exchange (D'Andrea and DeWitt 2009) and organic composition. Bioturbation (Kristensen et al. 2012) turns over and re-suspends sediment, which can increase erosion and sediment instability, having a negative effect on algae and seagrasses that require light for photosynthesis (e.g. *Zostera*, Dumbauld and Wyllie-Echeverria 2003) and suspension feeders (e.g. oysters, Dumbauld et al. 1996). In turn, seagrasses tend to solidify sediment and are not suitable habitats for ghost shrimp species (Berkenbusch et al. 2007). In controlled experiments, the presence of *U. pugettensis* lowers abundances of other estuarine crustaceans and polychaetes (Posey et al. 1991).

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