Pisaster ochraceus

Common Pacific sea star, ochre sea star, purple sea star

Phylum: Echinodermata, Asterozoa

Class: Asteroidea

Order: Forcipulatacea, Forcipulatida

Family: Asteriidae

Taxonomy: The genus *Pisaster* includes three Pacific coast sea star species, including *Pisaster ochraceus*. One can find many historic synonyms for *P. ochraceus*, including *P. confertus* and *P. fissispinus* for this species, but they are not currently used. Furthermore, two subspecies were erected for *P. ochraceus* in 1996 (Clark) but morphological and genetic data does not support this designation and, instead, recognizes the single species *P. ochraceus* (Stickle et al. 1992; Lambert 2000; Frontata-Uribe et al. 2008). Before becoming a member of the genus *Pisaster,* this species belonged to the, currently accepted, genus *Asterias* (synonyms *A. ochracea*, *A. fissispina*, *A. ianthina*, *A. janthina*, *A. margaritifera*) or the former genus *Asteracanthion* (now *Asterias*).

Description

Size: Average size (Monterey, California) is 140 mm in diameter, where each ray (arm) is 40 mm in length (Fisher 1930). The illustrated specimen is 150 mm in diameter. Puget Sound specimens are regularly 250 mm in diameter (Kozloff 1993). Weight ranges (wet weight) from 37.8–8.34 g (28 animals, Feder 1970).

Color: Aboral (dorsal) surface red, purple, brown or ochre (especially on open coast) (see Plate 25, Kozloff 1993). Specimens most commonly purple (Puget Sound, Washington). Oral (ventral) surface ochre. Juveniles gray with brown aboral patches (Feder 1970). Body color may vary with geographic region. Harley et al. (2006) found more brown (68–90%) and orange (6–28%) individuals in Washington (Olympic Peninsula), Oregon and California but more (95%) purple individuals in British Columbia and Puget Sound, Washington. This variation in color could be due to the predominating food source for *P. ochraceus* in the two regions, where mussels are more common in Washington, Oregon and California but barnacles are the most common food source in British Columbia and Puget Sound sites (Harley et al. 2006; see also http://echinoblog.blogspot.com/search/label/Pisaster%20ochraceus).

General Morphology: Sea stars (Asteroidea) are conspicuous members of the intertidal and subtidal. Their bodies are composed of a **central disc** from which arms or **rays** extend. The star-shaped body can be divided into the **oral** (or ventral) side where the mouth is located and **aboral** (or dorsal) side.

Body: Stiff body morphology that is hard to the touch.

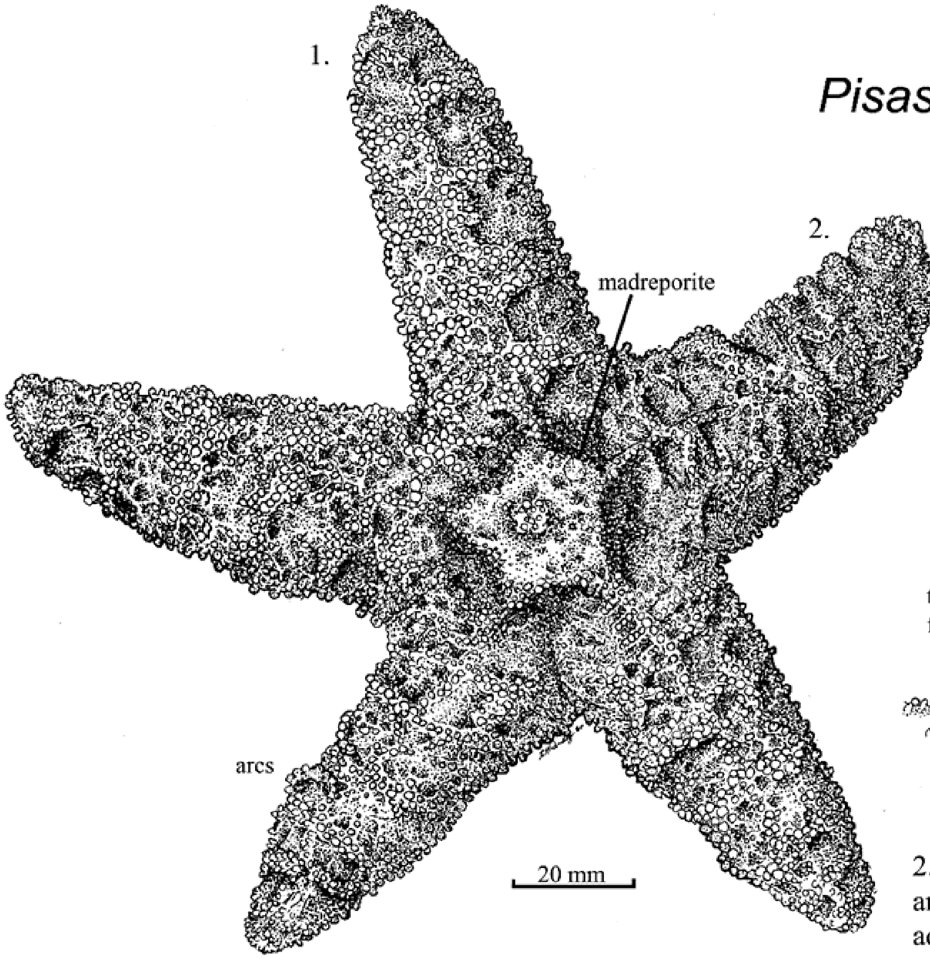
Rays: Five rays (unless damaged, can range from four to seven rays, Feder 1980). Each ray is tapering, thick, large, not sharply demarcated from disc and broadest where they join the central disc (Dyakonov 1950), but not broad enough to give webbed appearance (as in *Patiria* spp.).

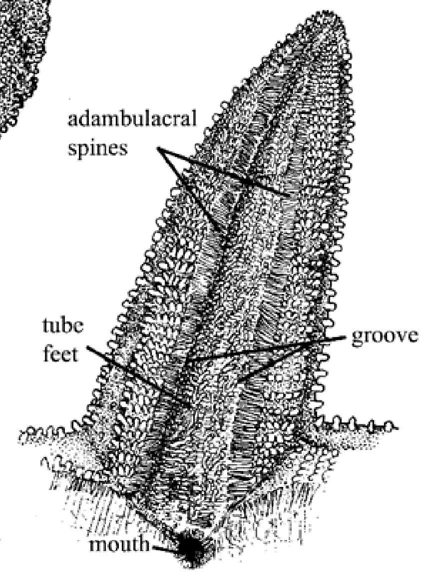
Central Disc: Large, convex, arched, not distinct or as disc-like as in Ophiuroidea (brittle stars). Contains (conspicuous) madreporite (Figs. 1, 3) and (less conspicuous) anus. Diameter of disc less than 1/3 body diameter.

Aboral Surface: Aboral surface rough in texture and red, purple, brown or ochre in color.

Spines: Low, small, serrated, rounded, bead-like or papillate (Figs. 1, 3). Spines form crescentic arcs at arm tips. No straight mid-

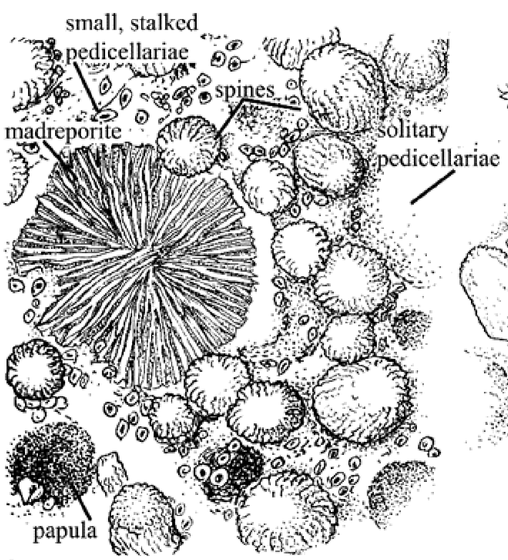
Pisaster ochraceus

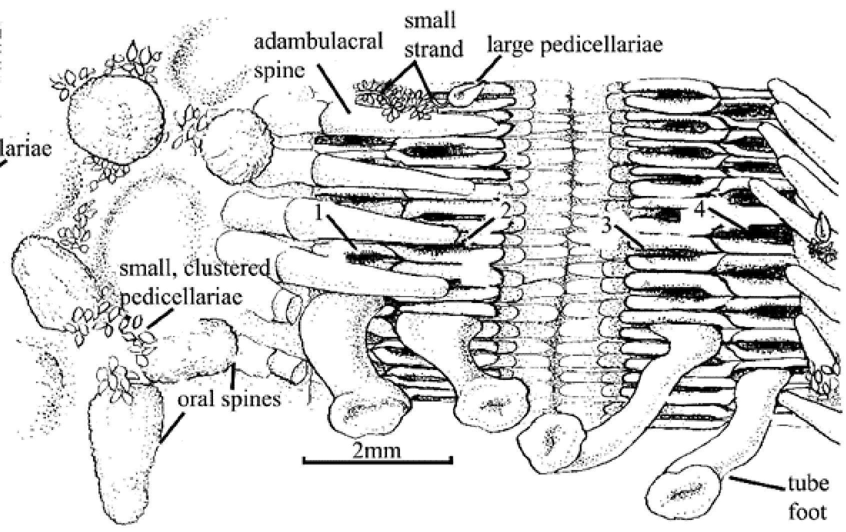




2. One ray (ventral view): ambulacral groove with tube feet; adambulacral spines.

1. *Pisaster ochraceus* (dorsal view) x1: stiff, harsh surface; reticulated pattern, spines in arcs; five thick, tapering arms; large arched central disc.





3. Madreporite, dorsal spines x12: madreporite large, flat, filter-like; dorsal spines short, rounded, bead-like; pedicellariae stalked, small, clustered; sessile, large, solitary.

4. Ambulacral groove (ventral view) x12: all tube feet removed except four, to show four rows across groove; adambulacral spines along groove; pedicellariae small, clustered on expandable strands; small and clustered at bases of oral spines.

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dorsal row of arm spines. Spines in center of disc form a distinct star in the illustrated specimen (Fig. 1). Two types of spines include: (1) small, clustered around dorsal spines and (2) a few solitary, large, sessile pedicellariae scattered over dorsal surface (Fig. 3).

Madreporite: A sieve-like structure which serves as the water intake into the stone canal is conspicuous about 1/3 of radius from center of disc (Fig. 1, between arms numbered 1 and 2).

Pedicellariae:

Anus: Inconspicuous, near center of aboral surface and is surrounded by small pedicellariae.

Oral Surface: Oral surface ochre in color and consists of hard, textured extension of aboral surface and ambulacral grooves running the length of each arm and converging at the mouth. Grooves are more fleshy in texture from presence of tube feet.

Spines: Spines serrated, blunt, heavy and more spine-like than bead-like (Fig. 4). Adambulacral spines (lining ambulacral grooves) are articulated, long, thin (Fig. 4). Three types of spines ventrally: (1) small, clustered around bases of oral spines (Fig. 4); (2) small pedicellariae clustered on expandable strands between adambulacral spines (Fig. 4); and (3) large pedicellariae on these same strands (Fig. 4). There are no pedicellariae on the adambulacral spines (*Pisaster*, Fisher 1930; Hyman 1955).

Mouth: Large, in center of disc (Fig. 2). *Pisaster* species can extrude the stomach through this opening, engulfing food and initiating digestion externally (Feder 1980).

Pedicellariae: Stalked or sessile appendages used for removing invaders (e.g. barnacles larvae) or deterring predators (e.g. *Leptasterias hexactis*, Wobber 1975; *Solaster dawsoni*, Van Veldhuizen and Oakes 1981). Pedicellariae are bird beak-like and two-jawed in *Pisaster* species.

Tube Feet: Used in locomotion and part of water vascular system. Present on ventral side in ambulacral grooves where they are staggered in pairs, four rows across and down each ambulacral groove (Fig. 4).

Ambulacral Grooves: Grooves are long furrows on oral surface of arms, which contain tube feet (Figs. 2, 4) (Boolootian 1966). Along each edge of groove are adambulacral spines intermixed with stalked clustered pedicellariae (Fig. 4).

Possible Misidentifications

Among the large five-armed sea stars, *Pisaster* species are noted for their thick arms, low papillate dorsal spines and pedicellariae. Two other Asteriidae species share these characteristics: (1) *Evasterias troschelii* is a low intertidal species with a small disc and slender arms compared to *P. ochraceus* and a varied, though generally orange-red coloration (Mah 2007). *Evasterias troschelii* has clusters of pedicellariae on its adambulacral spines, not just at their bases as in *P. ochraceus.* (2) *Orthasterias koehleri* has sharp dorsal spines, not blunt papillate ones. These spines are each surrounded by a distinct ring of large pedicellariae and the dorsal spines are arranged in distinct radial rows (those of *P. ochraceus* are not). *Orthasterias koehleri* is often red with yellow mottling and it occurs in the low intertidal and subtidally (Mah 2007).

Two other species of *Pisaster* can be found locally: (1) *Pisaster brevispinus* occurs not on rocks and pilings but on soft substrates, where it feeds on clams. Its aboral spines do not form reticulated patterns or arcs, but occur singly or in groups of two or three, and are separated by areas of soft tissue. *Pisaster brevispinus* has a straight, distinct row of mid-dorsal spines on each arm. This sea star is nearly always pink and it can be mottled with gray-green or maroon-purple color as well (Mah 2007). It is one of the largest asteroids, growing to 320 mm in diameter (Hyman 1955). (2) *Pisaster giganteus* is bluish gray and its dorsal spines are blunt, clubbed, each surrounded by a ring of blue flesh and around that a ring of pedicellariae. It has tiny pedicellariae that are thickly scattered between the dense spines and its spines are not arranged in radial or concentric rows. *Pisaster giganteus* is a low intertidal sea star usually found further south than Oregon. Despite its name, it is usually smaller than *P. ochraceus* (Ricketts and Calvin 1971; Mah 2007).

Sea stars are extremely variable intra-specifically. Fisher listed three forms ("forma") of *P. ochraceus* (Fisher 1930). Although these names are not used, taxonomically, it should be noted that the Puget Sound, Washington and Oregon outer coast variety of *P. ochraceus* has a flatter, smoother surface ornamentation than does our Oregon bay form (Roberts, personal communication). Subspecies have also been reported for *P. ochraceus* including *P. o. ochraceus* (north of Point Conception, California) and *P. o. segnis* (south of Point Conception) (Clark 1996), but morphological evidence and genetic homogeneity across populations of supposed subspecies and morphological forms (e.g. "forma" Fisher 1930; Harley et al. 2006) supports the single species *P. ochraceus* (Stickle et al. 1992; Lambert 2000; Frontana-Uribe et al. 2008; see also http://echinoblog.blogspot.com/search/label/Pisaster%20ochraceus).

Ecological Information

Range: Type locality is near Willapa Bay, Washington (Ahearn 1995). Range includes Sitka, Alaska south to Baja, Mexico (Ricketts and Calvin 1971). Reported subspecies with differing distribution include *P. o. ochraceus,* occurring north of Point Conception, California and *P. o. segnis,* which is found south of Point Conception (Clark 1996). However, these populations are likely a single species based on morphological and molecular evidence (e.g. Frontana-Uribe et al. 2008).

Local Distribution: Locally in Coos Bay and along the rocky shores of Cape Arago. Typically occurs on the open sea coast as well as in bays on jetties and pilings only in marine parts of large bays.

Habitat: Jetties, rocks, pilings, bay mussel beds and hard substrates. Larger individuals can stand prolonged exposure to air (Feder 1970). Body morphology has been shown to correlate with wave exposure, where thinner and lighter individuals are found in areas with more intense wave exposure (Hayne and Palmer 2013).

Salinity: Collected at salinities of 30 or higher and cannot tolerate long-term exposure to reduced salinities.

Temperature: Cold to temperate. *Pisaster ochraceus* is more tolerant to aerial exposure than other *Pisaster* species, e.g. *P. brevispinus*, (up to 50 hours exposure), but does not tolerate warm temperatures and/or low oxygen levels (Feder 1980).

Tidal Level: Intertidal to 88 meters (Feder 1980). Large sea stars usually found at low tide mark in Puget Sound, Washington (probably for warmth), but they do not move to the lower intertidal in Monterey, California (Feder 1970).

Associates: Mussels, barnacles, limpets and other snails. Other inhabitants of the mussel bed include polychaetes, anemones and nematodes. On pilings in quiet waters, associates include barnacles, anemones (e.g. *Metridium senile*) and tunicates (Ricketts and Calvin 1971). The parasitic ciliate *Orchitophrya stellarum* causes castration in males (Leighton et al. 1991). Several incidences of sudden sea star die off have occurred since 1972, but the most recent to the northwest coast of North America began in June 2013 and is called sea star wasting disease. Affected individuals have ectodermal lesions and tissue decay that eventually leads to death (within 2–3 days). The water-vascular system loses the ability to maintain hydrostatic pressure and individuals often look flaccid when infected. Increased temperature further heightens infection intensity (Bates et al. 2009). The current die off of sea stars is the most significant due to its widespread geographic range and large number of species infected (Hewson et al. 2014). Recently, researchers determined this disease is most likely associated with a family of single stranded DNA viruses (densovirus, *Parvoviridae*) and is now called sea star-associated densovirus (SSaDV). Incidentally, this same virus was detected in museum specimens and, thus, may have been present on the Pacific coast and undetected since those specimens were collected in 1942. Although the specific pathogen is not known in certainty, SSaDV is currently the most likely candidate (Hewson et al. 2014).

Abundance: The most conspicuous sea star of rocky intertidal areas (Puget Sound, Washington, Kozloff 1993; Mah 2007).

Life-History Information

Reproduction: Forcipulate asteroids primarily have separate sexes and free-swimming planktonic larvae (Fisher 1930; Chia et al. 1987). *Pisaster* species do not brood their eggs or young as do some Asteriidae (e.g. *Leptastarias,* Mah 2007). Many species can be induced to spawn and are routinely used in developmental research. One pair of gonads is present in each arm and, when spawning, sea stars lift their body supported by their arms and gametes are released through gonopores on the aboral surface (Chia et al. 1987). Ten gonads, like feathery tufts, two in each ray, occur next to the central disc in *P. ochraceus*. The spawning period is from March to June (Monterey, California Feder 1956, 1980) with peak spawning from May–June (San Juan Islands, Washington, Chia et al. 1987; Miller 2001). Eggs of *P. ochraceus* are pale orange and 150–160 μm in diameter and a 400 g female can produce up to 40 million eggs (Menge 1975). The gametogenic cycle of both sexes is regulated by photoperiod (Chia et al. 1987). At 12˚C, development proceeds as follows: 2 cells at 5hr, 4 cells at 6hr, 8 cells at 7hr, hatching at 29–32 hr, gastrula at 44–63 hr, planktotrophic bipinnaria larva at 5d post fertilization (Chia et al. 1987).

Larva: Embryos develop into planktotrophic larvae called bipinnariae (Chia et al. 1987; Miller 2001). These larvae are approximately 400 μm in length and metamorphose into juvenile sea stars after 76–228 days when they are 0.5 mm in length. Bipinnaria larvae are easily recognizable in the plankton (Fig. 26.1, 26.2, Chia et al. 1987), they are large, fleshy and uniformly ciliated with a distinct, continuous ciliated band that is used for feeding and swimming. Larvae have a large mouth, esophagus, intestine and anus. They can have many long arms, increasing in number with age and can become long and floppy (Fig. 3, Miller 2001). The juvenile sea star develops from the left posterior portion of the larval body. Late stage bipinnaria develop three arms (called brachiolar arms) and a central adhesive disc, anteriorly. Larvae at this stage are called brachiolaria (see Fig. 4, Miller 2001) and they use these arms to attach to the substratum at metamorphosis.

Juvenile: Sexual maturity is reached at five years when individuals are 70–95 g (wet weight) (Menge 1975).

Longevity:

Growth Rate: Varies with food availability and microhabitat (e.g. wave exposure). With constant food supply and proper conditions, a sea star can feed continuously and increase its weight from 2–30 times in a year (Feder 1970). It can survive at least 20 months without feeding. An individual's size is not related as much to age as to food availability. Calmer conditions in a bay ensure greater opportunities for feeding than do open coast conditions (Feder 1970). Asexual regeneration of arms is a characteristic of the Asteroidea. Regeneration of entire individual can occur from small portions of the arm, but is not possible without some portion of the central disc (Fisher 1930).

Food: Omnivorous (Mauzey et al. 1968). Favorite prey seems to include *Mytilus* (Mauzey et al. 1968), on which it grows fastest, but individuals also eat barnacles, clams, crabs, chitons. Prey items (e.g. mussels) are pulled open such that *P. ochraceus* can insert its stomach and begin digesting material externally. Individuals may feed year-round in central California, but less in winter months in Puget Sound, Washington (Feder 1980). Somewhat aggressive predators, *Pisaster* species are known to elicit escape responses in a variety of prey items (e.g. mollusks, crabs, other sea stars, Feder 1980). The common predator of the lower *Mytilus* beds (Ricketts and Calvin 1971). In the 1969, Paine described the selective predation of *P. ochraceus* on *Mytilus* species in shaping community structure and coined the term "keystone species" for *P. ochraceus*. Predation by *P. ochraceus* shapes the vertical zonation and community structure of rocky intertidal communities (e.g. Paine 1974, 1976, 1995; Mah and Blake 2012).

Predators: Seagulls (on adults), and other sea stars (e.g. *Solaster dawsoni*, Van Veldhuizen and Oakes 1981).

Behavior: Can right itself vigorously when oral surface is detached from substrate and can modulate store of fluid in response to outside air temperature during low tide (Pincebourde et al. 2009). Some invertebrates, (e.g. limpet *Lottia*) can avoid *P. ochraceus* by a special escape mechanism (see *Lottia pelta* in this guide).

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