

LEAST WANTED AQUATIC INVADERS FOR ELKHORN SLOUGH AND THE MONTEREY BAY AREA

*A guide for recognizing and reporting
potential aquatic invaders,
to prevent their establishment and spread*



This early detection program
is sponsored by:

**Elkhorn Slough National Estuarine Research Reserve
Monterey Bay National Marine Sanctuary
California Sea Grant Program**

Information in this booklet can also be viewed
on-line or downloaded as a pdf from:

<http://www.elkhornslough.org/invader>

HOW YOU CAN HELP DETECT NEW INVASIONS

- Familiarize yourself with the “least wanted invaders” described in this booklet. Review this booklet regularly.
- Bring this booklet with you and keep your eyes open for these species when you are in aquatic habitats in the Monterey Bay region.
- If you find something closely resembling one of the least wanted invaders, carefully collect a single voucher specimen (or at least take a photo or careful descriptive notes), and write down your exact location.
- Immediately contact the Elkhorn Slough National Estuarine Research Reserve at (831) 728-2822 to report sightings of any of these species; explicitly state that you are making an "urgent invasive report".
- Bring your voucher specimen to the Reserve (or arrange for it to be picked up at your convenience) for confirmation of the identification.
- By participating in this early detection program, you will help to protect our rich coastal ecosystems from aquatic invasions by non-native species.

The Monterey Bay is the focus of this program, but we welcome reports from as far south as Morro Bay and as far north as Moss Beach.

HOW YOU CAN PREVENT THE SPREAD OF INVASIVE SPECIES

- Make sure to dispose of unused fishing bait properly (in garbage cans, not aquatic habitats).
- Never dump aquarium contents into natural waterways or drainages that feed into them.
- When possible, clean boats and trailers before moving them between different areas (in particular, before bringing a badly fouled boat from a highly invaded area such as San Francisco Bay to a relatively pristine area such as Monterey Bay).
- Never bring any plants or animals home from travels abroad.
- Clean hiking boots and camping gear, and muddy car tires before and after excursions.
- When hiking be careful not to disturb natural terrestrial areas, and when diving take care not to disturb natural aquatic areas.
- Use native or at least non-invasive ornamental plants in landscaping and encourage nurseries to stop stocking highly invasive non-native plants.
- Do not attempt eradication of aquatic invaders yourself (fragmentation of algal species during removal attempts may increase spread).

AN EARLY DETECTION PROGRAM FOR AQUATIC INVADERS

Invasions of non-native organisms are now considered one of the leading causes of loss of global biodiversity. Hundreds of aquatic species have been introduced by humans, intentionally and accidentally, to coastal regions around the world, and introductions continue unabated. Some of these non-native species have been shown to have dramatic detrimental effects on native ecosystems. They may outcompete or prey on native species, affect community dynamics and food webs, or alter the physical structure of habitats.

Once non-native species are established and widespread, they can be difficult or impossible to control. However, if detected soon after initial invasion, non-native species can sometimes be successfully eradicated. The Elkhorn Slough National Estuarine Research Reserve, in partnership with the Monterey Bay National Marine Sanctuary and with funding from the California Sea Grant Program, has therefore developed an early detection program to widely disseminate information about potential invaders to local citizens frequenting aquatic habitats. Following confirmed reports of invasions by these species, a partnership of regional organizations will work together to implement the most appropriate rapid response strategy.

This booklet describes two dozen “least wanted” invaders. These are species that are not yet present in the Monterey Bay region, but have successfully invaded other coastal regions, becoming extremely abundant, spreading rapidly, and posing a threat to native ecosystems. These species were chosen because of their relatively large size and ability to be identified in the field by non-experts, and because of their history of invasion in other similar areas.

Caulerpa (*Caulerpa taxifolia*)



Description: Caulerpa resembles a network of bright green feathers, each about 1 cm wide, up to 65 cm high, and spaced about 2 cm apart along a root-like structure. While there are superficially similar native species, Caulerpa is more robust in structure, and has all the feather-like fronds growing in one plane. Moreover, our native species are typically only found in tiny tufts, while a typical early infestation of Caulerpa can measure from one to many meters in size. *Note: when collecting a specimen of Caulerpa to bring in for identification, be very careful just to remove one frond without fragmenting the rest of the infestation.*

Habitat: Caulerpa can colonize a variety of aquatic settings, such as sandy bottom habitats, rocky outcroppings, and mud flats. It can occupy both polluted and non-polluted waters, of the open coast and bays.

Origin: Northern Australia

Invaded Areas: Southern California, Europe (Mediterranean), and Southern Australia.

Concerns: Caulerpa can spread rapidly, carpeting the substrate and choking out native algae and invertebrates. In the Mediterranean, this species has become remarkably abundant and has grown over rocky reefs and has established itself among coral reef communities. Because of its ability to withstand a wide range of environments, the potential for invasions into new locations is great. Natural predators on Caulerpa are scarce, and its toxic leaves deter algae-eating organisms in newly invaded areas from keeping Caulerpa's growth under control. While ocean currents may facilitate the transfer of fragments into new locations, it is believed that anchor and fishing lines carrying fronds of Caulerpa are the principal modes of transfer. Moreover, fragments can survive out of water for up to 10 days. Another mode of introduction is through the aquarium trade and dumping of aquarium contents in local bays.

Description: This golden-brown kelp grows in one plane (it is flat), with leaf-like pinnae attached to a central midrib that is usually lighter in color than the rest of the frond. Frilly, ribbon-like reproductive structures (sporophylls) can occur at the base of the frond. Each frond is about 1-3 m in length, and Wakame is often found in dense aggregations.

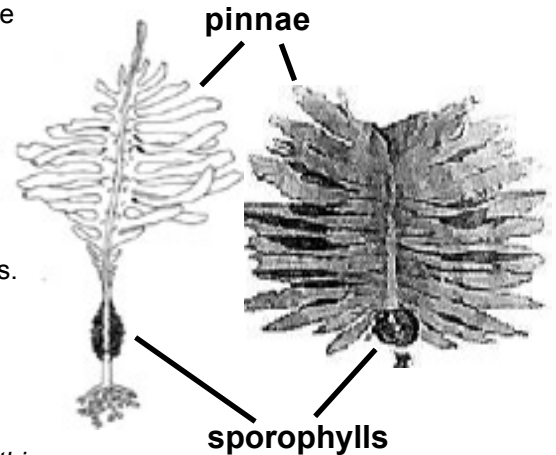
Habitat: Wakame can colonize a wide range of substrata in fairly protected water (such as bays and harbors). It ranges from the low tide mark down to 15 m in depth, but is especially abundant near the waterline on floating objects such as dock sides, boat hulls, and buoys.

Origin: Sea of Japan.

Invaded Areas: Southern and Baja California, Argentina, Europe, Australia, New Zealand, and Russia. *Note: this species appeared in Monterey Harbor in 2001. Efforts to control and monitor this recent invasion will be greatly helped by early reports of any expansions of its local range.*

Concerns: Wakame is intensely cultivated in Japan, and hence has great economic value. It is a popular Asian food item, responsible for giving miso soup its distinct taste. Wakame has been widely introduced, both intentionally and unintentionally, and has become extremely abundant in some invaded communities, outcompeting native species. Its spores settle on almost any surface, and therefore Wakame grows not only on hard bottom surfaces, but also other algae, sea grasses, and pier pilings.

Wakame (*Undaria pinnatifida*)



Smooth Cordgrass (*Spartina alterniflora*)



pink leaf sheath
(below mud surface)

Description: Morphology of this species can be variable due to a combination of environmental factors and its ability

to hybridize with our native cordgrass, *Spartina foliosa*. *S. alterniflora* resembles California cordgrass (*S. foliosa*), but a few key characteristics help in identifying this aggressive species. The leaf sheath that is below the mud surface is pink in young smooth cordgrass plants, while the native's is always white. This pink coloration is lost in older plants. The inflorescences of *Spartina alterniflora* have an open arrangement, but in *Spartina foliosa* they are arranged in a dense cylindrical orientation. In general, *Spartina alterniflora* is a larger plant and can be 250 cm high bearing leaves 20-55 cm long (the native *S. foliosa* grows up to 120 cm with leaves 45 cm).

Habitat: Occurs in mud-cobble mixes, tidal mudflats, saltmarshes, sheltered coasts, and in brackish waters.

Origin: Texas to the Gulf of St. Lawrence and Newfoundland; also native to Atlantic South America.

Invaded Areas: California, Oregon, and Washington; northwest Europe, New Zealand, and China.

Concerns: In estuaries with native cordgrass species (such as San Francisco Bay), this invader has been shown to outcompete or hybridize with the native. The invader has also spread farther down mudflats than the native, leaving smaller areas for shorebird foraging, blocking flood control channels, and hampering navigation. In Elkhorn Slough, there is no native cordgrass, so invasion by this species could dramatically alter the estuarine landscape by forming dense vegetated stands in areas previously occupied by intertidal mudflats.

Spotted Jellyfish

(*Phyllorhiza punctata*)

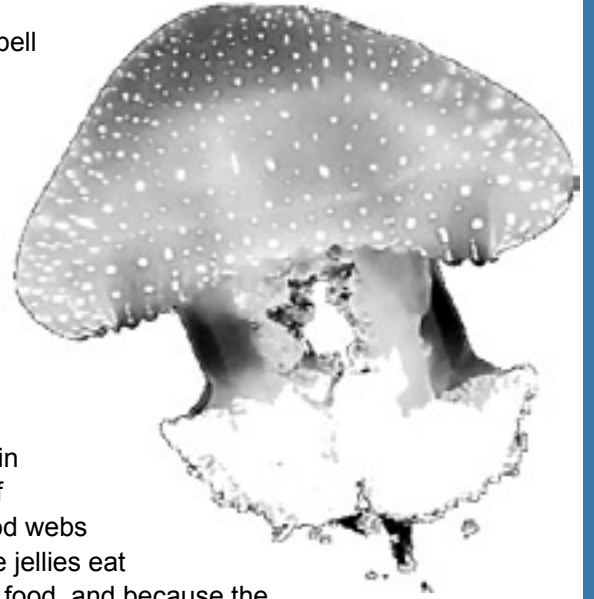
Description: This large sea jelly can reach a diameter of 60 cm and weigh up to 10 kg! The mushroom-shaped bell of this species is bluish-brown to creamy white in color and bears many evenly distributed opaque white spots. The underside of the bell bears eight stout feeding appendages.

Habitat: Warm temperate seas, often abundantly aggregated in nearshore waters.

Origin: Australia.

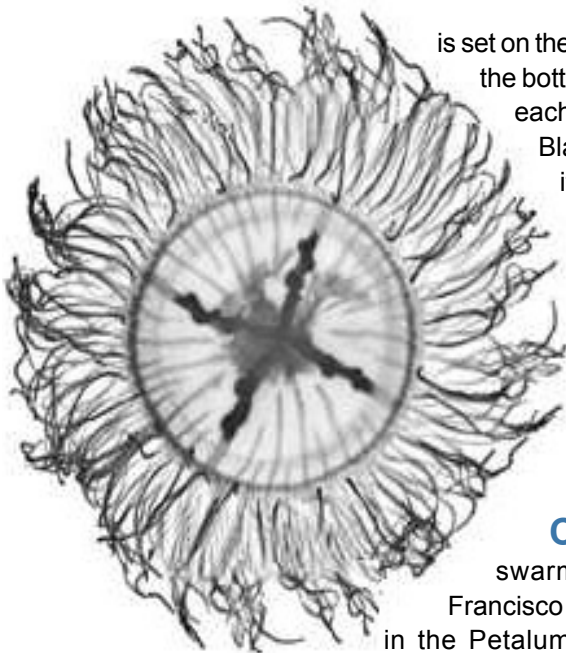
Invaded Areas: Abundant in the Gulf of Mexico; sightings in southern California, Hawaiian islands, Caribbean.

Concerns: In the Gulf, this invader has formed huge swarms in recent years. Each jelly can clear 50 cubic meters of water a day of suspended planktonic material, so dense aggregations can alter food webs in the water column. Gulf fisheries have been affected, because the jellies eat larval fish and compete with suspension feeding fish and shrimp for food, and because the jellies clog fishing nets. The attached polyp stage of this species, which buds off juvenile jellyfish, could be transported to our region on ship hulls.



Black Sea Jellyfish

(*Maeotias inexpectata*)



Description: This species of sea jelly is relatively small (maximum diameter 5.5 cm) and has particularly dense long tentacles (up to 600) lining the edge of the milky-white bell. The stomach, which is set on the underside of the bell and is relatively large, appears as a frilly "X" across the bottom. Also set on the underside of the bell are 4 distinct radial canals that each hold a curtain-like gonad. Unlike most of our common local jellies, the Black Sea jellyfish is not an active swimmer and only occasionally beats its bell. It often rests on the bottom where it feeds on bottom dwelling organisms, but it is also found in the water column and near the surface.

Habitat: The Black Sea jellyfish is typically abundant from late spring through summer in the brackish waters of bays, either near the bottom or in the water column.

Origin: Black Sea.

Invaded Areas: Brackish waters in Francisco Bay; Chesapeake Bay.

Concerns: This species can rapidly reproduce to form dense swarms of jellies. In the early 1990s, an introduction into the San Francisco Bay area may have been due to fouled ships. A bloom observed in the Petaluma river in 1993 attracted public interest. Dense populations of this jelly can alter estuarine food webs. The prey of this jelly includes small adult crustaceans and larvae, so local populations of crabs and their relatives could be diminished.

Mediterranean Fan Worm (*Sabella spallanzanii*)

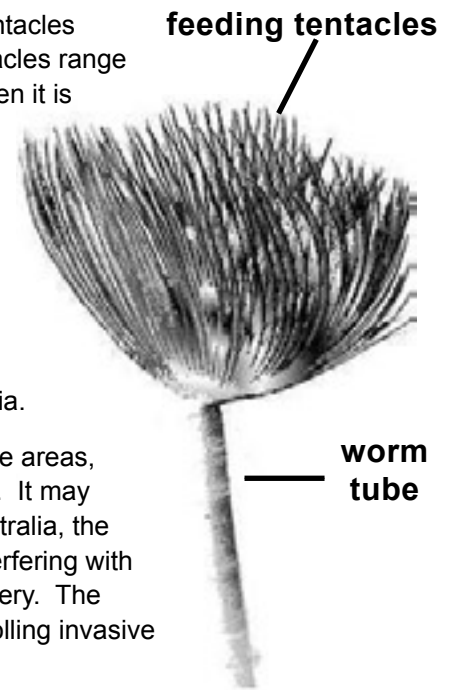
Description: This giant fan worm can attain a length of 40 cm in just a few years of growth. The worm is enclosed in a hard tube (about 1 cm diameter) that is attached to hard surfaces such as rocks, pilings, shells, and even mats of sea grass. When its feeding tentacles are extended, the worm resembles a feathery palm tree. The colors of the tentacles range from white to orange, and may bear banding patterns across the tentacles. When it is disturbed, the worm retracts its tentacles into the tube and rolls up the end.

Habitat: The fan worm is generally found in shallow subtidal areas of protected bays and harbors to depth of 30 m (in contrast, our native fan worms are rarely found in estuarine conditions). They readily form large, dense mats of individuals and quickly outnumber their neighbors.

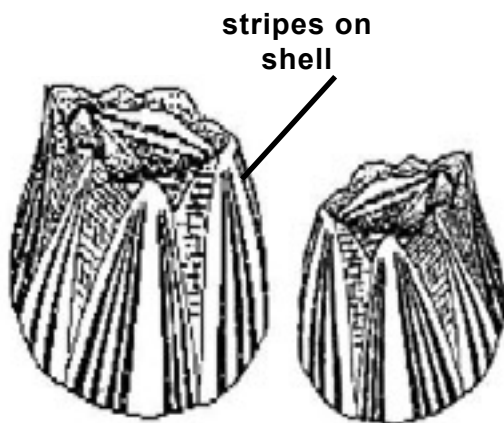
Origin: European Atlantic and Mediterranean coasts, Azores.

Invaded Areas: Atlantic coast of South America, Java, southeast Australia.

Concerns: Because this voracious suspension feeder rapidly carpets large areas, it has the ability to directly compete with native species for both food and space. It may also interfere with colonization of natives by predation on settling larvae. In Australia, the fan worm has been observed to rapidly colonize areas of seagrass dieback, interfering with normal succession by native plants and animals and preventing seagrass recovery. The presence of a toxin in fan worm tissue may prevent native predators from controlling invasive populations.



Striped Barnacle (*Balanus amphitrite*)



Description: The hard exterior is relatively smooth, with reddish or maroon vertical stripes. The base can grow to 20 mm wide (about the size of a nickel), and the barnacle grows about 20 mm high. While there are native species of barnacle with similar stripes, they are usually restricted to deeper water or exposed coasts.

Habitat: These barnacles can be found attached to rocks, wood, or other hard substrates (such as boat hulls) in the warmer portions of bays and harbors.

Origin: Southwestern Pacific and Indian Oceans.

Invaded Areas: San Francisco Bay, Southern California, in bays and harbors in warm seas worldwide.

Concerns: Striped acorn barnacles have successfully invaded harbors in many regions of the world, and have become problematically abundant in some of them. They are readily transported on ship hulls, and indeed can cause serious biofouling problems: studies have shown they can reduce a ship's speed by up to 40%. They breed year-round, and thus larvae have the potential to settle on ships in infested harbors at any time. In bays and harbors, the structure created by dense aggregations of barnacles can serve as a refuge for other alien species, such as the Harris mud crab.

Red Swamp Crayfish (*Procambarus clarkii*)

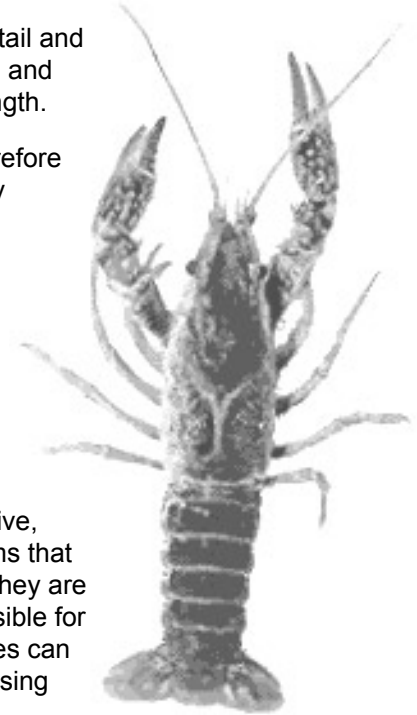
Description: Adult red swamp crayfish are colored dark red, whereas juveniles are a drab gray. A blue vein is visible under the tail of this species, and it also has a wedge-shaped black stripe on dorsal side of the abdomen. The texture of the carapace (shell) is rough, and the tail and carapace are not separated by an abrupt space. The pincers are narrow and long and may appear red in subadults. Full-grown adult crayfish can measure 20 cm in length.

Habitat: Red swamp crayfish are tolerant to a wide salinity range and are therefore found in both freshwater and brackish water habitats. They burrow into the muddy banks of sloughs, rivers, swamps and irrigation ditches.

Origin: Southeastern North America.

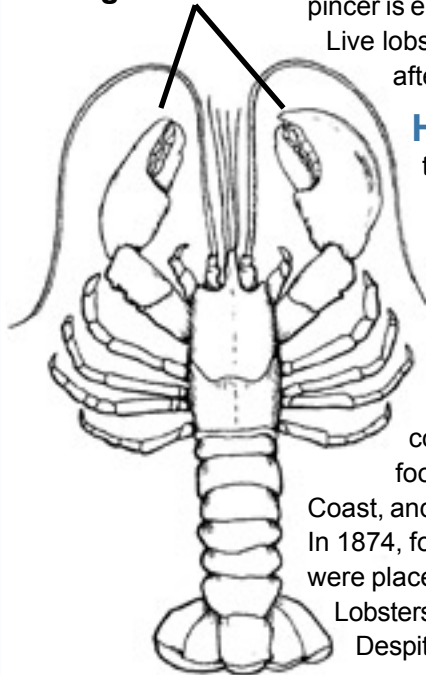
Invaded Areas: In North America, western states including California, Oregon, Idaho and New Mexico. Abroad: Europe, Africa and Asia.

Concerns: In their native range, red swamp crayfish are economically valuable, for instance as the basis of profitable aquaculture in Louisiana, where they are used for Cajun cooking. They have been intentionally introduced outside their native range for aquaculture operations. They are known to be very aggressive, territorial, and are generalist feeders, making them a formidable threat to organisms that rely on the same resources; in California, they may outcompete native crayfish. They are also known to prey upon endangered newts and are thought to be directly responsible for the decline in newt numbers in some areas. The burrowing behavior of this species can compromise the integrity of banks and levees, thereby increasing erosion and causing destruction to important wildlife habitat.



American Lobster (*Homarus americanus*)

large claws



One pincer is enlarged and thickened (used for crushing) while the other is finer (used for tearing). Live lobster colors can be a mottled reddish brown, white or blue; they turn bright red only after cooking. A typical adult lobster measures between 45 to 135 mm in length.

Habitat: They can be found in the subtidal zone on rock, sand, mud or hiding amongst the seaweed. Females are thought to enter warm, shallow waters such as bays to accelerate egg development. American lobsters come out of their dens at night to hunt.

Origin: East Coast of North America.

Invaded Areas: A few individuals sighted on California shores.

Concerns: The American lobster is an opportunistic feeder with a broad diet. Because of its adeptness at crushing shelled prey, an invasion of American lobsters could threaten native mollusks and compete with other species that share the same food sources. They are the basis of a commercially lucrative fishery on the East Coast, and individuals might be tempted to intentionally introduce lobsters to the West Coast. In 1874, four egg-bearing females were placed in San Francisco Bay. Four other shipments were placed in Monterey Bay and several lobsters were caught later by Monterey fisherman. Lobsters are also used for research at marine labs, and have been sighted in adjacent waters. Despite these sporadic introductions, no lobster populations have established in California.

Chinese Mitten Crab (*Eriocheir sinensis*)

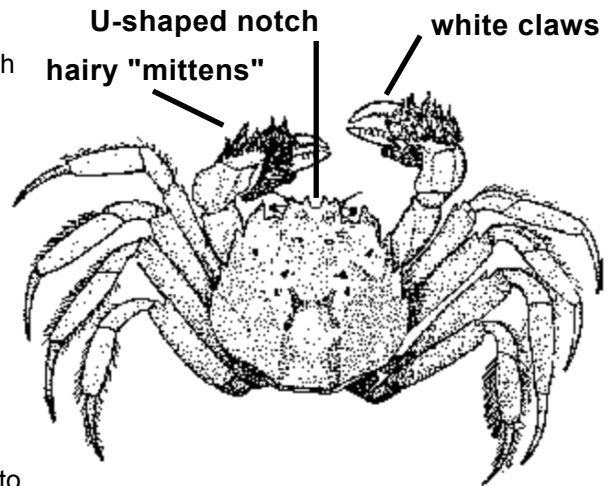
Description: The hairy “mittens” on the claws of this crab set it apart from any local species. The claws are white-tipped, while the rest of the body varies from an olive green to a dark brown color. The carapace is round, has four pronounced lateral spines on either side of the eye stalks, a distinctive U-shaped notch between the eyes, and can grow up to 80 mm across.

Habitat: The mitten crab is an excellent digger and burrows into the soft mud along the banks of waterways. Tolerating a wide range of salinity levels, it occupies rivers, estuaries, lagoons, and nearshore waters. Adult crabs reproduce in salt water, and offspring migrate to freshwater.

Origin: China and Korea.

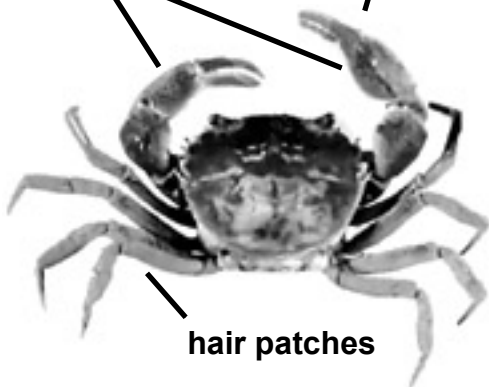
Invaded Areas: San Francisco Bay, Northern Europe.

Concerns: Considered a delicacy by Asian diners, this crab has the ability to cause ecological and economic damage, as well to pose a health risk to people who eat them. It is therefore illegal to import, transport, or possess live mitten crabs in the United States. In areas of high infestation, mitten crabs can increase erosion when burrow-ridden banks cave in. They may affect native invertebrates through predation or compete with benthic predators. Their impact on commercial fisheries is also of economic concern. For example, unintentionally caught mitten crabs cause considerable damage to fishing gear by cutting nets, and can feed on netted catch. In its native range, the Chinese mitten crab is a secondary intermediate host for the Oriental lung fluke.



Harris Mudcrab (*Rhithropanopeus harrisi*)

unequal claw sizes white tipped



Description: This small crab (max. size 20 mm) has white-tipped claws, one of which is bigger than the other. There are four spines on either side of the eyestalk; there is no prominent frontal notch (indentation in the front of the carapace between the eyes). Coloration is brown to olive green, and the legs bear sparse patches of hair. Two similar native species differ from this invader: *H. nudus* has red-spotted claws and hairless legs, while *H. oregonensis* has only three spines and a pronounced frontal notch.

Habitat: The Harris mud crab is primarily found in brackish waters, but also occurs in fresh water environments. It can be found in shallow water with muddy or sandy substrates.

Origin: East Coast of North America.

Invaded Areas: San Francisco Bay, Central Valley, various bays in Oregon; Europe.

Concerns: First discovered in California in 1937, the Harris mud crab has invaded much of San Francisco Bay's brackish waters and adjacent freshwater areas of the Central Valley. Because it may be a more aggressive and active predator than its native counterparts, this crab could outcompete them. Its tolerance of broad salinity conditions gives it the potential to spread widely through Californian coastal and inland waters.

Eastern Mud Snail

(*Ilyanassa obsoleta*)

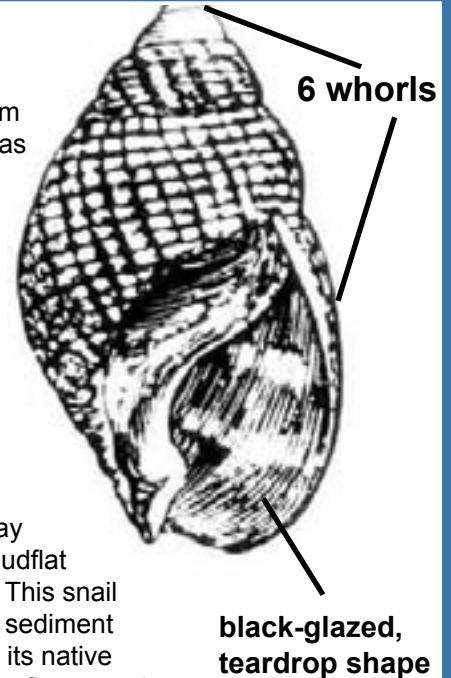
Description: The shell of the eastern mud snail is stoutly built, with 6 whorls, and is more rounded than the tall, cone-shaped shell of the native mud snail, *Cerithidea californica*, which has more than 6 whorls. The shell, which reaches a length of 2-3 cm, is dark brown to black and has crisscrossed lines that have minute knobs at the intersections. The aperture is black-glazed. *Ilyanassa* can be distinguished from littorine snails (*Littorina* spp.) by the shape of the aperture opening: *Ilyanassa* has an ovate, teardrop shaped aperture while the opening is circular in the littorine species.

Habitat: This snail is found in mud flats and salt marshes in sheltered waters.

Origin: East Coast of North America.

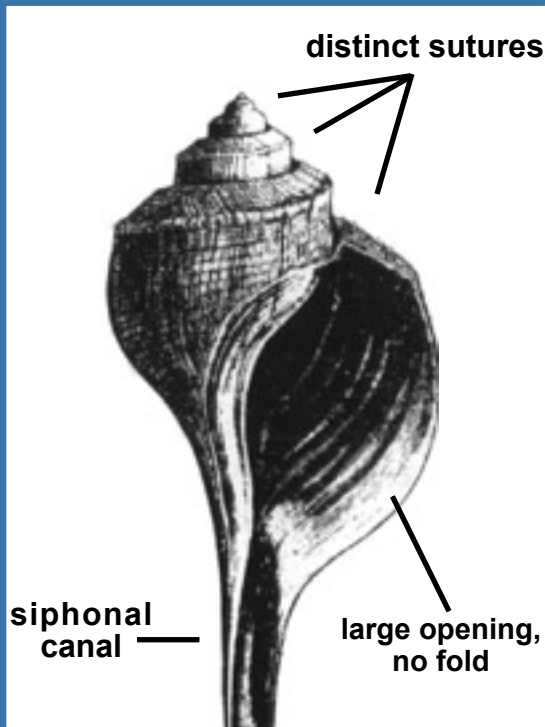
Invaded Areas: San Francisco, and various bays in Northern California, Oregon, Washington, and British Columbia.

Concerns: The eastern mud snail was first discovered in San Francisco Bay in 1907, probably introduced with oysters. It has since become the dominant mudflat snail in the Bay. It also occurs northwards of San Francisco in other estuaries. This snail has been shown to have significant effects on mudflat community structure and sediment composition. Experiments have also revealed that it can competitively displace its native counterpart, *Cerithidea californica*. The snail acts as an intermediate host for the flatworm that is responsible for swimmer's itch in humans.



Channeled Whelk

(*Busycotypus canaliculatus*)



Description: The long siphonal canal is diagnostic in this species of whelk. The aperture or opening of the shell is large and lacks a fold on the outer lip. The sutures are distinct and resemble a spiral staircase. The shell is smooth and virtually without sculpturing, and grows to 18 cm in length; it is larger than our native bay snails. It is usually brown or orange, but on rare occasions can be white or light purple. The egg capsules of this species can be found daisy-chained together in strings, and are often washed ashore.

Habitat: In bays. During the winter they are found in fairly shallow intertidal areas over mud, but during the summer they migrate to deeper waters.

Origin: East Coast of North America

Invaded Areas: San Francisco Bay.

Concerns: The channel whelk preys on bivalves, and if abundant, can seriously affect native clam and oyster populations, while outcompeting native predatory snails. Their floating egg cases have the potential to expand the distribution of the snail within bays, as well as to spread it between bays. This species is sold in the aquarium trade, and also is the basis for a fishery on the East Coast. It invaded San Francisco Bay around 1940, and became abundant there.

Veined Rapa Whelk (*Rapana venosa*)

Description: The orange colored surface of the large aperture, which contains small, elongate teeth, is the most notable feature of this whelk. The color of the heavily ribbed shell can vary from light gray to brown. Pronounced knobs form where the ribs meet the wide shoulder of the whorls. This whelk resembles our native whelk, the frilled dog winkle (*Nucella lamellosa*), but the relative size of the aperture is smaller in the dog winkle, and its maximum shell size is only 60 mm compared to 120 to 180 mm in the invasive whelk.

Habitat: Subtidally, on the sandy bottom areas of nearshore waters, bays, and estuaries. Veined Rapa whelks often buried themselves in the sand.

Origin: Sea of Japan, Yellow Sea, East China Sea, and the Gulf of Bohai.

Invaded Areas: North American East Coast: James River, Hampton Bar (Chesapeake Bay, Virginia). Europe: Mediterranean Sea, Black Sea, Aegean Sea, and Adriatic Sea.

Concerns: The Rapa whelk preys on bivalves such as oysters, clams, and mussels, and may also compete with them for burrowing space on sand flats. Temperature and salinity tolerance data suggest that *Rapana venosa* can successfully invade estuarine habitats as well as exposed shorelines. Because offspring originating from the same egg mass vary greatly in the amount of time spent before settling, some colonize locations near their parents while others end up far away. This capacity may result in rapid growth and spread of invasive populations, even when the number of founding adults is small.



Atlantic Ribbed Mussel (*Ischadium demissum*)



Description: The radial ribbing on the exterior of the shells is distinctive for this mussel. A native ribbed mussel (*Septifer bifurcatus*) is found in a different habitat, attached under rocks in the intertidal of the open coast. The beak of the Atlantic ribbed mussel is offset from the end of the shell, while *S. bifurcatus* and species of other mussels (*Mytilus*) have the beak set directly at the end of the shell. The shells are usually dark yellowish-brown or black, fairly thin, and can reach a maximum size of 10 cm in length.

Habitat: Anchored to marsh plants or other firm substrates in muddy habitats of bays and estuaries.

Origin: East Coast of North America.

Invaded Areas: San Francisco Bay and various bays in southern California.

Concerns: Ribbed mussels can form huge aggregations that cover large areas. In areas of high infestation (e.g., San Francisco Bay), this species poses a serious threat to native organisms and can alter the physical environment. In the San Francisco Bay, the Atlantic ribbed mussel directly competes for resources with native suspension-feeding groups of organisms belonging to many different taxonomic groups. This species has also been blamed for injuring and killing endangered California Clapper Rails that forage in mussel infested areas. The open shells of these mussels can close on rail feet, trapping the birds when the tide returns, resulting in death or amputation. The mussels can also clamp shut on the rails' beaks, resulting in starvation. This hardy species of mussel has the ability to thrive in varying environmental conditions and can tolerate polluted waters.

Green Mussel (*Perna* spp.)

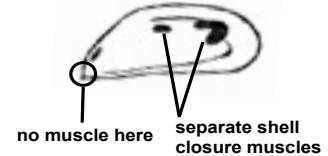
Description: This mussel can be recognized by the distinctive greenish hue that colors the exterior of its shell, differentiating it from the blue-black colored *Mytilus* mussels found in this area. It is typically 80-100 mm in length, but can attain a length of 165 mm. Internally, the green mussel lacks a small patch of muscle fiber near the beak which is present in *Mytilus* mussels, and it has two separate shell closure muscles while the *Mytilus* mussels have one joint muscle. There are three similar species in this genus, *Perna canaliculus*, *P. perna*, and *P. viridis*, which all fit this description.

Habitat: Primarily in estuarine habitats with salinities ranging from 18-33 ppt and temperatures ranging from 11-32 °C temperature, but with tolerance for extremes beyond these ranges. The green mussel forms dense aggregations on natural and man-made substrata such as wharves, pilings, buoys and mariculture stands.

Origin: New Zealand (*P. canaliculus*), South Africa and South America (*P. perna*); Southeast Asia (*P. viridis*).

Invaded Areas: Widely introduced for aquaculture to localities including South Pacific islands and Caribbean sites.

Concerns: In invaded areas such as Australia, the green mussel has rapidly formed dense aggregations that can outcompete native sessile organisms, and that have had substantial economic impacts by clogging flow pipes, and by fouling ships and mariculture facilities. In our region, the green mussel might alter physical habitats in estuaries by increasing the amount of hard substrate, and it might compete with native species such as the California mussel. The green mussel spawns continually throughout the year, thereby increasing the chances that individuals arriving on boat hulls could found a new population in a local harbor or bay, and contributing to potential rapid growth rate of a newly established population.



Northern Quahog (*Mercenaria mercenaria*)

Description: The exterior of the thick oval-shaped shell bears strong concentric rings. These rings are evenly spaced except for on the ends of the shell where they progressively crowd together.

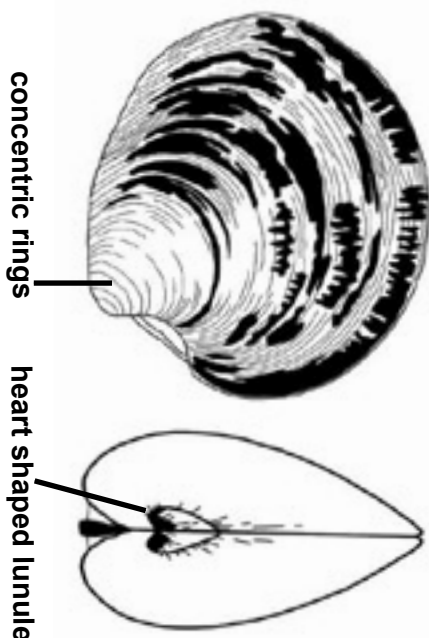
The lunule formed between the two shells makes a heart shape. This long-lived species can attain a length of 15 cm, though typical individuals are smaller. The external color varies from gray to fawn, while the inside of the shell is yellowish-white, usually with a purple spot near the hind end.

Habitat: This species burrows into sandy substrates or muddy bottoms of sheltered waters and ranges from the intertidal zone to a depth of 10 m. Northern quahogs can withstand a wide range of salinity conditions.

Origin: East Coast of North America.

Invaded Areas: Populations have become established in two or three west coast estuaries, including in Southern California (Colorado Lagoon) and British Columbia (Boundary Bay).

Concerns: The Northern Quahog can be readily purchased, alive, at local seafood stores. These clams originated on the East Coast, where they are the basis of a lucrative commercial fishery. They have been intentionally introduced to numerous areas outside their native range in the hopes of establishing a fishery, but can only reproduce when temperatures reach about 27°C, conditions that are only met in very shallow estuarine lagoons on this coast. Northern quahogs could outcompete native suspension feeders in such habitats.



False Angelwing (*Petricolaria pholadiformis*)

Description: The elongate shape and the heavy radial sculpturing of the shell help to distinguish the false angelwing from a similar native species (*Petricola carditoides*), which has fine radial sculpturing and a rounder shell shape. The false angel wing can reach a width of 25 to 80 mm. It ranges from the lower intertidal zone down to depths of 8 meters. False angel wing colors range from white to a creamy yellow.

Habitat: The false angel wing bores into soft sediments (e.g., heavy mud, clay and peat) of bays and estuaries. In contrast, the similar native species nestles in rock crevices and in the abandoned holes formed by piddocks along the open coast.

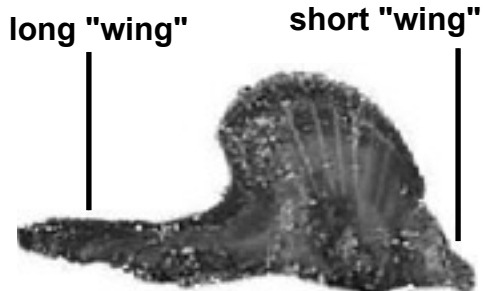
Origin: East Coast of North America.

Invaded Areas: San Francisco Bay, Newport Bay (Southern California), Willapa Bay (Washington); Europe.

Concerns: False angelwings compete with native suspension-feeding species for food, and with other boring organisms (e.g., native estuarine piddocks such as *Zirfaea pilsbryi*) for space. This species was first discovered in San Francisco Bay in 1927, introduced by shipping or oyster culturing, and may still be present there.



Winged Oyster (*Pteria sterna*)



Description: The shell of the winged oyster has two unequal sized lateral extensions that resemble wings, differentiating it from the shells of other oysters encountered in our area. One wing is long and narrow, and the other is short and stout. The exterior of the shell is purplish-brown to yellow, while the inside is pearly and variable in color. The shell is moderately thin, has lines sculpted on the surface, and can attain a length of 9 cm.

Habitat: Attached to living and non-living hard substrates at depths of 1-5 meters, in subtropical to warm temperate waters.

Origin: Gulf of California.

Invaded Areas: California Channel Islands.

Concerns: The lovely pearls of this species make this oyster the basis of a lucrative fishery in the Gulf of California. Its recent appearance at the Channel Islands suggests that the species might survive in more northern waters, especially if sea temperatures were to increase. Introduction of a new oyster species might threaten beds of native oysters in our area.

Description: The shells of the Asian clam are unequal in size giving this species a slight “overbite” that sets it apart from similar native species. This small clam only reaches a length of 2 to 3 cm. The exterior of the shell is sculptured with light concentric rings and yet can have a fairly smooth surface. The color of the shell can vary from white, tan, or yellow. It typically buries one-half to three-fourths of its body into the sediment and anchors itself with byssal threads from within the shell. The exposed portion of the clam is very often fouled with other organisms, differing from the clean shells of native clams that are entirely buried. Asian clams are often found in dense aggregations.

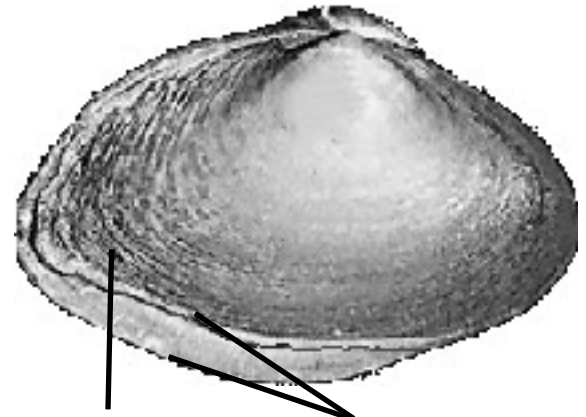
Habitat: This species is generally found living in mud, sand, and clay substrates in the intertidal or subtidal zone of bays and estuaries.

Origin: China, Japan and Korea.

Invaded Areas: San Francisco Bay.

Concerns: The Asian clam is a very resilient invader capable of exploiting waters ranging greatly in salinity, temperature, and pollution levels. During the late 1980s, a population became established in the San Francisco Bay. In northern parts of the Bay, it has come to dominate benthic habitats, at densities of up to 2,000 individuals per square meter (or approximately 750 clams in an area the size of the page you are reading!). With densities of this magnitude, Asian clams have altered the flow of energy across estuarine food webs, clearing the water of phytoplankton and zooplankton, as well as displacing native benthic species. By consuming the planktonic food resources upon which juvenile fish rely, Asian clams could also have dramatic economic effects on fisheries.

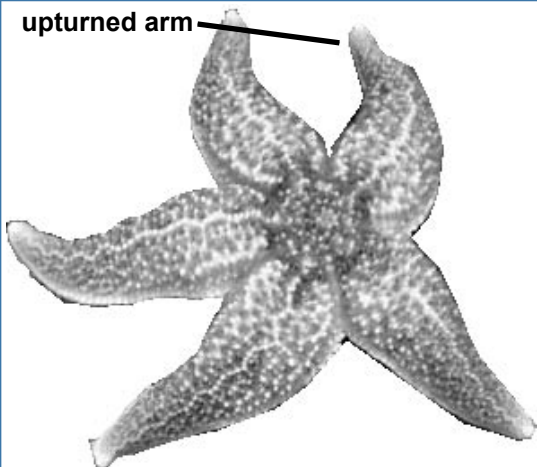
Asian Clam (*Potamocorbula amurensis*)



concentric rings

unequal shell sizes

Northern Pacific Seastar (*Asterias amurensis*)



Description: This is a large, hardy seastar that can grow to 40-50 cm in total diameter but has a relatively small central disk. The tips of the arms are distinctively turned upwards. The body is yellow and is sculptured with red and purple pigmentation on its top surface, while the underside is uniformly yellow. The native ocher star (*Pisaster ochraceus*) is superficially similar, but generally doesn't have such strongly upturned arm-tips. The native pink seastar (*P. brevispinus*) can be distinguished by its pink color, and the giant spined seastar (*P. giganteus*) by the distinctive blue rings surrounding spines on its top surface.

Habitat: This species is typically found in shallow water of protected coasts. It can tolerate a wide range of temperatures, and, unusual for an echinoderm, a wide range of salinities. Unlike the native *Pisaster* species, *Asterias* is often found in estuaries.

Origin: Northern China, Korea, Russia, Japan and far northern Pacific waters.

Invaded Areas: South Eastern Australia and the Tasmanian coast.

Concerns: Invasive *Asterias* number in the millions on parts of the Australian coastline. A voracious predator particularly on bivalves, this seastar has been shown to impact oyster culturing and shellfish production in these regions. Since estuaries on our coast do not have any native seastar predators, our native bivalves might be particularly vulnerable to an invasion by *Asterias*. Other native consumers of bivalves might also suffer from competition with rapidly burgeoning seastar populations.

Spaghetti Bryozoan (*Zoobotryon verticillatum*)

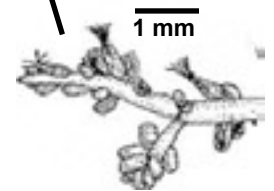
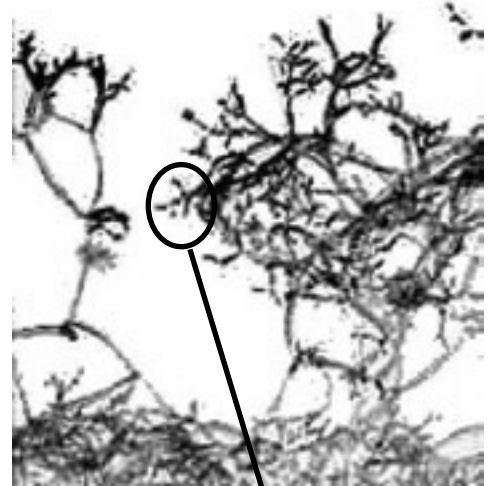
Description: This colonial animal forms transparent to white or yellowish bushes comprised of spaghetti or straw-like stalks that can be up to 45 cm long. This bryozoan superficially resembles an alga, but is paler than most, and close examination reveals tiny clusters of animal tentacles along the branches.

Habitat: The spaghetti bryozoan is found on hard substrates in bays and harbors. Large bushes are formed only when water warms to 22°C and above, although the colonies can overwinter during colder periods. Elevated temperature and salinity has been suggested to enhance outbreaks of this bryozoan.

Origin: Unknown; worldwide distribution in tropical and warm temperate seas.

Invaded Areas: On our coast, the species was introduced to San Francisco and Southern Californian bays; probably much of worldwide distribution is due to human-mediated introductions.

Concerns: The spaghetti bryozoan can form huge aggregations under optimal conditions. In 1905 large masses were reported in San Diego, and in 1992 it was found in San Francisco Bay. In Galveston, Texas, such abundant growth is known to negatively affect local fisheries by fouling fishing gear. The bushes of this animal tangle nets, and also block escape hatches for sea turtles. Colonies of this animal could also crowd out native sessile organisms and affect food webs in the water column by their active suspension feeding.



Chameleon Goby (*Tridentiger trigonocephalus*)

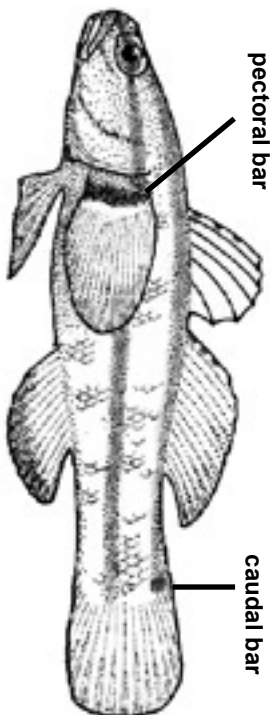
Description: The chameleon goby is named for its ability to rapidly switch between a light and dark form. When in the light form, it bears two horizontal stripes that run the length of the body, one towards the top and one along the middle of the body. The dark form exhibits vertical bars that give the fish a mottled appearance. In this form, the horizontal stripes are only faintly visible, outlined by a thin row of yellow scales. Diagnostic dark bars, which are visible in both forms, are located at the base of the pectoral fin and on the area just before the tail. A yellow area, which is very conspicuous when the fish is in the dark form, follows the bar at the pectoral fin. Adults can grow to be 110 mm in length.

Habitat: This goby is typically found in the shallow waters and tidal mud flats of bays, especially in areas that contain hard substrata (shellfish beds, old bottles) favored for spawning.

Origin: Japan, Korea, eastern China, and southeast Russia.

Invaded Areas: San Francisco Bay and Los Angeles Harbor; Australia.

Concerns: Chameleon gobies are aggressive and voracious predators of crustaceans, polychaetes, gastropods and fish eggs. Capable of feeding in total darkness and tolerant of wide ranges of salinity, temperature, and pollution, they may be able to outcompete native predators, including other gobies. They have a long reproductive period, aggressive tactics for procuring spawning sites, a short development time, and male nest-guarding, all of which can contribute to rapid population growth under favorable conditions.



Diamond Back Terrapin (*Malaclemys terrapin*)

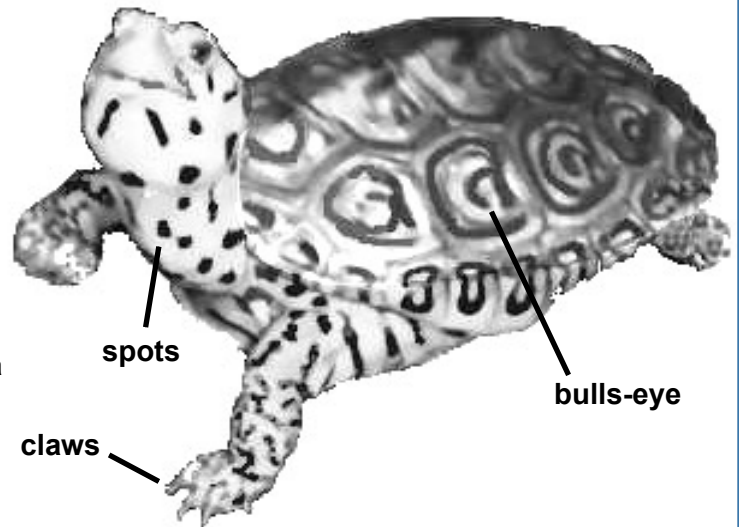
Description: The shell plates of this turtle are ornamented with a distinctive pattern resembling a green and yellow “bulls-eye”. The coloration of the body is variable with age: juveniles are dark brown to black, while adults are white with a striking dark “leopard spot” pattern. Their feet are webbed and bear sharp claws. Adult females are larger than males: females can grow to 19 cm long while adult males reach 13 cm.

Habitat: Terrapins are found in brackish water habitats (salt marshes, tidal flats, and lagoons), and even sometimes in the open sea.

Origin: From the Northeast Coast of North America (Cape Cod) to the Gulf Coast (Texas).

Invaded Areas: California.

Concerns: Because they are popular pets sold throughout the US, terrapins could easily become introduced to our area, following release by irresponsible owners. As voracious predators of clams, snails, crabs, shrimp and marsh plants, terrapins could significantly alter invaded estuarine communities. Meanwhile on their native East Coast, terrapins are protected and rare, due to over harvesting for terrapin soup in the late 1800s and early 1900s.



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