Invasive species of the Pacific Northwest:

Sphaeroma quoianum (_S. quoyanum)_, Burrowing Isopod, Australasian Isopod, New Zealand Isopod

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Fish 423: Olden

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Figure 1: Magnified view of *Sphaeroma quoianum.* Photo from http://www.roboastra.com/Crustacea1/brde834.htm

Classification

Phylum: Arthropoda
Subphylum: Crustacea
Class: Malacostrata
Superorder: Peracardia
Order: Isopoda
Suborder: Flabellifera
Family: Sphaeromatidae
Genus: *Sphaeroma*
Species: *quoianum*

Common names

Burrowing isopod, Australasian isopod, New Zealand isopod, New Zealand pillbug

Identification Key

Sphaeroma quoianum is a small, filter-feeding isopod that is about 15 mm in length and is either a dark gray color or a sandy brown with black sports. They can be differentiated from other isopods by their "paddle-like" appendages that are also serrated in the hind region as well as two rows of tubercles on the telson. They also have seven pereon segments, seven pereopods, and a pleon composed of two segments (Hurley and Jansen 6-7). A more accurate description from Bruce (1993) includes:

> Cephalon not fused with pereonite 1; pereonites 2-7 with coxal plates usually indicated by sutures; pleonite 1 tergite often discrete, pleonites 2-5 fused bearing partial sutures, lateral suture lines variously indicated. Pleotelson wholly or partly fused with pleonites. Frontal lamina and clypeus fused, forming epistome; labrum present. Antennule peduncle 3-articled; antennal peduncle 5-articled. Mandible stout, usually with multicusped incisor; lacinia mobilis short, multicusped, usually present on left mandible; spine row present; molar process forming flat nodulose, grinding or smooth crushing surface, or chitinised lobe. Medial lobe of maxillule with 3 or 4 long pectinate spines and 1 simple spine; lateral lobe gnathal surface with 9-13 stout, simple and/or serrate spines. Maxilla with 3 elongate lobes each bearing long setae, those of lateral and middle lobes being serrate, medial lobe plumose. Maxilliped endite elongate, bearing terminal plumose spines, usually with variously ornamented spines, usually with single coupling hook; palp 5-articled, with articles 2-4 usually expanded to form lobes. Pereopods ambulatory, usually robust; pereopod 1 notchelate, not expanded, may be lobed dactylus usually with distinct secondary unguis. Pleopods all biramous, usually lamellar, occasionally pleopod 1 indurate, operculate; pleopods 1-3 with plumose marginal setae; pleopods 4 and 5 with or without thickened ridges, exopod of pleopod 5 with distal scaled patches. Uropods anterolateral in position on pleotelson, endopod fused to peduncle when present; exopod articulating or reduced, set laterally into endopod when present, often absent. (p. 157)

The family Sphaeromatidae can be differentiated from other closely related isopods in the suborder Flabellifera by the presence of thickened ridges on pleopods 4 and 5 (Bruce, 1993). In addition, it can be identified by its extensive burrows that resembles "swiss cheese" or by the trait that it curls up into a ball when disturbed (Oregon Public Broadcasting).

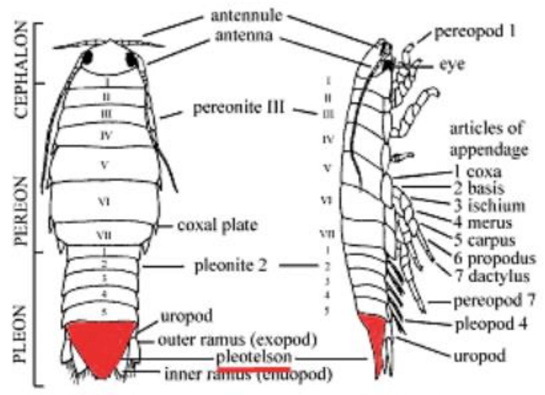

Figure 2: Detailed illustrations of the dorsal and lateral view of the burrowing isopod. Photo from http://www.reu.pdx.edu/presentations/2009/Anne_Phillip.pdf

Figure 3: Dorsal view of the Burrrowing isopod, *Sphaeroma quoianum.* Photo from inaturalist.org

Life History and Basic Ecology

Life Cycle

Sphaeroma quoianum is known to undergo direct development and juveniles are released from their mother`s marsupium as fully developed juveniles after the gestation period. The growth rate of juveniles is highest in the spring and they become sexually mature after 6 months and often live from 1.5 to 2 years (Schneider, 1976). They spend most of their life filter feeding in extensive burrows in a variety of substrates including wood, mud, and Styrofoam (Davidson, Hewitt and Campbell, 2008).

Feeding Habits

The Burrowing isopod is a filter feeder that does not ingest particles from the substrate that it burrows into such as Styrofoam, wood, or mud. Filter feeding is initiated by creating a current with their pleopods, which draws phytoplankton and particles of detritus through the setal brushes on the first 3 pairs of legs. Then the isopod uses

Figure 4: Ventral view of the Burrowing isopod. Photo from inaturalist.org

its maxillipeds to clean the setal brushes and ingests the food (Rotramel, 1975a).

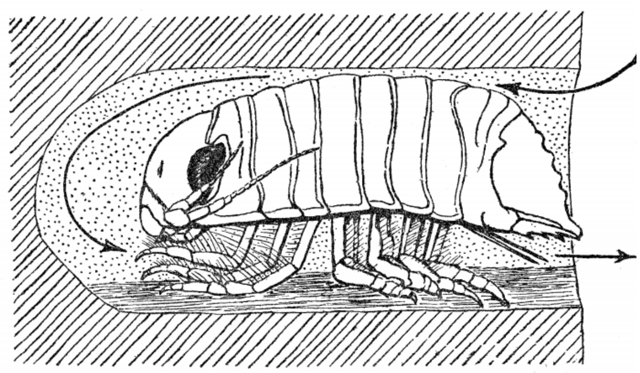

Figure 5: Illustration of burrowing behavior and feeding of *Sphaeroma quoianum.*The arrows show the direction of water flow. Notice the filtering of the water through its setal brushes on its maxillipeds (Rotramel 1975).

Reproductive Strategy

Sexually mature *Sphaeroma quoanium* can reproduce continuously throughout the year, but the times of highest reproductive output are late spring and early summer (ISSG). After copulation between a male and female, the fertilized eggs are brooded in a marsupium formed from oostegites also known as ventral coxal plates. After gestation subjuveniles are released that have have not yet fully developed the eighth thoracopods (Brusca and Brusca 557). According to Schneider et al., the brood size averages 19.5 in spring and 64 in spring (1976).

Enivronmental Optima and Tolerances

Sphaeroma quoianum can live in a variety of substrates including wood, friable rock such as sandstone, marsh banks and Styrofoam floats including those on docks. However, even though they are considered generalists, they may prefer decayed wood over other substratum (Davidson, Rumrill and Shanks, 2008). In addition, the burrowing isopod can tolerate mesohaline and polyhaline conditions or habitats with a salinity value anywhere from 5 to 30 (Davidson, Hewitt and Campbell, 2008). This restricts *Sphaeroma quoianum* the coastal habitats where the salinity value is lower.

Although decayed wood may be preferred over other substrata, a study by Talley et al. examined the sediment properties of marsh banks in both San Diego and San Franciso bay and recorded the densities of the Burrowing isopod in each. They found higher densities of *Sphaeroma quoianum* in *Salcornia* vegetated marsh where the bank was more vertical and undercut as well as at higher tidal elevations compared to native *Spartina* vegetated marsh. The *Salcornia* vegetated marsh bank also had more peaty and firm sediments which are preferred (2001). Based on their results, *Sphaeroma quoianum* may be prefer the firm sediments where *Salcornia* are often found as well as higher tidal elevations where the tide has less of an impact.

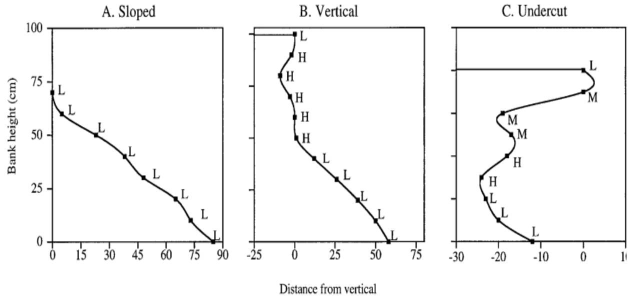

Figure 6: Diagrams showing the shapes of sloped, vertical, and undercut marsh bank. The x-axis is the distance from vertical, while the y-axis is the bank length in centimeters. Diagrams from Talley et al. 2001.

Biotic Associations

One biotic association of *S. quoianum* is commensalism by providing a habitat where that other organisms can inhabit temporarily or permanently. Davidson et al. examined the fauna of species living in the burrows constructed by *S. quoianum* in Coos Bay, Oregon. They found high levels of both native and non-native species living in the burrows and most of the species were either other isopods or amphipods. Most of the species found were motile and mesograzers, but there were also a few predators and detritivores found as well. These inhabitors of the burrows could be using the burrows as a temporary escape from predators or physical stresses or as a place of permanent residence (Davidson, Shanks and Rumrill, 2010). Regardless, the species inside the burrow created by *S. quoianum* are benefitting from the shelter and this association can be considered commensalism between the species.

Another commensal relationship of *S. quoianum* is with the isopod *Iais californica. I. californica* is known to scavenge for food in the burrows of *S. quoianum* as well as remove food from the setal brushes of the burrowing isopod. Both species have been found together in some locations in California since 1904 when they were both observed in Sausalito, California (Rotramel, 1972). *I. californica* ususally positions itself directly onto the burrowing isopod either onto the maxillopeds, the last legs, or the pleopodal chamber. These areas are all areas with low water current (1975b). To further examine the relationship between the two species, Rotramel recorded the survival of the two species living independently or together in the field. Over a 10 day period, he found them mean survival of *S. quoianum* to be 87% when alone and 96% with *I. californica* and for *I. californica* he found the mean survival to be 18% when alone and 78% with *Sphaeroma* (1975b). Overall, *S. quoianum* is a dependable source of food, a form of shelter, and a vector for dispersal for *Iais californica* and as far as researchers can tell, dependence on the burrowing isopod does not negatively effect the host organism (Rotramel, 1975).

Current Geographic Distribution

The native habitat range of *Sphaeroma quoianum* includes the coast of both New Zealand as well as southern Australia (ISSG). However, through a variety of vectors they have become established in many parts of the Pacific coastline in the US. They now inhabit 16 embayments from San Quitin bay in Baja California to Yaquina bay, Oregon (Davidson, Hewitt and Campbell, 2010). Although it`s native range is New Zealand and Australia, the burrowing isopod is actually found in greater densities in invaded embayments of the US pacific coastline. This is hypothesized by Davidson et al. to be a result of the enemy release hypotheses in that the Burrowing isopod is released from the parasites it encounters in its native region (Davison, Hewitt and Campbell, 2008).

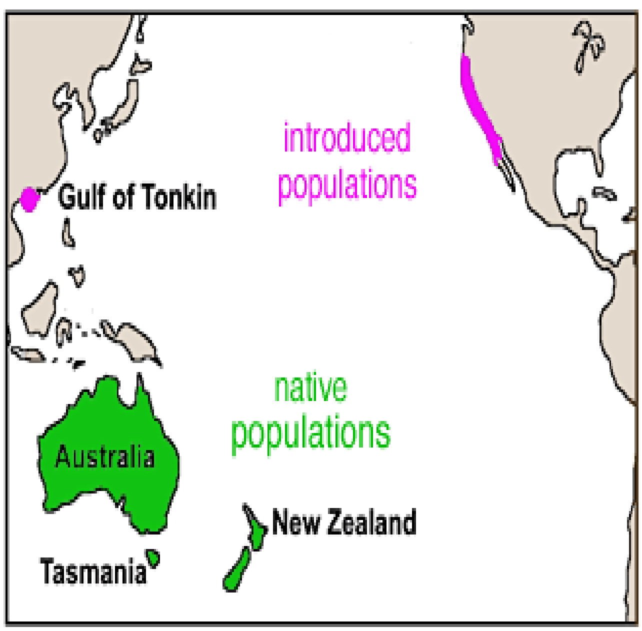

Figure 7: Map showing the native and introduced populations of along the Pacific Coast. Map from Davidson, Hewitt and Campbell, 2008.

Figure 8: Map showing the locations that *Sphaeroma quoianum* has invaded. The year next to the name of the location is the date of invasion. From Davidson, Hewitt and Campbell, 2008.

History of Invasiveness

Sphaeroma quoianum was originally introduced into the US in San Francisco bay in the mid 1893 most likely through hull fouling of a wooden ship. However, because wooden ships have been around for such a long time, it is difficult to distinguish which locations were invaded, and which were its natural habitat (Davidson, 2008). These invasions may have taken place before biological records had been kept, but there are records documenting over 100 years of invasion of the burrowing isopod. The most recent invasions have occurred along the US pacific coastline at Coos bay, Oregon and Los Angeles bay, California. In addition, although it is not shown in figure 8, *S. quoianum* has recently spread to Yaquina bay in Oregon in 2005, which is the northernmost location they have established. Davidson and de Rivera suggest that they were spread by hull fouling on either recreational or commercial vessels (Regional surveys and outreach for the non-indigenous burrowing isopod, 2001).

Invasion Process

Pathways, Vectors or Routes of Introduction

In the past, the most common pathways for *Sphaeroma quoianum* were through trade and boating activities. They sometimes burrow into the hulls of ships and are then transported into a new region. As stated in the section, History of Invasiveness, the Burrowing isopod was originally introduced to the West coast of the US in 1893 by hull fouling of a wooden ship (“Davidson, 2008). This ship most likely came from Australia in search of gold during the California gold rush. (Talley et al., 2001). Although the Burrowing isopod may have been first introduced by a wooden ship, another vector for its spread may be through floating Styrofoam floats or wood. *Sphaeroma quoianum* lacks a larval stage so the only vector of passive spread is by boring into floating pieces debris (Carlton and Cohen 1995). The burrowing isopod is able to withstand conditions of high salinity for brief periods of time and there is a great likelihood they can survive burrowed into a piece of Styrofoam or wood until they reach a new bay or estuary (Davidson, 2008).

Factors Influencing Establishment and Control

The greatest factor influencing whether or not populations of *Sphaeroma quoianum* will establish is the salinity level of the recipient region. The isopods are typically found at mean salinities between 5 and 30 and according to Davidson, they can tolerate lower and higher salinities for brief periods of times (2008). This large tolerance of salinites makes the burrowing isopod not only likely to establish, but also likely to spread to other locations with nearly the same salinity. Due to their high salinity tolerance *Sphaeroma quoianum* can even inhabit sections of rivers that connect to saltwater estuaries for brief periods of time.

In addition to salinity, the temperature of the water also determines whether or not *S. quoianum* will establish in a new area. When looking at the effect of temperature on the survivorship as well as reproduction Davidson, de Rivera and Carlton found that temperature did not have an effect of the survivorship or the number of offspring for each individual of *S. quoianum.* However, temperature did have an effect on whether or not reproduction occurred or not (2013). The temperature range at which *S. quoianum* can survive has not been tested extensively, but this study implies that the burrowing isopod might be able to survive in colder water, but would not be able to reproduce and establish self-sustaining populations. It has been suggested that the main factor keeping *S. quoianum* from spreading to more northern locations is the lower water temperature in the northeast portion of the Pacific ocean, but this may not be true (Smith powerpoint presentation). Jansen suggests that the *S. quoianum* can survive temperatures of 5 degrees celsius (as cited in Regional surveys and outreach for the non-indeigenous burrowing isopod). The temperature tolerance of *S. quoianum* needs to be researched in more detail because as Davidson pointed out, *S. quoianum* was also able to survive being transported in the hull of a ship from Australia, and they may have encountered lower water temperatures and may have the ability to tolerate low water temperature for brief periods of time (2008).

Another factor that is currently under debate that could effect whether or not the burrowing isopod establishes is the type of substrate that is available at the recipient region. One study by Davidson supported the fact that they prefer decayed wood over other substratum (Davidson, Rumrill and Shanks, 2008). However, this has been under debate and more recent studies show a range of densities in different substrates at different locations. These differences may be attributed to differences in locations, with *Sphaeroma quoianum* preferring different substrates at different locations. There is a possibility that the type of substrate present could determine whether or not populations establish, but this is currently being researched in greater detail.

One more factor influencing the dispersal as well as the growth of populations of *S. quoianum* is the concept of density dependent growth. Anne Phillip tested the hypothesis that the burrowing isopod will leave locations with low density of individuals to inhabit locations will a high density of individuals. She found this to be true, but more experiments need to be done in order to provide more support to the hypothesis.

Figure 9: Top: Population of *S. quoianum* burrows in a slab of sandstone with individuals on surface (Tim Davidson, Oregon Institute of Marine Biology). Bottom: Burrows of *S. quoianum* into a streambank http://decapoda.nhm.org/pdfs/27563/27563.pdf

In addition to their wide environmental tolerances, *Sphaeroma quoianum* are also likely to establish populations in the recipient region because they are direct developers. They lack a pelagic larval stage, which results in many species being transported by currents away from the recipient region of their mother. This means that juvenile isopods are likely to inhabit the same region they are born in and these populations are likely to flourish (Davidson and de Rivera, 2012). Johannesson suggests that the threat of spread is higher in species exhibiting direct larval dispersal compared to species with pelagic larval dispersal (as cited in Regional survey and Outreach of the non-indigenous burrowing isopod). This means that *S. quoianum* may be likely to spread, but more research needs to be completed.

Potential Ecological and/or Environmental Impacts

The most common and dramatic impact that the Burrowing isopod has on the recipient environment is that it creates extensive burrows, which accelerate the erosion or marsh banks. A study by Talley et al. examined the alteration of habitat by *Sphaeroma quoianum* in salt marshes in California. They found a positive correlation between the amount of bank undercutting and the density of the *Sphaeroma quoianum.* In addition, the authors tested the shear strength of the slope and found the shear strength to be 1.3-2.6 times higher in areas of low density of Burrowing isopods compared to areas of high density (2001). Although the amount of shoreline that is strictly caused by the burrowing activity is hard to quantify, this study demonstrates that the burrowing isopod does have an effect on the soil properties and erosion rates in areas where burrowing density is high.

Figure 10: Erosion of Coos bay exacerbated by the burrowing activity of *S. quoianum.* Photo from www.asnailoddessey.com

One more factor that could effect the rate of erosion of marsh bank facilitated by the burrowing activity of *S. quoianum* is temperature. Davidson et al. set up experiments using tanks filled with seawater at different temperatures and examined the rates of burrowing into a Styrofoam block placed in each tank. They added 20 individuals to each tank and after 62 days recorded the total length of burrows and the total volume extracted from the block. The burrowing activity was greatest in the tank at moderate water temperatures ranging from 13.8-18.3 degrees Celsius. This temperature range is 1.1-5.6 degrees higher than Coos bay, Oregon from which the organisms came and from the experiment, they estimate that the erosion rates in Coos bay may increase by 14.7-22.7% with small increases in water temperature anywhere from 1.5-1.6 degrees Celsius (2013). With the increase in ocean temperature caused by global warming, certain areas will experience an increased erosion rate and this will cause an increase in economic and ecological harm. However, there rates of erosion in areas where *S. quoianum* has already established could decrease if the water temperature becomes greater than 18.3 degrees Celsius (Davidson, de Rivera and Carlton, 2013).

Figure 11: Erosion of a shoreline causes by the burrowing activity of *S. quoianum.* Photo from http://sfbay.wr.usgs.gov/benthic_eco/exotic_species/images/sphaeroma2.jpg

In addition to causing erosion of the banks of salt marshes, *Sphaeroma quoianum* also bores into wooden substrates and Styrofoam. Davidson and de Rivera examined the per capita effects of *Sphaeroma quoianum* as a result of boring into a marsh banks, wood, Styrofoam, and sandstone. Although they found the isopods to create longer and more burrows in marsh banks, they also found the Burrowing isopod to create long burrows in Styrofoam substrates, but there are less burrows created (2012). This burrowing activity is damaging to docks because most include Styrofoam as a means of flotation. Even though *Sphaeroma quoianum* may burrow at a lower rate than other boring invertebrates, the density of their populations in addition to their widespread tolerance and use a of variety of substrates causes them to be a concern to marsh banks and numerous man-made structures (Davidson and de Rivera, 2012).

The burrowing activity of *Sphaeroma quoianum* not only directly damages man made structure such as wood, Styrofoam, and marsh bank habitat, but also facilitates the establishment of

other non-native species into the same substrates.
In another study in Coos bay,

Figure 12: Left: Picture showing the burrowing activity of *Spaheroma quoianum* into a Syrofoam block. On the right are Styrofoam floats that were heavily damaged by the burrowing isopod in Newport, Oregon. Photos from http://www.fws.gov/answest/Projects/SphaeromaFinalReport.pdf

Oregon, Davidson et al. examined what fauna were inhabiting the burrows created by *Sphaeroma quoianum*, whether or not the density of non-native fauna differed between substrates, and if the density of *Sphaeroma quoianum* related to the density of fauna also inhabiting the burrows. First off, the researchers found the percentage of non-native species to be: 25.8% in sandstone, 29.0% in wood, and 31.4% in marsh banks. They also occurred in 40% of all samples collected and were mostly other isopods and amphipods. Second, they found a higher density of burrow inhabitants in sandstone and wood compared to marsh banks with nearly one-half of the samples with a density of burrow inhabitors greater than or equal to the density of *S. quoianum.* Lastly, they found density of *S. quoianum* to be correlated with the richness, density and diversity of the fauna inhabiting the burrows (Davidson, Shanks and Rumrill, 2012). When they surveyed other sites that did not contain burrows as a result from the activity of *S. quoianum*, they found a very low number of total species. Besides the potential for other non-natives to have a direct impact on the recipient environment, the facilitation of species into the burrows may alter community level interactions such as trophic level changes as well as allow certain organisms to live at higher tidal elevations (Davidson, Shanks, and Rumrill, 2012).

As a result of their burrowing activity into polystirine floats on docks, *Sphaeroma quoianum* may cause increased pollution in oceanic waters by releasing microplastic particles. Another study performed by Davidson quantified the effects of the burrowing activity of *Sphaeroma quoianum* and how much microplastic pollution is created by the burrowing activity. He found that increased burrowing activity not only directly causes microplastic to be released but also found that burrowing weakens the polystyrene so that wave activity as well as debris rubbing against the dock also shears off more microplastic compared to unaffected floats. For each individual isopod, a burrow 17.3 mm burrow into Styrofoam can release up to 4360 plastic particles into the surrounding water. These microplastic particles may enter the digestive tract of many organisms and may even be toxic when they are broken down (Davidson, 2012). Along with the increased erosion rate caused by an increase in ocean temperature, the rate of pollution of microplastic particles will also increase (Davidson, Shanks, and Rumrill, 2012).

Overall, Davidson and de Rivera found that a population of 100,000 burrowing isopods in a cubic meter of substrate could remove: 176 L of marsh bank, 103 L of Styrofoam, 72 L of sandstone, and 29 L of non-decayed wood (2012). This eroding may have not only substantial economic cost, but also ecological costs due to pollution or loss of habitat when the marsh bank is eroded.

Management Strategies and Control Methods

One strategy to control the damage the Burrowing isopod can have on Styrofoam floats of docks as well as prevent their spread is to use floats that are extruded or covered by a thick material. Davidson suggest using a hardened polyethylene shell around and XPS foam core (Davidson, 2012). In addition to preventing damage to the floats, preventing the boring of isopods into floats will also remove one of the possible vectors. Since large populations of over 100,000 individuals can inhabit a cubic meter of Styrofoam, if these pieces break off, they could possibly establish into a new area (Davidson, 2012). Covering or protecting Styrofoam floats will provide economic benefits because fewer docks will be damaged as well as prevent ecological harm because there would be fewer microplastic particles released.

Another possible management strategy would be to identify marshes that are susceptible to invasion and then alter the marsh bank so that it is sloped instead of undercut, which is preferred by the burrowing isopod. This would also include making sure the banks are vegetated with the non-preferred native *Spartini foliosa* instead of *Salcornia* (Talley et al., 2001). However, the effect of this potential alteration of the habitat needs to be examined before any action is taken.

A couple strategies that have been mentioned by Davidson are to allow *Sphaeroma quoianum* to remove sections of substrates in which the isopod has burrowed, filling in the burrows and smothering the organisms, and using the pesticide carbaryl (Davidson and de Rivera 2012). This physical removal of substrate may work best in areas where they have not spread into numerous areas, otherwise this process would become very labor intensive and costly. In addition, this strategy would only work on man-made substrates such as wood or Styrofoam and would not be plausible to remove colonies from marsh bank or friable rock. Filling in the burrows also has not been tested but may be a possible option. Lastly using the pesticide carbaryl may be effective, but the effect of it on other organisms, including the natives living in the same burrows, needs to be researched to avoid any unwanted side effects.

Another potential vector that could be involved in spreading *S. quoianum* are any activity using wooden boats. As it was originally introduced, hull-fouling by the isopod burrowing into the hull of a ship is a possible vector for its spread. However, this vector is now less likely as many ships used in trade are made from materials other than wood. In addition, many ships are employing anti-fouling paint that may also prevent the boring of *S. quoianum.* The monitoring of wooden vessels traveling along the Pacific coast may help prevent future spread.

For the most part there have not been many actions taken to remove the burrowing isopods from invaded regions, but this does not mean their impacts are not substantial. For now, the main management strategy may be to prevent the invasions of new regions by decreasing the availability of suitable habitat. Solutions such as covering exposed Styrofoam as well as creating sloped marshed banks with *Spartina* need to be employed before more economic and ecological harm is done.

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Other Key Sources of Information and Bibliographies

Oregon Public Broadcasting
www.opb.org

Fish and Wildlife Service
http://www.fws.gov/answest/Projects/SphaeromaFinalReport.pdf

ISSG Database
http://www.serc.si.edu/labs/marine_invasions/vector_ecology/fouling.aspx

Expert Contact Information in PNW

Tim Davidson is the foremost expert of *Sphaeroma quoianum* in the pacific northwest and is can be reached at the Department of Environmental Science and Management, Portland State University (ESM), PO Box 751, Portland, OR 97207, United States.

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Current Research and Management Efforts

The main focus of current research and management efforts is to stop the spread of the burrowing isopod. Containment of the current established populations is the easiest and simplest step for controlling the populations. Currently, *Sphaeroma quoianum* is restricted to warmer waters such as along the Coast of California and has only recently spread along the coast into Oregon. However, with global warming expected to increase the temperature of the ocean, the burrowing isopod will most likely spread into more northern coastline such as the bays in Washington. Preventing the spread of these invasives will be critical in preventing both ecological and economic damage in numerous embayments and estuaries.
Another area of current research is estimating the economic cost of the burrowing activity of *S. quoianum* into man-made structures such as docks and pilings. The burrowing isopod has only recently established in Yaquina bay, Oregon, but has already severely damaged the docks belonging to Oregon Oyster (FWS). The economic damage is substantial, but there have not been estimates done to quantify the effects of the burrowing isopod and this needs to be done in order to show the true severity of the damaged caused by *S. quoianum.*