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Mud Blister Worms and Oyster Aquaculture

Dana L. Morse
University of Maine, dana.morse@maine.edu

Paul D. Rawson
University of Maine, prawson@maine.edu

John N. Kraeuter
University of New England

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by Dana L. Morse, Paul D. Rawson, and John N. Kraeuter

Introduction

The mud blister worm, *Polydora websteri* Hartman (Loosanoff and Engle 1943), burrows into the shells of bivalve mollusks, including Eastern oysters (*Crassostrea virginica*), sea scallops (*Placopecten magellanicus*) and blue mussels (*Mytilus edulis*).

The mud blister worm, a marine polychaete, lives worldwide and is distributed throughout the estuarine waters of Maine and the northeastern U.S., and has been found in the shells of other mollusks common to the region (Blake 1971). The earliest descriptions of *Polydora* date back to the 1890s (Whitlegge 1890) and early 1900s. More recently, attention on this species has focused on damage to stocks of oysters in Australia and along the U.S. Atlantic and Gulf Coasts, attributed to the growth of the half-shell market for oysters, and in the negative reaction by some markets toward product that exhibits blister worm infestation. While some markets have remained strong for oysters with some level of infestation, producers report buyer responses that range from reduced demand, to reduced farm-gate prices, to outright rejection of the product.

This report is for oyster producers interested in controlling mud blister worms, which when present in large numbers can reduce the value of oysters sold to the half-shell market. Although other species of blister-causing worms occur in several genera including *Polydora*, *Pseudopolydora,* and *Boccardia*, this report focuses specifically on *Polydora websteri*.

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Blister worm burrows most often begin at the edge of the shell, or lip, and extend inward. The burrows can be up to 20 mm long and 10 mm wide, and are typically U-shaped with both ends open to the outside of the oyster shell (Zottoli and Carriker 1974). Once the worm bores into the shell, the oyster responds by depositing additional layers of shell (nacre) to prevent the worm from contacting the viscera. The worm deposits detritus, mud, and fecal material inside the burrow, creating a dark "blister." These blisters are visible from the inside of the shell (*Figure 1*) and often break when an infested oyster is shucked. For oysters served on the half-shell, the blisters not only create a less attractive product, but, if punctured, can result in off-flavors. Estimates of economic damage are difficult to obtain, but observations from growers make it clear that losses can be very high, and can potentially make an entire crop worthless.

Description and Life History

Adult *P. websteri* individuals can grow to 20 mm in length, 1–2 mm in diameter, and are typically pale yellow to orange in color with a reddish digestive tract (*Figure 2*). They feed on materials deposited on the shell surface or particles in the water column, using tentacle-like structures called palps, which are located on the head at the anterior end of the organism. Reproduction takes place inside the burrow, with fertilization occurring when a male deposits a

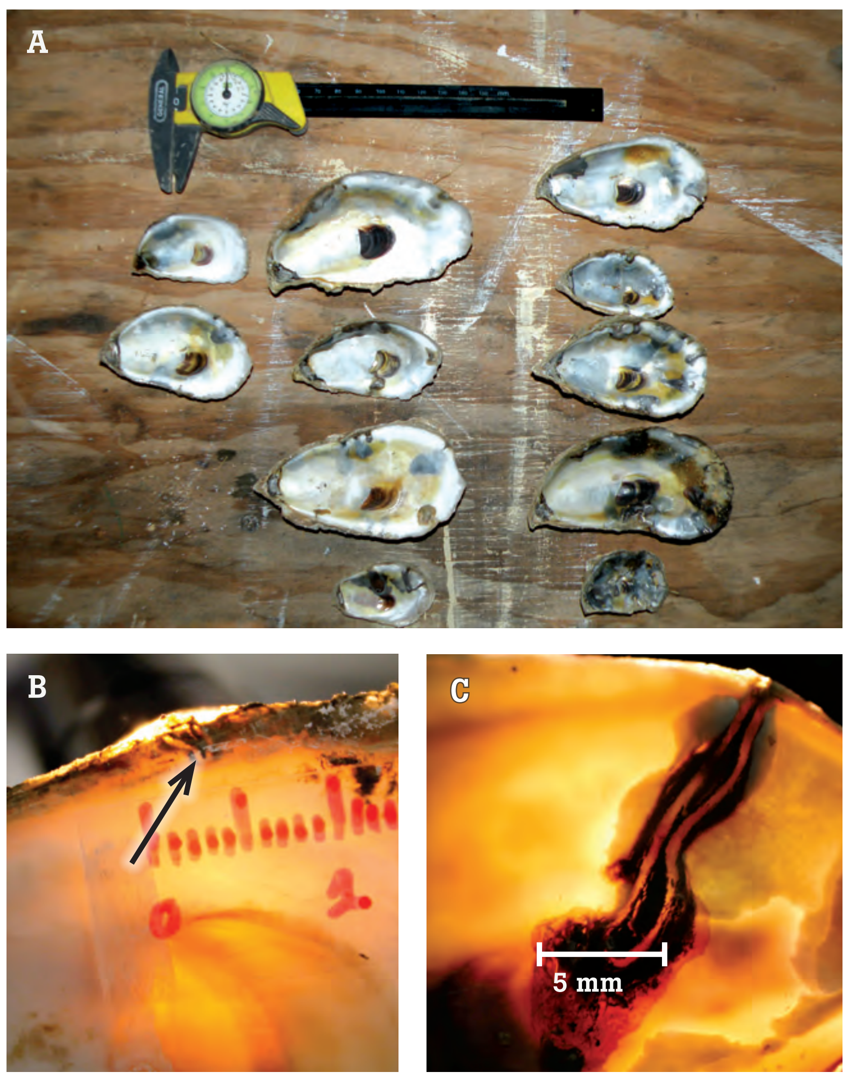

Figure 1 (A) Oysters with light infestations (top, left) and heavy infestations (lower right) of blister worm. D. Morse photo. (B) Close-up of the top edge of an oyster shell with a newly minted juvenile burrow (arrow). From the earliest stages *P. websteri* burrows have a characteristic u-shape with both ends extending to the external surface of the bivalve shell. Photo courtesy of Ian Ellis. (C) Close-up of a large adult *P. websteri* burrow as viewed from the inside of the shell. The u-shaped worm burrow extends from the lip of the oyster shell toward the adductor muscle (at lower left) and is covered by a thin layer of conchiolin and shell nacre. The mud and fecal deposits lining the burrow are clearly visible. P. Rawson photo.

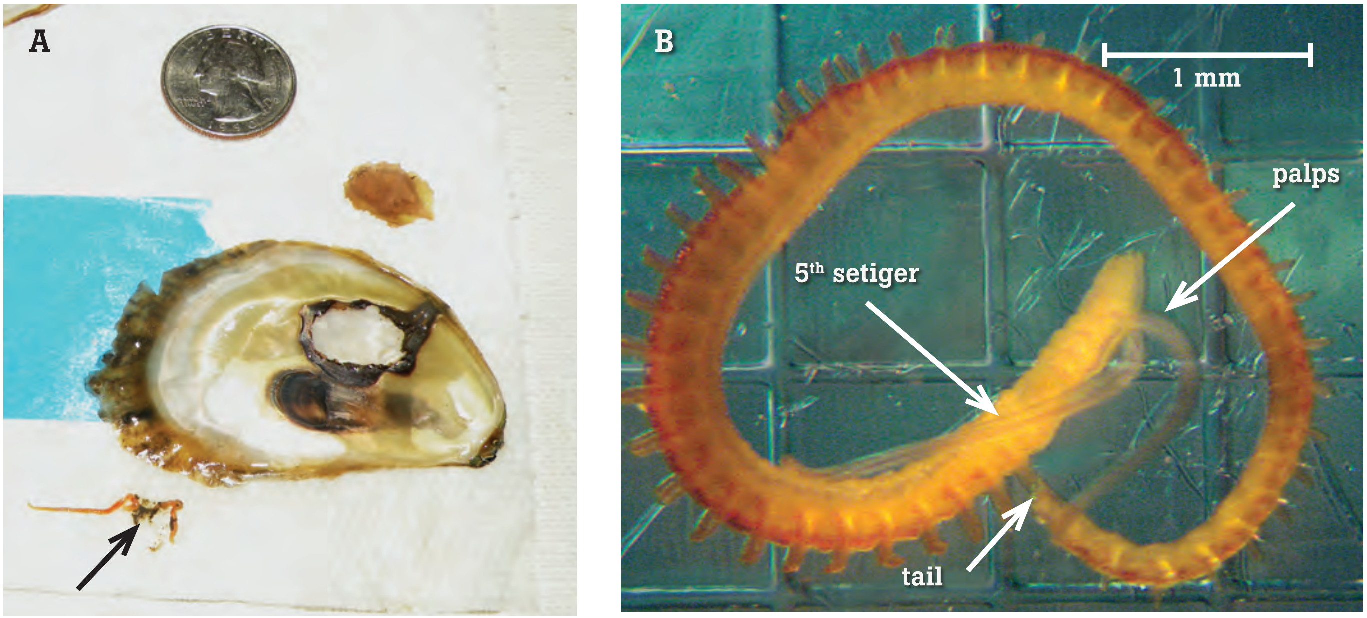

Figure 2 (A) Large blister worm excavated from well-established burrow. The chip of shell that had coverd the burrow is shown next to the quarter. D. Morse photo. (B) Photo-micrograph (12x) of adult blister worm showing palps at anterior (head) end, modified 5th setiger, and tail fan or pygidium. S. Brown photo.

spermataphore(s) in the burrow of the female. The female will deposit egg cases along the wall of the burrow and each egg case can contain 50 or more yellowish to orange eggs. The burrows of large females may contain several dozen egg capsules arranged "like beads in a string" (Blake 1971) (*Figure 3A*).

Upon hatching, the three-segmented larvae are approximately 230 microns in length (about one quarter of a millimeter) (Orth 1971). Characteristic black pigment bars soon develop (*Figure 3B*). The growth rate of larvae in the plankton are temperature dependent; Blake (1971) found that the larvae of *P. websteri* reach 14-15 segments in length within 40 days at 15 °C (59 °F). Growth is slower at colder temperatures and at 6 °C (42.8 °F) larvae will not be past eight segments even 60 days after hatch. Typically, *P. websteri* larvae are ready to settle onto calcareous substrates and metamorphose when they reach 17 segments (about 45 days post-hatch). Given the extended planktonic period for this species, it is generally

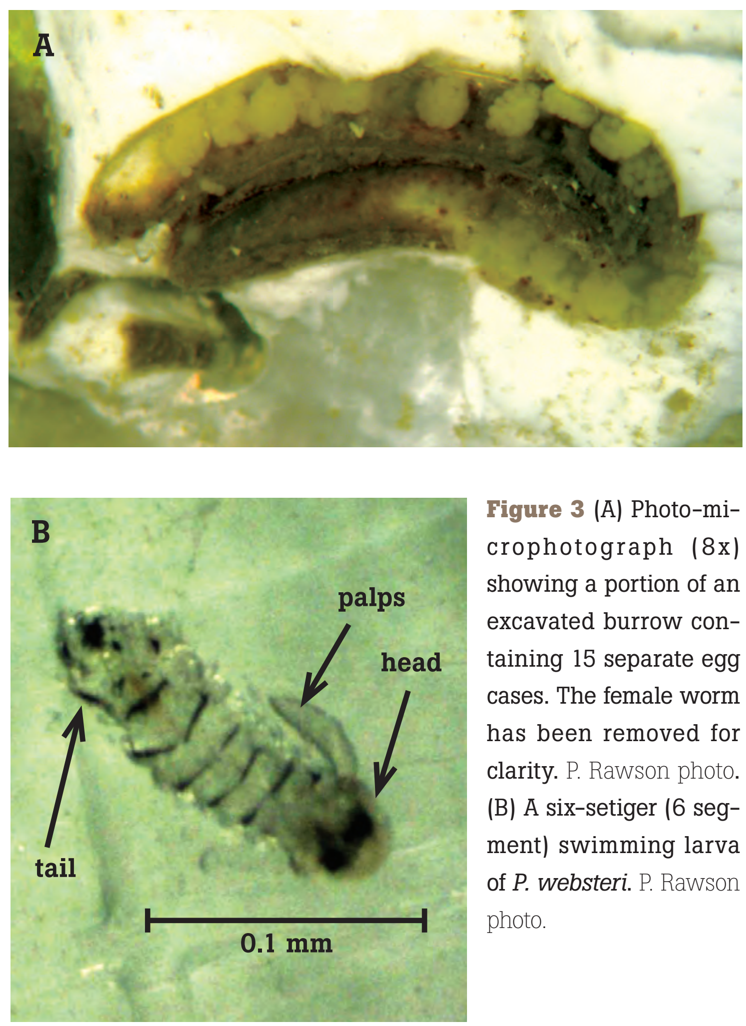

Figure 3 (A) Photo-microphotograph (8x) showing a portion of an excavated burrow containing 15 separate egg cases. The female worm has been removed for clarity. P. Rawson photo. (B) A six-setiger (6 segment) swimming larva of *P. websteri*. P. Rawson photo.

assumed that the larvae disperse broadly, but there have been no studies confirming this. Interestingly, Haigler (1969) suggested two different types of larval development in *P. websteri*; in addition to larvae that are released at the three segment stage, she observed that in some cases, the larvae that hatched earliest consume undeveloped "nurse" eggs and may complete development to the 17-segment stage within the burrow. It is unclear how commonly this occurs, and the impact of variation in release stage on dispersal and the severity of blister worm infestations on individual oyster farms.

Settlement and burrowing

Blister worm burrows in Eastern oysters occur on both the flat and cupped valves of the shell. According to Zottoli and Carriker (1974), larval worms will settle wherever there are cracks and crevices in the shell surface. Recently-settled worms first build a mud tube on the surface of the shell and then extend the burrow by penetrating the shell itself (*Figure 1B*). Juvenile and adult worms in the genus *Polydora* have a specialized fifth segment and it was initially thought this segment played a key role in excavation of the burrow. Haigler (1969), however, provided evidence that the penetration of the shell is likely achieved through chemical means and the modified segments are more likely to function in securing the worm within the burrow and in building the tube that lines the burrow. Consistent with Haigler's observations, Zottoli and Carriker (1974) reported that worms secrete a "viscous fluid" onto the surface of the burrow that loosens the shell structure.

Once within the burrow, blister worms combine mucus, shell material, and detritus to build a tube within the excavated burrow. The outer opening of the burrow will be visible, appearing as a circular hole (0.5 mm in diameter) at or near the shell margin. It is currently unknown whether there is a minimal shell size in oysters below which they are free from infestation by *P. websteri*.

Treatments

Treatment of infested oysters has proven to be extremely difficult, and no single method with universal application has been identified. The following is a brief summary of the more common methods, including some recently designed treatments that appear promising.

Exposure during the tidal cycle

Reports from growers, along with the results of a study by Littlewood and colleagues (1992), suggest that a regular period of air-drying during each tidal cycle may be effective in reducing or eliminating problems with blister worms. Intertidal culture, such as rack-and-bag, cages, or adjustable longlines, are well suited for this approach (*Figure 4*). Littlewood et al. (1992) noted that aerial exposure lasting approximately 40 percent of the tidal cycle (for example, five hours during each low tide) was helpful in reducing blister worms. The exact elevation, relative to mean low water, where oyster cages should be placed to achieve such exposures is site-dependent. The efficacy of exposures will depend on the timing of low tides and weather, and growers will have to make adjustments to achieve suitable exposures based on their local conditions. Recent advances in flippable/submersible cages allow growers to regularly air-dry oysters even when they do not have access to intertidal or shallow-water lease sites.

Figure 4 Rack-and-bag systems like this may help to reduce blister worm presence by regular exposure during each tidal cycle. D. Morse photo.

Bottom culture

Conflicting information has emerged over the incidence of blisters on bottom-planted oysters. Some producers report that bottom culture of oysters appears to curb blister worm infestations, citing that oysters grown on the bottom become covered with a thin layer of silt that may reduce blister worm settlement or result in direct mortality by suffocating worm. Oysters grown in higher-flow areas, typified by gravel or cobble substrates, also appear to have lower incidences. On the other hand, some growers have seen heavy infestations in bottom-grown oysters, and the exact factors behind these observations are not fully understood. Whether bottom culture provides any protection from blister worm infestations is unclear. Growers should experiment with the use of bottom grow-out first, before broad-scale adoption of the method.

Salt brine and freshwater dips

Several reports suggest submerging oysters into salt-saturated or freshwater solutions may rid oysters of blister worm infestations. For example, Nel and colleagues (1996) report reduced pest loads when *C. gigas* infested with the mudworm *P. hoplura* were treated by a twelve-hour freshwater soak. Dunphy and colleagues (2005) exposed *Tiostrea chilensis* infested with another shell-boring polychaete (*Boccardia acus*) to freshwater or brine treatments for three to five hours. The freshwater baths were more effective than brine baths.

Freshwater and brine dips have been combined with treatments at different water temperatures in an attempt to kill blister worm. Nel and colleagues (1996) used a heated (70 °C/150 °F) saltwater soak for 40 seconds and noted reduced worm infestation without significantly affecting oyster survival. Recent experiments in Australia and Tasmania have focused on a hypersaline (brine) cold dip to control overset of oysters and infestations of different species of blister worms. Dubbed "The Super Salty Slush Puppy," this approach uses salt-saturated seawater held at –19 °C (–2 °F) and a dip of approximately 60 seconds. Initial trials have looked promising against blister worm infestations, but additional work needs to be conducted to confirm those results.

Other treatments combine freshwater or brine dips with periods of air exposure. Hooper (2001) described a treatment applied on oyster farms in North Carolina, where infested oysters were given a 15-minute saturated salt immersion, followed by a one-hour air exposure before placing oysters back into bottom cages. Hooper noted that air-drying substantially increased worm mortality and general marketability, but also found good results with bottom-seeding in his experiment. Rheault (pers. comm.) found good success in Rhode Island, with a 10-minute bath, followed by an air dry of several hours.

The general conclusions that can be drawn from these reports are that infested oysters can be treated in salt-saturated seawater for times ranging from 5 to 15 minutes, but such treatments should be followed with an air-exposure immediately afterward for a minimum of one hour and possibly up to 24 hours…and results may be mixed. Due to the heat of solution for concentrated brines, the temperature of brines will initially be above that of ambient seawater, and this may impart stress on the oysters and increase oyster mortality. Similarly, heated/chilled seawater dips can be effective, but may be difficult to apply on many farms and growers need to carefully monitor for damage to the oysters themselves.

Freshwater dips require a lengthy treatment lasting between three and six hours, along with an air exposure time of an hour or more. The salinity of a freshwater bath increases as successive batches of oysters are treated, so frequent changes of the bath are required for the method to be effective, and on farms where access to an adequate supply of freshwater is limited, this will not be the method of choice. Growers should be aware that the timing of dips and aerial exposures relative to hot or cold weather can have a substantial impact on the subsequent recovery, survival, and growth of treated oysters, particularly for smaller size classes (<25 mm shell height) of oysters.

Cool air storage

Placing oysters in cool air storage on land has been used in Maine to successfully treat blister worm infestations (J. Leach and N. Brown, unpublished data). In this treatment, oysters are held at a temperature of 3 °C (38 °F), for three to four weeks, during which time 100 percent of adult worms are killed. The oysters are then redeployed on the farm to allow the oysters to lay down a new layer of nacre and cover over the blisters. This treatment is similar to methods used for overwintering oysters in Maine (Hidu et al. 1988, Morse 2006). Application of cool air storage treatments for killing blister worm should follow the same general rule used for overwintering regarding temperature control, air movement, moist conditions and containment:

- maintain temperature at or near 3 °C (38 °F);
- keep constant, moderate air flow;
- cover oysters with a damp cloth to prevent them from drying out;
- hold oysters in containers that do not permit standing water;
- apply mild pressure on the oysters to assist in keeping the valves closed, such as packing the oysters densely or in mesh bags.

At present, the effect of cool air storage on the viability of blister worm eggs in burrows has not been determined. However, the eggs are not a “resting stage” (like a cyst) and thus are likely to be more vulnerable than adult worms to this treatment.

There are logistical and labor issues associated with cool-air storage, including rental of a facility and transportation of the stock. Although oyster mortality is usually low when this treatment is applied during winter months, mortality increases when the treatment is applied at other times of the year (J. Leach, pers. comm.). Thus, cold storage is best applied in winter when oysters have built up glycogen reserves and oyster metabolism has decreased with decreasing water temperatures.

Lastly, a combination of freshwater bath and cool air storage may provide a synergistic effect, where the use of both is more effective than one or the other used singly. Brown (2012) found that 14 days in storage resulted in 100 percent mortality of blister worms, when done following 72-hour baths in anything from fresh water to seawater at 30 ppt. Given the impracticalities of 72-hour baths, but the effectiveness of the relatively short storage time, it may be that a dip of fairly short duration and low salinity (not necessarily zero) could be combined with short-duration storage, and still achieve a successful result.

CAUTION! For any of the techniques mentioned above there are a wide range of variables to take into account: ambient temperature, ambient salinity, length of treatment, size and health of the oysters, etc. To prevent loss of a large number of oysters, growers should ALWAYS test a small group of before subjecting large numbers of individuals to any treatment.

Chemical treatments (not recommended)

A wide variety of chemical treatments have been used to treat blister worm infestations. Examples include soaking oysters in copper sulfate ($CuSO_4$), chlorine, formaldehyde, marine dipterenes from algae, phenol, calcium hydroxide (lime), tetrachorethylene (Dunphy et al. 2005, Gallo-Garcia et al. 2004, Nel et al. 1996) as well as iodine, bleach, acetic acid, or a hydrated lime solution. While these chemicals may kill mudworms within their burrows, many are toxic, have significantly negative ecological impacts, require careful handling and permitting, and are likely to render the oysters unmarketable or harmful to human health. Given the environmental risks associated with the use of these chemicals, growers should avoid their use.

Biosecurity

While the blister worm is native to Maine, infestation levels are not consistent across the state. With some notable exceptions, moving oysters (seed and adults) within Maine is less regulated than interstate movement, although infestations may have occurred in previously unaffected areas due to the movement of infested oysters. While *P. websteri* has been widely observed in Maine estuaries, it remains unclear as to why this species is a pest in some locations, but not in others. Even so, growers are strongly urged to limit the movement of shellfish from areas of known heavy *Polydora* infestations.

A simple test can be used to determine presence of blister worms in shellfish by placing oysters in a solution of one part alcohol (even using something such as vodka or whiskey) combined with 19 parts seawater. Over the course of a few hours, worms will emerge and can then be identified (*Figure 5*). Treatment such as cold storage followed by testing should be conducted to be sure that the worms have been destroyed prior to authorizing shipment to a different area.

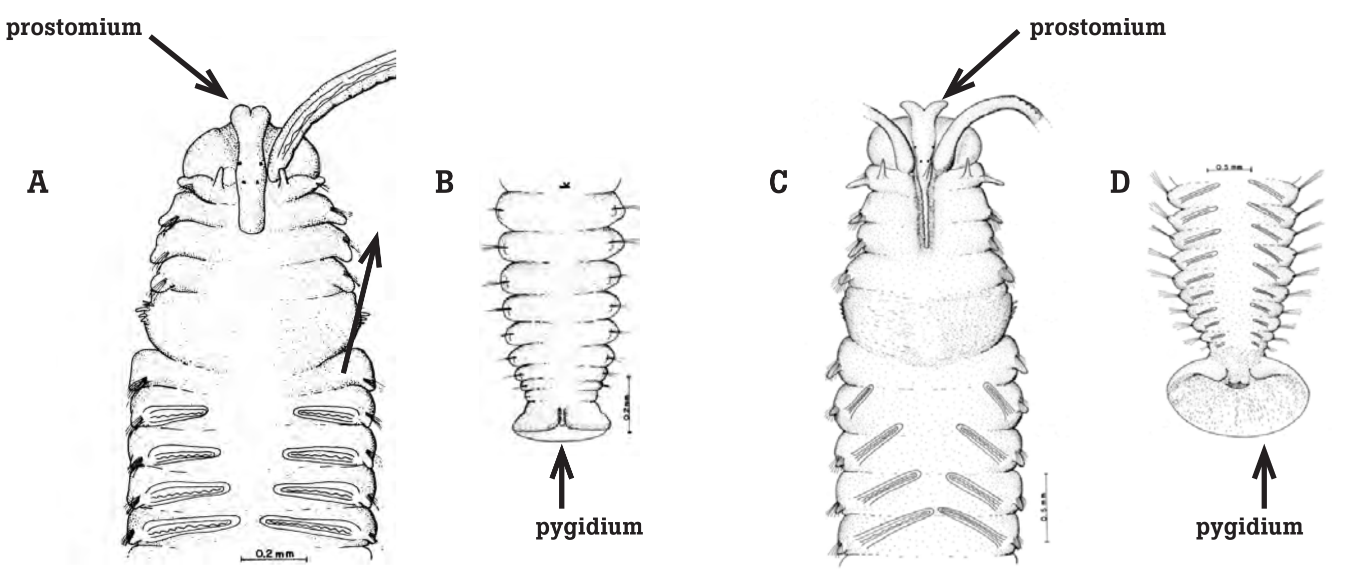

Figure 5. Two species of *Polydora*, *P. websteri* and *P. cornuta*, are found in close association with eastern oysters. Although these species are morphologically similar, only *P. websteri* is known to burrow into oyster shells while *P. cornuta* often builds mud tubes on the surface of oysters or cages. A comparison of anterior segments of *Polydora websteri* (A) and *P. cornuta* (C) shows that the prostomium in *P. websteri* is typically rounded while that of *P. cornuta* is flared and bifurcated. At the posterior end, the pygidium is cup-shaped in *P. websteri* (B) and is broadly flared in *P. cornuta* (D). From Blake (1971).

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