Report to World Organisation for Animal Health (OIE)
A Case Study: proposed measures to minimize the threat of* Polydora *spp. to Washington State shellfish aquaculture

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SHELL-BORING POLYCHAETES: AN UNACCOUNTED RISK **|** When preparing a pot of soup, ingredients can be added, but not removed. If a spice that interferes with other flavors is added by mistake, there is no recourse. Like soup, estuaries retain organisms once they are introduced, and invasive species can interfere with other "ingredients" (Naylor, Williams, and Strong 2001). Once introduced, aquatic invasive species are rarely eradicated, and the most feasible option is often to limit further geographic spread of the invader (Çinar 2013; Paladini et al. 2017; Bower, McGladdery, and Price 1994). *Polydora*, a genus of marine worms, is one such invader. The shell-boring *Polydora* spp. are parasitic polychaetes, and while they infect a broad range of hosts (e.g., bivalves, gastropods, coralline algae), they pose a major risk to shellfish aquaculture species, such as oysters.

Polydora infections compromise shell integrity, kill some host species, stunt growth, and reduce the oyster half-shell market value (review, C. A. Simon and Sato-Okoshi 2015). As *Poldora* tunnel into shells, they build a burrow with shell fragments, mucus and detritus (Wilson 1928; Zottoli and Carriker 1974). The oyster responds to the worm by forming a blister over the burrow (Whitelegge 1890; Lunz 1941). This often results in the tube of detritus becoming anoxic, and is the primary cause of half-shell oyster depreciation. If the blister is nicked during shucking, the detritus can contaminate the oyster meat and brine, detracting from the flavor and presentation (Morse et al. 2015). Oyster industries around the globe have experienced massive economic losses due to negative consumer responses to mud worms and blisters in their freshly shucked oyster (Shinn et al. 2015). Oyster producers are also burdened with costs associated with infection control, such as modifying gear, reducing stock density, and implementing expensive treatment measures (Bailey-Brock and Ringwood 1982; Hooper and Kirby-Smith 2001; Loosanoff and Engle 1943; Nell 2001).

Polydora worms do not usually kill the host, nor do they inhabit host tissue, so infections can often unnoticed (Korringa 1976). Consequently, *Polydora* spp. and other shell-boring parasites are not explicitly monitored or regulated as invasive species of concern in the United States, despite historic economic loss and risk to currently uninfected regions with valuable aquaculture production (Shinn et al. 2015). Early warning protocols address other risks to shellfish, particularly those that result in large-scale mortality events and consumer safety concerns (Shumway 1990). Where shellfish are harvested or produced commercially, health departments regularly monitor water for fecal contamination and paralytic shellfish toxins to ensure consumer safety (Shumway et al. 2003). Shellfish hatcheries use complex water filtration systems to avoid invasion against pathogenic bacteria such as *Vibrio* spp. (Jorquera et al. 2002; Brown and Russo 1979; Utting and Helm 1985). When large mortality events occur, shellfish hatcheries and farms are required to screen for disease such as the Oyster Herpes Virus (OsHV-1), and to quarantine animals exhibiting symptoms (Paul-Pont et al. 2014; Meyer 1991). No analagous regulations or protocols exist for for parasitic shell borers such as *Polydora (C. A. Simon and Sato-Okoshi 2015)* in the United States. This is an important oversight, as *Polydora* spp. has a long history of invading estuaries, decimating farms, and persisting as an invasive pest species.

In the early 1880's, oysters infected with mud worms were imported from New Zealand into Southeast Australia; before being sold in Australian markets, they were routinely refreshed or fattened in bays adjascent to native shellfish beds (Cox 1889; Edgar 2001; Quinan, 1883). By

1889, *Polydora* oubreaks had infected thirteen separate estuaries in the region, and subsequently destroyed the native oyster beds, some of which never recovered (Cox 1889; Quinan 1884; Benson and Gyler 1887; Grant 1889; reviewed in Ogburn 2011). More recently, *Polydora spp*. were introduced into Hawaii, likely via stock shipped from mainland United States and Mexico (Eldredge 1994). In one case, *Polydora websteri* brought to Oahu via California oyster seed resulted in a severe infestation, and caused farmers to abandon their land-locked oyster pond (Bailey-Brock and Ringwood 1982).

While not all invasion events are documented, there is extensive literature on the impact of already-established *Polydora* species on shellfish aquaculture, and a long list of regions that are constantly battling *Polydora* infestations. For example, *Polydora hoplura* killed over 50% of abalone stocks in Tasmania and South Australia between 1995 and 2000. In British Columbia, *Polydora websteri* caused up to 84% mortality in scallop grow-out sites from 1989 to 1990 (Shinn et al. 2015). In the summer of 1997, one million juvenile scallops were culled from a Norwegian scallop nursery due to a P*olydora* sp. infestation; in total, one-third of Norway's 1997 scallop cohort was lost (Mortensen et al. 2000). In 1998, very intense infestations (up to 100 worms per oyster) of *Polydora ciliata* in *Crassostrea gigas* oysters in Normandy, France resulted in considerable reduction in growth and meat weight, which may have contributed to unusually high summer mortality rates that year of up to 51% (Royer et al. 2006). Commercial operations in the United States Atlantic and Gulf Coasts have been battling the native *P. websteri* and *P. ciliata* since oyster farming began, experimenting with various culture methods and treatments to minimize impact (Lafferty and Kuris 1996).

***PURPOSE OF THIS REPORT* |** In this report, I examine the threat of *Polydora* spp. invasion to oyster aquaculture in the Puget Sound in Washington State, United States. This case study investigates the risks associated with *Polydora* spp. to an estuary with a growing shellfish aquaculture industry, no described native burrowing *Polydora* spp., no documented infections of exotic *Polydora* (although there have been recent sightings), and no aquatic parasite invasive species regulations in place. I review *Polydora* transmission modes, life history, host pathology, and distribution. I then propose survey, regulatory, and biosecurity measures to avoid introduction of *Polydora* to uninfected regions.

Oysters are hosts to many invasive species **|** Oysters comprise nearly 31% of the molluscan species cultured worldwide for commercial purposes (FAO 2014), and have been translocated throughout the world for millennia; ancient Romans considered oysters to be a delicacy, importing them from Britain (Andrews 1948; Mckindsey et al. 2007). Today, modern practices include large-scale movement of stock. Market-ready oysters are commonly shipped live, and spat (juvenile oysters) are captured or cultured in one location and sold to growers, often across state borders (Ruesink et al. 2005; Mckindsey et al. 2007; Wolff and Reise 2002). Eighteen oyster species have been moved between 73 countries, with the dominant Pacific oyster, *Crassostrea gigas*, translocated from its native Sea of Japan to over 50 countries (Lucas and Southgate 2012; Troost 2010). Oysters serve as attachment substrate for other organisms, and their rippled shell morphology provides ample habitat for epibionts, including parasitic species (Ruesink et al. 2005). Oysters have introduced more invasive species to Northern and Western European coasts than ship hulls or ballast water, and movement of *C. gigas* alone is estimated to have introduced over 20 invasive species to Europe (Wolff and Reise 2002). It is important to note that non-oysters can transmit *Polydora*; for example a shipment of shrimp from Mexico may have introduced the non-boring species *Polydora nuchalis* to Hawaii (Bailey-Brock 1990).

Once invasive *Polydora* spp. are introduced to new regions via shellfish transport, they can disperse locally to infect shellfish within a basin. *Polydora* species have a short (1–3 week) free-swimming larval stage, after which they are sessile and parasitic, burrowing into their host's shell after settlement (C. A. Simon and Sato-Okoshi 2015; Blake and Arnofsky 1999; David, Matthee, and Simon 2014; Hansen et al. 2010). During the larval stage, *Polydora* can spread locally with the water current, and can infect nearby oysters. Shellfish farmers grow oysters in high-density bags, racks or lines. A *Polydora* infestation spreads readily within a farm, and the subsequent movement of stock is the primary method for *Polydora* introduction into new regions (C. A. Simon and Sato-Okoshi 2015). Because infected oyster tissue is asymptomatic, the *Polydora* infection is usually not detected via traditional disease screening. Once introduced, *Polydora* may not be noticed until a region is fully infested, and it may be impossible to identify the original means by which *Polydora* was introduced.

Table 1: *Polydora* species of concern in shellfish aquaculture. Adapted and expanded from *Sato-Okoshi, 2015.*

Polydora species	Hosts Infected	Origin	Invasive in
P. aura	*C. gigas, H. discus discus, Pinctada fucata*	Japan	Japan, Korea
P. bioccipitalis	*Mesodesma donacium*	California	Chile
P. brevipalpa	*H. discus hannai, P. yessoensis, C. gigas, Crassostrea rhizophorae*	Sea of Japan, Vostock Bay	China, Japan, Brazil
P. ciliata	*C. gigas, M. edulis, Ostrea madrasensis, P. fucata, Tapes philippinarum*	England	India, France, Germany, Italy, UK
P. cornuta	*Crassostrea virginica*	USA Atlantic Coast	USA

P. ecuadoriana	*C. gigas,* *C. rhizophorae*	Ecuador	Brazil
P. haswelli	*C. gigas, M. edulis, O. chilensis, Pecten novaezelandiae, Perna canaliculus, P. fucata, S. cucullata, H. discus discus*	Australia	Australia, Korea, Japan, New Zealand
P. hoplura	*C. gigas, M. edulis, H. midae, Haliotis tuberculata coccinea, H. rubra, Haliotis laevigata*	Bay of Naples	Australia, Belgium, France, Holland,New Zealand, South Africa, Spain (Canary Islands)
P. onagawaensis	*Aequipecten tehuelchus, A. purpuratus, Nodipecten nodosus, C. gigas, H. rufescens*	Japan	China, Japan
P. rickettsi	*Aequipecten tehuelchus, A. purpuratus, Nodipecten nodosus, C. gigas, H. rufescens*	Southern California	Argentina, Brazil, Chile
P. uncinata	*C. gigas, H. discus discus, H. discus hannai,* *H. diversicolor, Haliotis diversicolor supertexta, Haliotis gigantea, Haliotis roei, H. laevigata*	Japan	Australia, Chile, Japan, Korea
P. websteri	*C. gigas, C. rhizophorae, C. virginica, M. edulis, P. yessoensis, Placopecten magellanicus, P. fucata, Pinctada imbricata, S. commercialis,* *S. cucullata, Saccostrea glomerata*	USA Atlantic Coast	Australia, Brazil, Canada, China, Japan, Namibia, Mexico, New Zealand, South Africa, USA, Ukraine, Venezuela

GENERAL LIFE CYCLE OF* POLYDORA *SPECIES **|** *Polydora* is a genus of polychaete worms in the phylum Annelida (Table 2). According to the World Register of Marine Species, 159 *Polydora* species are described and span marine environments on all continents (WoRMS, accessed November 19, 2017) . The species of *Polydora* that are most destructive to shellfish aquaculture are those bore into calcareous shells. After a brief planktonic, larval stage, a burrowing *Polydora* worm settles onto the prospective host's shell and begins building a tunnel in which it will live (Wilson 1928; Loosanoff and Engle 1943; Blake 1969; Blake and Arnofsky 1999). The worm enters along the margin of the shell and excavates its burrow toward the shell center, secreting a viscous fluid to dissolve the calcium carbonate shell material, and using its specialized segment, the 5th setiger, to stabilize its tunnel during burrowing (Haigler 1969; Zottoli and Carriker 1974). A *Polydora* species' burrow morphology is often a unique, identifying feature (Sato-Okoshi and Okoshi 1997; C. A. Simon and Sato-Okoshi 2015).

Table 2: Taxonomy of the genus *Polydora*

Kingdom	Animalia
Phylum	Annelida
Class	Polychaeta
Subclass	Sedentaria
Infraclass	Canalipalpata
Order	Spionida
Suborder	Spioniformia
Family	Spionidae
Genus	*Polydora*
# Spp.	159

As the *Polydora* adult grows, reproduces, and deposits feces and mud in its burrow, it feeds on particles in the water column and on materials on the shell surface (Loosanoff and Engle 1943). Reproduction occurs when the male deposits sperm in a female's burrow, and the female deposits up to several dozen egg casings along the burrow wall, with each case containing dozens of eggs. One fecund female can produce hundreds of larval progeny (Blake 1969). It should be noted that some hermaphroditic species have been observed (e.g. *Polydora commensalis*)(Hatfield 1965).

Larvae hatch from eggs and emerge from their maternal burrow as free-swimming larvae until they settle onto a substrate (Orth 1971; Blake 1969). Growth rate in the larval stage depends on ambient water temperature, and thus the time spent in the water column differs between species and with local environmental conditions, but can be as long as 85 days (Blake and

Woodwick 1971; Blake and Arnofsky 1999). This relatively long larval stage may allow for long dispersal distances (C. A. Simon and Sato-Okoshi 2015). Additionally, in some instances, early hatched larvae can feed off underdeveloped eggs ("nurse eggs"), and complete development in the burrow (Haigler 1969). This could result in an individual host's parasitic burden compounding over time due to high rates of autoinfection.

POLYDORA *HOST PATHOLOGY* | *Polydora* is colloquially known as the mud worm, or mud blister worm. Three burrowing species, *Polydora websteri, Polydora ciliata,* and *Polydora hoplura,* are the most widely distributed and the most destructive to shellfish aquaculture (Radashevsky, Lana, and Nalesso 2006) (see Table 1). Many *Polydora* species have broad host selectivity, and are distributed worldwide; for example, *P. websteri* is native to the United States Atlantic Coast, but infects 9 commercially important cultured bivalve species around the world including 7 oyster, 1 mussel, and 3 scallop species (C. A. Simon and Sato-Okoshi 2015). Non-boring species, such as *Polydora nuchalis,* can also have negative effects by fouling culture equipment with large masses of sediment and tubes (Bailey-Brock 1990).

While *Polydora* do not penetrate host tissues, the host responds to burrowing activity by laying down a proteinaceous layer called *nacre* to protect soft tissues from the irritation of shell penetration (Whitelegge 1890; Lunz 1941). Parasite burden is negatively correlated with growth rate, and while the mechanisms are not fully understood, this is possibly due to changes in physiology from nacre production (Carol A. Simon 2011; Boonzaaier et al. 2014; Lleonart, Handlinger, and Powell 2003; Kojima and Imajima jan1982; Wargo and Ford 1993; Royer et al. 2006). For example, *C. gigas* infected with *P. websteri* showed poorer growth, more frequent but shorter valve gaping, and higher blood oxygenation, with a three-fold increase in a protein involved in oxidative stress (Cytochrome P450 production)(Chambon et al. 2007). High worm burden also negatively correlates with shell strength and increases host vulnerability to predation in *Mytilus edulis* (Kent 1981). Interestingly, fecundity increased in *Striostrea margaritacea*, a rock oyster, when infested with *P. websteri* (Schleyer 1991). This may be a stress response –an effort to reproduce while resources allow, similar to nematode-parasitized mice producing larger litters (Kristan 2004), or to plants prematurely reproducing ("bolting") during periods of drought (Barnabás, Jäger, and Fehér 2008).

***STATUS OF* POLYDORA *IN PUGET SOUND,* WA |** The Puget Sound, one of the largest shellfish production areas of North America, may be on the verge of a *Polydora* infestation. *P. websteri,* one of the most common and destructive *Polydora* species, has been identified in commercially-sold oysters grown in South Puget Sound (Chelsea Wood & Heather Lopes, Pers. comm.). This indicates that invasion may have already occurred, despite no documentation to date by resource managers, researchers, or farmers. Washington State has no native, shell-boring *Polydora* species, nor any prior record of alien species. In a 1963–1964 survey of benthic species in the Puget Sound, no *Polydora* species were identified (four species were misidentified, but have since been reassigned)(Lie 1968). Shellfish farmers do not associate any production loss to *Polydora* (Washington Sea Grant 2015) and are largely naive to the worm and to its threat, since it has not historically been an issue in the region (Ken Chew Shellfish Restoration Hatchery, Taylor Shellfish Company, Pers. comm.). That infection has been discovered in South Puget Sound suggests that *Polydora* were likely introduced via shellfish translocation, as the nearest region with documented, introduced *P. websteri* populations is California (Sato-Okoshi and Okoshi 1997; Blake 2017).

The observation of *P. websteri* in South Puget Sound is the first reported sighting of any *Polydora* species in Washington State. This worm poses a serious threat to the region's iconic shellfish industry. While the distribution and intensity of infection is currently unknown, *Polydora's* presence warrants immediate action to avoid future introduction and control further spread.

***Recommended control measures in Puget Sound, WA* |** I recommend a five-pronged approach to control the spread of *Polydora* spp. in Puget Sound. This approach also aims to minimize the financial and labor burden to shellfish farmers and aquaculture facilities.

1. Quantitative survey of oyster products in Washington State to establish a baseline *P. websteri* for geographic distribution, prevalence, and intensity
2. Require regular screenings of commercial imported and translocated products
3. Add *Polydora* and other shell-boring, parasitic polychaete species to regulated invasive species of concern
4. Require hatchery intake treatments to kill broodstock epibionts
5. Alert shellfish industry of the risk, and train handlers to identify blisters

Action 1. Baseline quantitative survey: *Polydora* presence and baseline infestation rates need to be established to control further spread into uninfected areas. Washington Department of Fish and Wildlife (WDFW) should conduct a quantitative survey of live oyster stock at each farm in each subbasin. Willapa Bay, a coastal estuary, should be included due to frequent transport of live oysters between water bodies (Taylor Shellfish Farms, Pers. comm). Oyster condition should be estimated for organisms in tandem with *Polydora* burden to assess impacts of infection on tissue production. This initial survey should include sampling 50 oysters at each farm for the following metrics: oyster total weight and shell weight, to estimate condition; presence/absence of any *Polydora* species; worm burden for each oyster; number of blisters on each oyster. Sampling site coordinates and shellfish company details should also be collected to merge with transfer and import permits, will help identify the *P. websteri* point of invasion by retracing the movememt of infected oysters into and throughought the state.

Action 2. Regular screenings: Any group importing shellfish or cultch (empty shells) into Washington State should be required to inspect a subset of the product for *Polydora* spp. upon arrival, and report findings to WDFW. Regular screenings of all imported live shellfish and cultch and will ensure that *Polydora*-infested shellfish are identified before they touch Washington's marine waters.

Transfer permits are currently required in Washington State for the transfer of live shellfish between subbasins. I recommend the following additional requirement: any entity operating in a potentially infected zone must submit a subsample of their stock to WDFW for inspection prior to receiving a transfer permit for movement between Washington State basins. If a location is found to be infected, no stock may be exported. Infected stock may be sold commercially for consumption, but must include a tag warning consumers to not hold oysters or discard shells in marine waters.

I recommend that, during inspection, 2% or 150 animals are sampled, whichever is lesser. This is consistent with new Abalone Aquaculture Translocation Protocol in Victoria, Australia, which seeks to control the spread of *Polydora hoplura* and other mud worms (Victorian Fisheries Authority 2015). The best method to screen for *Polydora* in oysters is to shuck and inspect the inside of the valves for evidence of burrowing and blisters. Governing agencies that require sampling (Department of Health, WDFW) should coordinate shellfish sampling, so as to minimize shellfish producers' burden and product loss.

Action 3. Regulatory measures: Under WAC 220-370-200, import permits are mandatory for any entity importing live shellfish from outside Washington State. This includes shellfish used for any purpose including aquaculture, research or display, but excludes animals that are market-ready and are not expected to contact Washington waters. These permits are regulated by WDFW, and minimize the risks of disease by requiring a “clean bill of health” certifying that the origin is disease free. This regulation does not, however, certify the organisms as free of *Polydora*, as the certification screens tissue, not shell. Furthermore, the “market-ready” loophole does not stop people from introducing *Polydora* spp. by purchasing live oysters and holding them off their beach or dock, or throwing the shells on the beach (which is in fact encouraged in the Puget Sound area to increase shell surface for native oysters). For effective control in Puget Sound, import permits must include screening for invasive *Polydora* species.

Currently, transfer permits are required when moving adult oysters, seed, shell and cultch between basins. These are intended to eliminate the risk of introducing invasives and pests. Identified pests are currently limited to those known naturalized invasive species (e.g., oyster drills). Regardless of the current status of *Polydora* in Washington State, risk to the shellfish industry is high and it must be added to the list of species for which we inspect.

Under WAC 220-640-020 and WAC 220-640-010, it is prohibited to import live aquatic organisms without a zebra-mussel free certificate, and to transport water or any aquatic contents from bodies of water infected with known aquatic nuisance species. These sites are primarily freshwater lakes that are infected with the invasive species, such as zebra mussels and European green crab. No polychaete or parasitic species are currently listed under this regulation; we should consider classifying *Polydora* as a nuisance species.

Under current law, WAC 220-370-180 requires aquaculture groups to report any disease outbreak immediately to the WDFW. Consequently, hatchery staff and farmers monitor for large mortality events that indicate disease. Regulations should also require presence of mud blisters to be reported to WDFW. Failure to do so can result in revocation of the company's shellfish aquaculture permit. Growers should be able to anonymously report farmers that they suspect to have *Polydora* infections, and WDFW should conduct inspections at random to ensure compliance.

Action 4. Hatchery intake treatments: Hatcheries in Puget Sound produce the majority of seed grown in Washington State. Hatcheries are therefore particularly important in parasite management, since they are the node from which oysters move about the region. With transfer permits dependent on *Polydora* screenings, an infestation in broodstock or nursery sites would render that facility inoperable. It is therefore incumbent upon hatcheries to practice strict biosecurity measures. Hatcheries must treat all incoming stock and regularly screen for *Polydora* (discussed above) prior to distributing product.

Researchers have tested numerous treatment methods, but none have been shown to be fully effective. Currently, the most effective method is the "Super Salty Slush Puppy" (SSSP) first developed by Cox et al. (2012). The protocol is a 2-minute full submersion of oysters in brine (250 g/L) between -10°C and -30°C (i.e., ice-water), followed by air drying for 3 hours. The SSSP also effectively kills other nuisance epibionts, such as barnacles. Peterson (2016) recently compared the SSSP method against other saltwater, freshwater and chemical dips followed by air exposure, and confirmed SSSP as the best method, killing 95% of *P. websteri* while causing only minimal mortality in *C. gigas.*

Other methods investigated include freshwater and salt brine soaks, heat treatments, and chemical treatments (Nel, Coetzee, and Van Niekerk 1996; Dunphy, Wells, and Jeffs 2005; Hooper and Kirby-Smith 2001; Gallo-García, Ulloa-Gómez, and Godínez-Siordia 2004). A potentially effective method not yet documented in the scientific literature is long-term cold storage. Leacy and Brown store oysters at 3°C for 3-4 weeks for highly effective *Polydora* mortality (est. 100%), without increases in oyster mortality. It should be noted that oysters must be covered with a damp cloth in no standing water, and packed tightly to minimize gaping, with constant, moderate air flow. No method to date has recorded the rate at which these interventions render *Polydora* eggs unviable, which is an important question that needs to be answered.

Action 5. Industry education: The proposed new regulations will require growers to recognize a *Polydora*-infected bivalve, and to understand that *Polydora* is a threat to their business. Additionally, farms infected with *Polydora* will be severely limited in their ability to move stock, and will endure additional, inconvenient regulations. Growers in uninfected basins will be greatly incentivized to recognize infection in imported live shellfish, and those with early signs of infection will be incentivized to control spread. Farmers, aquaculturists, and direct-to-consumer purveyors (e.g., oyster shuckers) should also be trained to recognize blisters. Regulators should produce a *Polydora* field guide with images of infected valves, and provide laminated hard-copies to leave at facilities.

BROADER ISSUE: NO NATIONAL REGULATION FOR MARINE PARASITES | According to a 2013 review, 292 polychaete species (15% of all described polychaetes) have been relocated to new marine regions via human transport. Of these, 180 are now established, and 16 are in the genus *Polydora* (Çinar 2013). Despite this threat, there is no international or national governing body regulating this transport.

This oversight is evident in United States wildlife regulations. The United States Lacey Act of 1900 bans trafficking of illegal wildlife, particularly injurious species, but no annelids are listed as injurious (US Fish and Wildlife 2017). Furthermore, United States National Invasive Species Council, formed in 1999, stated in their 2016–2018 management plan, "the United States currently lacks a comprehensive authority to effectively prevent, eradicate, and control invasive species that cause or transmit wildlife disease" (National Invasive Species Council 2016). While the United States Department of Agriculture's 2017 reportable disease list does include 7 molluscan parasites, it do not include shell-boring polychaete (US Department of Agriculture 2017). Aquatic parasites are not recognized on any US list of invasive or injurious species. For example, the United States Geological Services list of Nonindigenous Aquatic Species includes only two annelids, both freshwater species (U.S. Department of the Interior and U.S. Geological Survey 2017).

CONCLUDING REMARKS **|** According to the United States federal government, shell-boring parasitic polychaetes are not recognized as an invasive species, nor are they recognized as a disease agent. Damaged and devalued shellfish farms across the globe due to *Polydora* infections, and a broad body of academic research, suggest that this could be a costly oversight. Washington State should set a national standard for managing against the risks associated with shell-boring polycheates. Given the economic threats of *Polydora* spp. infestation, the $92 million shellfish aquaculture industry in Washington State (Washington Sea Grant 2015), and the recent sightings of *Polydora websteri* in Puget Sound, I recommend immediate action to contain the spread of current *Polydora* infections. A small investment now will mitigate the devastation associated with widespread infestation, which is inevitable if left unmanaged.

FOOTNOTE: IN SUPPORT OF SHELLFISH AQUACULTURE **|** The global human population reached 7.550 billion in 2017, and is projected to reach 9.772 by 2050, increasing at nearly 70 million people per year (United Nations, Department of Economic and Social Affairs, Population Division 2017). As the population grows and countries develop, demand for animal protein will increase. Not all protein sources are created equal. Unlike other large-scale protein production methods, shellfish aquaculture is carbon neutral, with negative nitrogen and phosphorus emissions (Hall 2011; Béné et al. 2015). Filter-feeding shellfish feed on phytoplankton, extract anthropogenic nutrient pollution (e.g., agricultural fertilizer runoff), improve water quality and reduce the frequencies of algal blooms and hypoxia (Nijdam, Rood, and Westhoek 2012). Seafood is a valuable food source, as it contains essential amino acids, micronutrients, and high levels of long-chain poly-unsaturated fatty acids (LC-PUFAs), which is unique among protein sources (Naylor et al. 2009).

Marine aquaculture's full potential is yet to be realized, but is identified as a resource-efficient and sustainable seafood source (U.S. Department of Commerce 2015). Investment in shellfish aquaculture is occurring world-wide to meet the growing demand for more sustainable animal protein. As such, we must consider threats to the shellfish aquaculture as a threat to global food security.

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