To Gail Gatton and Rich Doenges,

Introduction: The decision by the Department of Ecology (DOE) to probably deny shellfish farmers a permit to continue to control the encroachment of the destructive decapod, *Neotrypaea californiensis,* on their lands, will prove detrimental to many or most members of Willapa Bay intertidal biota. This will likely impact a large percentage of the avian species dependent on the stable sediments of the oyster beds as reliable forage areas. In fact, the decline started three years ago when our permit was cancelled and if pest control is not possible, will probably continue over the next several decades. My personal interest is on the shorebirds, especially the sandpiper types, that will continue to lose their rich forage grounds on the oyster cultivating areas. Over the past, there were normally 1000 acres per year (± 2% of Willapa Bay intertidal), based on measurable criteria which would be treated and kept at optimal productivity levels. A greatly reduced proposal submitted this year for 500 acres was made to incorporate additional monitoring with funds supplied by the legislature, to fill in new scientific concerns DOE claims are lacking. Sadly around half of the oyster growers have given up on ghost shrimp control which can only have a negative impact on the entire estuary. These lower intertidal areas shellfish growing areas including the oyster lands are the ones which not only seem to attract the pelagic ghost shrimp larvae but offer optimal growth and survival of the adults and yearly recruits.

The intertidal areas of a bay like Willapa are not uniform or equally suitable for habitat of specific biota. Two major factors of the nearly 50,000 intertidal acres in Willapa are elevation and salinity; the former by closeness to contributor streams and the latter a factor of proximity to the bay mouth. Other more local conditions also effect the biota such as wind and tidal currents, etc. The richer faunal areas tend to be those lower elevation and higher salinity areas which are both public and private in ownership. The private deeded properties are for shellfish growing only. Most of the suitable lower elevation higher salinity publicly owned intertidal mudflats have already been modified by burrowing shrimp with the biotic elements replaced. To date, over 8,000 acres of once productive public intertidal lands (ref. Dr. Brett Dumbauld) and probably over 2,000 acres of additional private ownership parcels representing about 20% of the intertidal area of Willapa bay, are now devoid of nearly all biota except ghost shrimp. Is this the goal of Audubon Wa to support DOE turning productive privately owned oyster growing areas into these biotic wastelands? It seems the only outcome possible with out any means of control. Even those who claim oysters can grow above the benthic destruction on ropes or in bags miss the point that a major source of the nutrition for their crop will be eliminated plus have a negative impact for the other members of the food web. Over time many of these off bottom cultivation methods utilizing tons of plastics are absorbed into the soupy sediments as particles or in total.

In the marine nearshore intertidal the high productivity necessary to support the rich biotic assemblage must rely on an autotrophic component to produce carbohydrates and fatty acids. This is critical for dozens of invertebrate consumers at the lower trophic levels of the food web. The benthic diatoms fill this bill if the bioturbation of the intertidal sediments (mixing and hydrating) by ghost shrimp does not make that impossible. Ghost shrimp remove nearly all usual benthic biota including the biofilm, diatoms, eelgrass, and dozens of invertebrate species. I have written comment papers on various aspects of the Willapa bay intertidal benthic and in a recent posting, Sand to Shorebirds, I try to explain why the physical and biological components make the intertidal of Willapa Bay outstanding for primary productivity and the food web. That is until ghost shrimp disrupt the process.

History: In the late 1950's the oyster farmers along with both state and federal fisheries biologists realized the increasing sediment modification and loss of many members of the estuary fauna and flora related to the increasing abundance of burrowing shrimp. They could observe and understood the damage to the entire biota. They began testing various control methods including pesticides available at that time. Criteria was developed to estimate density and size. Burrowing shrimp abundance with respect to sediment modification and species replacement was indicated by burrow counts and the change in sediment stability. In 1963 the pesticide carbaryl was selected as least damaging to the benthos as it could reduce the ghost shrimp numbers with an application on the bare sediment between

crops. Carbaryl was not persistent, lasting only a short time with no residue or ability to bioaccumulate. It was completely absent before the next crop was planted. It was also obvious that after treatment return of normal biotic forms would occur in greater abundance. Increases in eelgrass and Dungeness crabs become obvious plus one could walk over the area without sinking in a soft soupy sand. Imidacloprid, an even more benign organic mimic chemical was recently selected after years of testing. It was effective while only using one sixteenth the active chemical per acre.

Those early actions by agencies and continual treatment by growers has kept many of the oyster ownership areas productive for growing shellfish while assuring the important intertidal surface remains acceptable for other members of the benthic biota. It kept a level of primary productivity going by keeping the sediment stable. Two oyster beds, provide example with treatment vs non treatment and note the time aspect for some of the biotic factors that can occur over that interval. I drew from Dr. Brooks research sampling data for numbers of amphipods due to their known importance in the food web. The typical time between treatments in beds needing repeated control on our farm usually is around five to six years but in some cases longer. Time is variable as it depends on yearly recruitment and survival of past larval ghost shrimp. In that time between treatments, usually two or three seed crops or four or more harvest crops would have been planted, survived and removed off the treated mudflat. But really important and often missed, it also allows several years of diatom production and support for many invertebrate grazers and thus forage area for the higher trophic levels like birds, fish, crabs, etc.

It was, in part, those productive lower elevation mudflats with higher salinity that were made available for private ownership for shellfish culture soon after statehood. They have continued to support an optimal abundance and diversity of natural species important for the transference of nutrients through the food web. These natural conditions are also the most optimal under which to grow shellfish and thus the incentive for the oyster farmer to fight to maintain. It is important to understand that the intertidal areas which were allowed to be owned for growing out oysters were generally not those areas of the bay where massive beds of native oysters once reproduced and grew. Those areas were kept in public ownership and today are known as the ‘oyster reserves’. Generally, they are not the areas favored by ghost shrimp but where they have been invaded, without any control, today are biotic wastelands.

The Food Web: It is important to understand nutrient production up through often many trophic levels involving both invertebrate grazers and predators and culminating in the higher trophic levels such as fish and birds. This natural process can be eliminated by the massive population expansion of burrowing shrimp. Sampling the mudflat surface on areas of heavy ghost shrimp occupation shows diatoms and biofilm basically missing due to the unstable surface sediment. Not a lot of attention has been given this situation especially the key role diatoms play in converting nutrients with solar energy into forming the estuary biota. For example there are over 85 species of benthic diatoms identified from the Willapa Bay intertidal areas.

I have taken hundreds of biofilm samples from the sedimentary surface on many of our oyster growing areas and posted some examples; Benthic Diatoms and Biofilm. The images will hopefully give a better idea of diatom size and diversity. Most images show approximately one square millimeter in area in a Rafter cell are one millimeter deep. A scale is also marked in most. These samples prior to viewing had been diluted, not concentrated, to free the diatoms from their biofilm so an idea of abundance is available. A healthy diatom covering over a square meter might contain over ten million motile diatom cells and they in turn could be capable of doubling their numbers every few days. The benthic diatoms, most of which are motile, often resuspend and move as single forms or as a cloud along the bottom probably seeking new areas. Attachment to sessile forms such as eelgrass and oysters can increase the diatom abundance.

We need to recognize and elevate the importance of benthic diatoms for their unique productivity with high lipid input into the food web of the intertidal. Then realize ghost shrimp can prevent them from developing the biofilm and abundance on the sediment surface. In non ghost shrimp areas such as the usually higher elevation or low salinity areas or oyster growing lands, a rich forage area is created on the sediment surface, which starts with a layer of benthic diatoms and their biofilm. Since many diatoms produce more carbohydrates and lipids than can be retained within their silica shells the excess is extruded as the biofilm. This is a protective film which seems to act as cover for the diatoms plus from my observation entrap fine particles to aid in stability. The sedimentary surface biofilm give a bonus to the intertidal richness with extruded carbohydrates and lipids. Lipids and fatty acids are a major constituent of diatom cells and the lipid content, although variable, can reach up to 25% of dry weight according to various reports. Shorebirds don't eat eelgrass or chase mixotrophic algal types for their migratory and nesting fat energy. They have to take prey that is left when the tide leaves the mudflat. Normally, this requires those prey which can survive on the mudflat between tides within the upper few centimeters of sediment or under and around sessile forms or in the biofilm. Of course, this is in areas without abundant burrowing shrimp. In addition, without benthic diatoms and those important invertebrate amphipod vectors such as *Corophium* the food web is broken. Fish feeding on those primary consumers obtain their lipid nutrients from the diatoms (e.g. small crustaceans - zooplankton). Autotrophic forms, like diatoms, depend upon the necessary inorganic components to convert to nutrients thus the importance of the weathering of igneous silicate minerals.

With the nutrient by-products from the weathering of igneous silicate minerals and especially important, the soluble silica plus the solar input. Then there is the importance of the diatoms pulling CO_2 from the water and atmosphere plus utilizing (sequestering) that which was part of the weathering process and taken up as bicarbonates, etc. The role and important niche of benthic diatoms is not only possible but of prime importance to the estuary. Keeping the fine surface sand exposed to weathering also seems to enhance the diatom numbers. Sampling of newly cleaned off oyster areas showed healthy biofilm and diatom numbers in just a few days. However, benthic diatoms cannot exist on the unstable sediment surface caused by ghost shrimp as they are probably carried away by tidal currents or buried in the soupy sand. With the loss of the diatom nutrient contribution to the micro invertebrate gazers primary productivity gradually is lost. Other factors can also effect the productivity on the intertidal sediments. If the silicate mineral sands are covered with organic deposits due to reduced currents such as decomposing eelgrass an unfavorable diatom habitat is created. These decomposing areas can bring a deleterious pH change and a more sulfidic composition and can even be toxic to some benthic forms. Blocking currents and/or solar input, if shaded with structures, grass, etc. effect benthic productivity of the diatoms. All of these must be made part of a plan of awareness and maintenance to have optimal productivity from the intertidal.

Some research reports imply the diatoms which provide the biotic nutrients are oceanic derived. That they sweep into the bay with upwelling and hungry shellfish reduce their numbers. This ignores the mass of benthic intertidal forms of Willapa Bay a location where necessary nutrients and solar meet. Besides the abundance of the benthic diatoms as a covering on the intertidal surface there is also more open evidence. Examination of the digestive area of oysters, especially in fall and winter, show mostly benthic type diatoms have been filtered out. The benthic diatom production needs further research as to its importance, which seems to be sadly underestimated and poorly understood. Again, thinking about the importance of the intertidal mudflats, from which the burrowing shrimp are certainly decreasing the diatom productivity.

Perhaps the most relevant aspect for shorebirds regarding the important role the sediment stability and diatom densities plays is demonstrated by the amphipods Corophium (burrower) and Leptochila (tube builder) both of which can remain on the mudflat when the tide recedes. Both are dependent upon benthic diatoms and biofilm and in fact serve to emphasize the importance of benthic diatoms. *Corophium* an important small (5-10 mm) crustacean constructs a lined burrow and at densities

typically over 10,000 per m² on ghost shrimp free oyster beds. This amphipod, by remaining on the mudflat at low tide, is the important prey species for shorebirds. *Corophium* depends on being able to scrape in lipid rich benthic diatoms that are within reach of its burrow (a few millimeters). Ghost shrimp not only will reduce and eliminate the benthic diatoms, but they change the sediment into a soupy mixture which will not support a *Corophium* burrow. The decades of important research on this sand flea cousin and their importance for shorebirds on the Bay of Fundy is very good information for Willapa Bay and also enjoyable reading. Their report is titled the "Keystone Corophium":

As the ghost shrimp numbers and size (biomass) increase over a particular area, sedimentary modification and hydration will remove most living benthic forms. Diatoms and the biofilm are probably first to go but are first to return when control is applied. Some estimate a ghost shrimp life span to be up to ten years so several years of new recruits can be added to a local assemblage and destruction can increase over time with new yearly recruits gaining in size and increasing their overall biomass and bioturbidity. Initially, ghost shrimp destabilize and over time decrease then basically eliminate that critical diatom-biofilm interface on the igneous silicate sedimentary deposits.

Discussion: For over forty years I have been an Audubon Society member (including a past board member) along with starting and building an oyster farm here on Willapa Bay. In short, the traditional use of the intertidal to raise oysters is ideally sustainable and not only compatible but beneficial for the natural flora and fauna of the bay. In fact the estuary biota and how it interacts was largely the reason to leave academics and work with the life on the mudflat. To assist in finding a method to control burrowing shrimp, over the past decades I have donated land and work area for science based research with many researchers from different universities, agencies or companies. The common goal was to attempt to find ways of controlling the ghost shrimp and to slow their benthic takeover and destruction without long term harm. One problem seems to be the small size of the diatoms. Even though marine diatoms make up over 25% (if I recall) of the ocean biomass they are basically not visible. They don't get attention like the eelgrass which does little or nothing good in terms of the food web or benthic environment.

The DOE decision to most likely end ghost shrimp control is based on what they say is science based but if so from a skewed perspective then erroneous methodology. It is just not valid. In addition, they do not consider the impact on the other biota of the benthic. They are not considering the continual removal of benthic productivity by allowing the continuation of ghost shrimp takeover of the intertidal. The support of DOE by the state Audubon indicates a serious lack of understanding which will result in damage to numerous members of the fauna and flora. The total damage will probably not be fully realized for a decades and even then perhaps the reason why will not be fully understood by those now advocating the action. How much biological abundance and diversity have we lost today with public intertidal lands that have been turned into biotic wastelands should cause some rational thinking? Shorebirds depend on the unique forage opportunity to allow obtaining lipid reserves to make the nesting flights and are directly impacted by ghost shrimp. I have detailed this in the links given and state again that because ghost shrimp have removed the diatom and biofilm coating where nearshore production occurs the means of a sandpiper needing to feed on high lipid crustaceans is diminished or missing. Those touting the banning of the nicotine based imidacloprid should consider the impact this will have on the entire biotic assemblage and is it worth curtailing oyster culture. The question could be, how is a Dunlin to build up fat reserves on the Willapa intertidal for its nesting flight? Do those who applaud the action of DOE know this? Or in general, how lipids, critical for that energy reserve, in say birds and fish, might be obtained if not initially from the diatoms on the mudflat free of ghost shrimp? How much have we lost already and what is the substitute?

Not supporting the chemical control of burrowing shrimp after decades of research on specific formulations will prove a most critical mistake. Chemical control is not cheap or easy and was only used after trying other mechanical and biological methods that might be effective. It was a last resort to save parts of the benthic biota. The search for shrimp control not using chemicals goes on today but there is

nothing that works. Many types of mechanical control leave the intertidal sediments in a destructive mess disrupting all physical and biological components often worse than the ghost shrimp would impart. Also, most mechanical methods do not kill a significant number of ghost shrimp. The scientists, experienced in estuary ecology, have pointed out that tests of the nicotine mimic, imidacloprid, only remains active a few hours on the sediment surface and is short lived in the sediment depending on characteristics such as grain size, permeability and porosity. It is applied to the sediment surface at low concentrations (± 60 mg/m²) during the summer time when solar exposure and microbial activity aid in breakdown. Yes, some crustacean invertebrates if still able to exist on a ghost shrimp infested area, might be killed by chemical but if left untreated they would be displaced completely over time with no chance of reestablishing. The benthic diatoms, a few days after treatment, increase in numbers or drift in to reestablish their biofilm habitat or just as fast as the sediment stabilizes. Furthermore, a treated area is quickly utilized again by invertebrate grazers (e.g. the zooplanktonic types or those in the biofilm) as soon as the benthic diatoms establish. In a matter of weeks the basic benthic productivity with most micro faunal and flora elements again utilizing the newly stabilized sediments. Tests show this is typically at much greater abundance and diversity than prior to treatment. Within a few weeks after spring and summer treatment it is common for the eelgrass to reseed and sprout. I posted a data set by Dr. Brooks that shows the faunal recovery of key invertebrates after ghost shrimp reduction with carbaryl (pg, 8-10), The same recovery is seen with the short lived imidacloprid: Benthic Comments

Does Audubon have any plans to help head off the loss of these important feeding areas for those birds, which have relied upon the intertidal including oyster growing areas for fueling up prior to heading north for nesting. This will be in addition to the loss to date of thousands of acres of similar productive public intertidal lands in Willapa Bay. The respective resource agencies have stood by while the benthos is destroyed by ghost shrimp and now seem to be supporting the same fate for the oyster growing areas. I thought Audubon was above this. It is easy to get the picture of this destruction by just walking (if possible) out into a ghost shrimp area which over time has completely lost nearly all the normal benthic fauna and flora. Eelgrass is one of the first visible forms to go as the ghost shrimp quickly uproot it and stop seed from sprouting. Experience this biotic absence while sinking in the soft watery sand. Even with closer microscopic examination it is difficult to find any living forms on or in the unstable surface sediment.

I do hope Wa Audubon realize what a haphazard and deadly decision will be rendered if control is not possible. Especially control this year to again confirm prior scientific facts on the treatment. Willapa needs ghost shrimp control now .. not years from now. Originally it seemed, Audubon Washington wanted to stop oyster farming and get rid of those doing work out on the intertidal. I recall their published quote: "*Over the next year, our goal at Audubon Washington is to identify key reforms needed in commercial shellfish operations and permitting to benefit birds and their habitats and to develop a strategic campaign to advance"*. That was read by many as get rid of aquatic food production even when cultivation methods prove compatible with the natural elements of the benthos. It was thought somewhat a carry over from the Puget Sound campaign and generally interpreted as 'using marine nearshore for culture of shellfish harmed wildlife'. Ground oyster and clam culture is not only compatible and sustainable relative with and to nature but actually supports and enhances the other biota. People need to eat .. we do not want to go back to hunting shorebirds. There is a lack of experience and scientific facts regarding the benthic intertidal thus this stance against a long proven beneficial use such as ground based oyster culture, is alarming.

Perhaps the reasons now are to rely on the bad and scary reputation of the WWII pesticide histories to condemn all chemical uses and get rid of those shellfish farmers who might have to use them to save their property and their life time investment? Either way, what is being missed is the heavy damage burrowing shrimp are imposing on many important species with most oyster growers and people of science who have studied the problem with open mind, the only ones aware of this pending disaster. Others have suggested, perhaps this stance against ghost shrimp control and oyster farmers, help add members to our Audubon organization? And if so, are those the type of members we want? Politics has

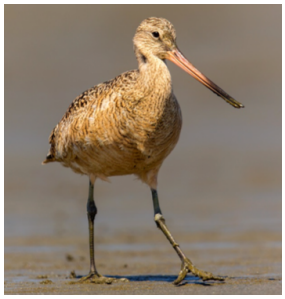
been suggested for this action, as a way to attract more voters for certain future candidates. Will these same people you praise for this decision, such as chairperson, Bellon, be willing to take responsibility and except the fact of the increasing detrimental impact and lost of the estuary fauna and flora is resulting from the continual ghost shrimp take over of the nearshore intertidal? Hopefully, the future might also mean a realistic review of why the burrowing shrimp have become so abundant. Many reasons and perhaps several play a role, are presented with most coming down to mismanagement of our natural resources without a sound long term base in science. As example, decrease in forage fish that would though feeding on ocean zooplankton reduce the number of swimming ghost shrimp larvae. However, right at this time someone needs to understand and take action on the ghost shrimp takeover on maintained intertidal areas, which now in is a third year.

In short, I would hope that an honest future review and fuller understanding by Audubon of the damage ghost shrimp have done to date and continue to impart on benthic sediments as they expand over greater areas of the intertidal. Maybe if Audubon realized the extent of the problem they could financially support looking for solutions. Millions have been spent, and probably tens of thousands of hours of field research to date. No one has put a dollar amount on the ghost shrimp damage and most likely those who object to the use of a pesticide are not aware of the biological facts regarding biotic damage by burrowing shrimp. Also, what will happen if more ghost shrimp invade other areas such as the razor clam beaches along the coast or as they expand throughout Puget Sound? The more abundant and dispersed they become, the more swimming larvae will be released to settle back into the nearshore areas. How much have shorebird populations been reduced in numbers by letting prime public coastal intertidal land become barren biological wastelands over the past few decades? It seems unavoidable that our Audubon name will probably be associated with the future decline of important avian types that resulted from the uninformed support of the rejection of ghost shrimp control by DOE. Again, it is easy to see what will continue to happen, just take that slog across some of the thousands of barren burrowing shrimp dominated intertidal areas. No need for binoculars to observe shorebirds as they don't land and forage on these thousands of unstable sandy acres in Willapa Bay.

Dick

Dick

Richard Wilson, Ph.D.



Addendum - related notes (one on the lighter side):

I do like that particular shorebird Gail Gatton pictures on her praise for the denial of the permit. Obviously this marbled godwit is not trying to forage over ghost shrimp ground. In return, here is a link to images of the marbled godwits on roof, of our oyster processing plant that they use daily as a gathering and resting area between tides during the winter. Images taken a couple of weeks ago. Godwits are a daily enjoyment for the workers - of course during the winter and now they are leaving this first part of May for the northern great plains.

At low tide they will be foraging on the intertidal and often among our oysters. I estimate currently these ± 400 marbled godwits are finding this a great safe area between tides. Thirty feet off the tidal flat, good view, etc. and they do not seem concerned with our boats, workers or machinery as can be noted in one of the images. In fact, they seem to enjoy watching us work. They arrive in a flurry and then in spectacular formations they take off in groups on the ebb to work the first intertidal exposed with the receding tide. They move lower to richer lower ghost shrimp free intertidal areas. Of course, most are oyster grounds. Of note, and perhaps a lesson, years ago, that entire 600 acres of high intertidal mudflat across the Palix River (about 100 meters from their roof top resting area) had become a solid *Spartina* meadow and thus not available for any shorebird foragers let alone primary productivity. A pesticide (herbicide) after much study finally reversed this situation. The godwits depend upon the mudflat productivity as do other sandpipers so when ghost shrimp remove mollusks, worms, crustaceans, diatoms, etc., they will be impacted. The godwits have utilized our roof for several years and their numbers have grown. If ghost shrimp are not controlled the numbers almost certainly will decline.

Native or not?; yes ghost shrimp, *Neotrypaea californiensis,* are native but that should not imply they cannot become a damage causing 'pest'. Although somewhat subjective, it is estimated nearly half of recognized harmful 'pest' species are native, one example today is the Bark Beetle. A more common usually factual statement is 'most' pest species result because of human actions, i.e. anthropogenic causes. It can take some dedicated work to uncover what that might be like; remove the predators, transport and relocate from another area, change the climate and or the vegetation, salinity, pollution, etc. Also, after careful research, Audubon has encouraged the use of chemical remedies for hard to solve management problems. I think I recall not long ago our magazine wrote about the use of a pesticide on ? fire ants effecting nesting sea birds on ?Guam. Then more currently here in Willapa Bay, it was finally realized, at least at the national Audubon level, the real damage to birds was by the loss of the productive open mudflat habitat by the invading Cord Grass, *Spartina*. Yes, the estuary was basically saved by a pesticide, but there still are those who claim it should not have been used and most likely are active in getting Audubon to oppose imidacloprid. Japanese eelgrass is taking over in a similar manner to the upper mudflat as it covers the sediment, blocks solar input, stops currents and allows build up of decomposing organic debris. Ghost shrimp currently are at a similar stage of areal destruction of the lower intertidal and this should be recognized but instead there seems a chance ghost shrimp will be gifted with more highly productive intertidal mudflat to further take away the natural food web with the negative effect of reducing biotic diversity and abundance.

Not your father's DDT: Over forty years ago as a new assistant professor, I was one of the early members of Alternatives to Pesticides in Oregon under Cha Smith. We battled Dupont, etc as chemicals were killing off the life in streams or being sprayed over forests (dirty agent orange) etc. I feel great changes have been made and today the new organic copied chemicals are much more in tune with mother nature who puts out 99.9% of the pesticides you encounter every day in your veggies, fruits, and spices. Then there is caffeine a pesticide more toxic than imidacloprid. The trend, which we need to be aware of are safer pesticides as usually copied from those you encounter daily. Sounds funny but should not. Study what a particular chemical does, the safe guards in place today and will it do the duty safely. Interesting reading on this subject of pesticide residues, etc. by Dr. Allison Bernstein.