How Local Effects of Climate Change Could Affect Invasive Species in the Lower Coos Watershed

Several climate change-related changes are expected on the Oregon coast that will potentially affect invasive species:

- *Climate-related changes will likely facilitate invasive species invasions to alter the ecological communities in the Coos estuary*
- *Climate change is expected to increase the severity of extreme weather events, water temperature, hypoxia, sea level rise and alter oceanographic conditions each of which may promote invasive species invasions by creating conditions hospitable to non-native species*
- *Climate change could allow non-native species to more readily out-compete native species altering the population dynamics of biological communities in the lower the Coos watershed.*


Invasive tunicate (Didemnum vexillum) infestation.


Gorse. Photo: David Dalton, Reed College.

Climate change and invasive species are two topics at the forefront of the global environmental change crisis. Scientists have only recently begun to investigate the complex interactions between these two drivers of environmental change (Rahel and Olden 2008). Each poses a great threat to both ecological and human communities especially since the local and regional effects of climate change are expected to facilitate the spread of invasive plant and animal species. Changing climate may promote species invasions by creating environments that favor the survival of non-native over native species (Stachowicz et al. 2002).

Coastal regions are responding differently to climate change, so predicting the climate-related changes the project area will experience in the future is difficult (Scavia et al. 2002; USGS n.d.). We can predict that many aspects of climate change, including changing weather patterns, increasing ocean temperatures, increasing hypoxia events, sea level rise, and change in oceanographic conditions, will more than likely facilitate local non-native species invasions and range expansions.

In addition, the incidence of human-induced species introductions will likely change. Humans both knowingly and unknowingly transport plants, animals, fungi, and molds, (including vectors for pathogens), throughout the world. But successful introduction of these organisms to new habitats and hosts is often prevented due to the inhospitable conditions they encounter. Increasing ocean and air temperatures, and changing storm patterns and hydrologic conditions may create more hospitable conditions for new invaders making successful formerly unsuccessful invasions (Stachowicz et al. 2002). It should be noted that climate-related changes will also make inhospitable some formerly hospitable habitats and hosts. So in some areas climate change will also likely result in invasive species relief.

Changing Weather Patterns

Increased frequency and intensity of winter storms may change the current distribution of some invasive species in intertidal and subtidal estuarine habitats. For example, Bando (2006) showed that disturbance events "substantially enhanced *Zostera japonica* (a non-native eelgrass) productivity and fitness," suggesting that this invasive species' success is the result of both competitive interactions with native eelgrass and its positive response to disturbance events.

Although shifting weather patterns are likely to result in distributional changes to eelgrass species, this trend may not necessary result in a net loss of native species. Researchers in Willapa Bay, Washington, for example, have noted that the establishment of *Z. japonica* in intertidal habitats has resulted in changes to sedimentation that have facilitated the spread of native eelgrass into areas that would have otherwise been unsuitable (Fisher et al. 2011).

Increasing Ocean Temperatures

According to the Oregon Climate Change Research Institute (OCCRI)(2010), ocean surface waters are expected to increase 2-4°C (4-7°F) in Oregon within the next 100 years. Increased ocean temperatures will lead to range shifts requiring native marine organisms to shift northward or deeper in the ocean in pursuit of the cooler waters they require (OCCRI 2010). Higher ocean temperatures could exceed the physiological tolerances of many native species, allowing non-native species to out-compete them

Increasing Ocean Temperatures

Worldwide, ocean temperatures rose at an average rate of 0.13°F per decade between 1901 to 2012. Since 1880, when reliable ocean temperature observations first began, there have been no periods with higher ocean temperatures than those during the period from 1982 – 2012. The periods between 1910 and 1940 (after a cooling period between 1880 and 1910), and 1970 and the present are the periods during which ocean temperatures have mainly increased.

Translating worldwide ocean temperature trends to trends off the Oregon coast is complicated because of the high variability of sea surface temperatures affected by seasonal upwelling/downwelling and various climatic events that occur in irregular cycles (e.g., El Nino). Nearly 30 years (1967-1994) of water temperature data collected near the mouth of the Coos estuary suggest a very weak trend towards warming water temperatures. Fifteen years (1995-2010) of data from multiple stations in the Coos estuary's South Slough inlet show very little water temperature change.

Sources: EPA 2013; Shore Stations Program 1997; Cornu et al. 2012

and fill their ecological niches (OCCRI 2010). Increased ocean temperatures can also affect water quality, cause shifts in food web dynamics, and alter the length or timing of reproductive and growing seasons each of which could aid the spread of non-native species (Carlton 2000).

For example, the invasive clubbed tunicate (*Styela clava*), present in the Coos estuary, is capable of withstanding temperature and salinity fluctuations beyond the range of many local native invertebrate species (Global Invasive Species Database n.d.). Clubbed tunicates have been collected on the Oregon Coast in water temperatures ranging from 11-27°C (52-81°F)(OSU 2013) but they're unable to reproduce at temperatures less than 15°C (59°F)(Eno et al. 1997). The clubbed tunicate may exhibit more reproductive success in higher ocean temperatures, allowing it to out-compete native species.

The Humboldt squid (*Dosidicus gigas*), a voracious predator that feeds on invertebrates (e.g., crustaceans) and small fish, and which normally ranges in warm waters from Chile to California, is an example of how increasing ocean temperatures can influence natural ranges. This species has already been sighted as far north as Puget Sound, WA, a northward range expansion expected to increase as oceans continue to warm (OCCRI 2010). Although this species has not been introduced from overseas, its arrival has the potential to significantly affect the structure of existing marine communities, because altering fundamental interactions within an ecosystem (e.g., predator-prey relationships) can change the way that plants and animals distribute themselves in their environment (Yamada 1977; Carlton 2000). Along with ecological concerns, there are economic implications to disrupting food webs that support commercially important fish in the northern Pacific ocean.

Anthropogenic dispersal of non-native species will be affected by warming ocean waters. Aquaculture is a major source of inadvertent non-native species releases into local environments. Increased ocean temperatures will force these facilities to move northward into colder waters (Rahel and Olden 2008), further increasing the non-native species pool available to invade new waters. This will be a concern for the Coos estuary should new aquaculture operations become established here.

Sea Level Rise

Our local NOAA tide station in Charleston has documented an average rate of sea level rise (SLR) of 0.84 mm (0.03 inches) per year averaged over the past 30 years (0.27 feet in 100 years). The rate of SLR is expected to accelerate over time. For example, according to the National Research Council (NRC), predicted SLR rates for the area to the north of California's Cape Mendocino (the study's closest site to the Coos estuary), are reported as high as +23 cm (9 inches) by 2030; +48 cm (19 inches) by 2050; and +143 cm (56 inches) by 2100 .

Sources: NOAA Tides and Currents 2013, NRC 2012

Increasing Frequency of Hypoxia Events

Dissolved oxygen concentrations in estuaries could be influenced by many factors associated with climate change including temperature, river flow, and ocean conditions. Dissolved oxygen concentration along the coastal Oregon ocean floor have been close to or fully depleted during recent summers (called hypoxic or dead zones), and have occurred more frequently along the Oregon coast in recent decades (OCCRI 2010, Grantham et al. 2004). Jewett and colleagues (2005) found that invasive invertebrate species cover was greatest on experimental settlement plates exposed to low dissolved oxygen waters and concluded that low dissolved oxygen events may enhance the success of invasive species.

Although scientists predict that global climate change will facilitate invasive species introductions that will likely alter community structure in estuaries (Stachowicz et al. 2002), all hope may not be lost. Norkko and colleagues (2011) showed that an invasive polychaete (*Marenzelleria spp*.) aided in the mitigation of hypoxia in the Baltic Sea through "bioirrigation" behavior (i.e., flushing their burrows with overlying water), which in turn decreased sediment-induced eutrophication. The Baltic Sea is far from the Coos estuary but this case study demonstrates possible local responses to climate change and its effects on invasive species.

El Niño Southern Oscillation (ENSO)

ENSO, characterized by an abnormal warming of tropical Pacific waters, is a cyclical climate pattern that occurs every two to seven years. It affects weather and ocean currents in and around the Pacific ocean. Locally, ENSO is associated with drier conditions, warmer temperatures, and lower precipitation levels, although it can also result in greater winter storminess and flooding.

Source: Mysak 1986

Sea Level Rise

Sea level rise is another climate-related change that has the potential to facilitate the spread of existing and newly arriving invasive species in our area. For example, Chinook salmon (*Oncorchynchus tshawytsacha*) compete for food and space with the non-native American shad (*Alosa sapidissima*), a competition that has caused migratory delays for Chinook in the Columbia River (Hesselman 2012). Since changes in sea level have been linked negatively to Chinook salmon growth, maturation and return rates (Wells et al. 2007), these fish could be placed at a competitive disadvantage with respect to American shad as sea levels continue to rise- potentially leading to an increase in shad populations.

As sea level rises, Oregon's estuaries will become more inundated with marine water. Organisms associated with tidal wetlands further up the estuary will need to adjust to both longer tidal inundation periods and higher salinity levels. As changes in species distributions occur through the slow-moving disturbances caused by sea level rise, estuarine habitats may become more susceptible to invasive species.

On the other hand, sea level rise may aid in the management of invasive species already established in Oregon's estuaries. For example, purple loosestrife (*Lythrum salicaria*), an invasive freshwater marsh plant present in the lower Coos watershed (ODA 2014), does not tolerate saline conditions (Konisky and Bordick 2004). Sea level rise has the potential to relieve the Coos estuary of some of its purple loosestrife stands and other non-salt tolerant species (e.g., reed canary grass) in freshwater wetlands located in tidal systems.

Change in Oceanographic Conditions

Climate-related changes in oceanographic conditions including ocean acidification, local wind patterns, ocean currents, timing and intensity of coastal upwelling, and El Nino Southern Oscillation (ENSO) events (see sidebars) will have myriad effects on non-native species in Oregon's coastal watersheds by changing the productivity and water quality (including pH) in estuarine environments- the same conditions which are likely to facilitate the spread of invasive species (OCCRI 2010).

Change related to ocean conditions is expected to affect both terrestrial and aquatic organisms' dispersal patterns, a primary driver shaping ecological communities (Davis et al. 1998). Carlton (2000) explains that non-native marine organisms, especially those whose dispersal patterns are strongly affected by ENSO patterns, are generally expected to gradually shift northward with rising ocean and air temperatures, establishing themselves in newly hospitable environments in northward regions. He cites several examples of this phenomenon, including northward migrations of the following non-native marine species that originated in the western Pacific ocean and were first found in northern and central California then transported by ocean currents to the southern Oregon coast: *Blackfordia virginica* (hydroid), *Sphaeroma quoyanum* and *Iais californica* (isopods), *Palaemon macrodactylus* (shrimp), and *Styela clava* (clubbed tunicate).

Over the past 20 years, the Oregon coast has experienced increased intensity of coastal upwelling. However, OCCRI (2010) suggests that future changes to the coastal surface winds that drive upwelling are likely to be minimal. However, they warn of increased variability in coastal upwelling. For example, Barth and colleagues (2007) found that early season upwelling was delayed and late season upwelling was stronger than average during their 2005 study. This finding was consistent with work done by Snyder and colleagues (2003), who predicted that increases in the contrast between land and ocean temperatures are likely to continue, driving stronger and more variable upwelling conditions.

Ocean Upwelling

Ocean upwelling is a seasonal wind-driven phenomenon that influences nutrient abundance in coastal waters. Upwelling occurs when strong spring and summertime winds drive surface ocean waters both along the coast and offshore in a process known as "Ekman transport." Ocean bottom waters, typically cold and nutrient-rich, rise to the surface to replace surface waters moved by the wind. Uninterrupted upwelling events can last days to weeks and are characteristic of the Oregon coast.

By providing nutrients that promote plankton growth, upwelling reinforces the base of the marine and estuarine food web that supports seabirds, marine mammals, and fisheries, including Dungeness crab, Pacific sardines, Chinook salmon, albacore tuna, halibut and other fin and shellfish species.

Source: Peterson et al. 2013, Iles et al. 2011, Dalton et al. 2013

Ocean Acidification

Since the late 18th century, the average open ocean surface pH levels worldwide have decreased by about 0.1 pH units, a decrease of pH from about 8.2 before the industrial revolution to about 8.1 today. A 0.1 change in pH is significant since it represents about a 30 percent increase in ocean acidity (the pH scale is logarithmic, meaning that for every one point change in pH, the actual concentration changes by a factor of ten). Scientists estimate that by 2100 ocean waters could be nearly 150% more acidic than they are now, resulting in ocean acidity not experienced on earth in 20 million years. The best Pacific Northwest ocean acidification data we have so far are from the Puget Sound area where pH has decreased about as much as the worldwide average (a decrease ranging from 0.05 to 0.15 units).

Sources: Feely et al. 2010; NOAA PMEL Carbon Program 2013

Another effect of increased intensity of coastal upwelling exacerbate ocean acidification's effects on marine and estuarine organisms. Increased coastal upwelling intensity is expected to expose native marine and estuarine communities to low pH ocean waters with limited calcium carbonate (necessary for skeleton and shell formation)- specifically aragonite, the more soluble form of calcium carbonate (Feely et al. 2008). Rising ocean acidity (lowering pH levels) is expected to adversely effect the larvae of many marine invertebrates that incorporate calcite or aragonite into their shells (Orr et al. 2005). If those larvae are unable to mature, competition in estuarine invertebrate communities will diminish, potentially creating opportunities for non-native species to invade more readily (OCCRI 2010).

Increasing Air Temperatures/Decreasing Summer Precipitation

According to the OCCRI (2010), average annual air temperatures are estimated to increase 0.2-1.0° F each decade in Oregon. Summers in particular are expected to become warmer and drier, with an estimated decrease in summer precipitation of 14% by 2080 (OCCRI 2010). While warmer average air temperatures may provide beneficial opportunities to various agriculture industries (e.g., wine grape growers), it will also almost certainly mean new invasive plant pathogens will become more prevalent (Brooks et al. 2004; OCCRI 2010).

Changes to precipitation and air temperature are likely to increase invasive plant species' ranges, further altering native plant ecosystems - with serious economic implications such as increased fire disturbance (by increasing fuel load) and decreased livestock production (OCCRI 2010). Increasing fire events, in turn, will cause openings, providing additional opportunities for the expansion of invasive species (D'Antonio 2000 as cited in OCCRI 2010).

As summer precipitation decreases, the timing of amphibian breeding are likely to shift, possibly causing competition for breeding habitats where none currently exist (OCCRI 2010). For example, the invasive American bullfrog (*Lithobates catesbeianus*) has a later breeding period than native amphibians. As amphibian breeding periods shift to match higher moisture conditions earlier in the year, competition with native species for breeding habitat will increase (Bury and Whelan 1984).

Uncertainty in Predicting Local Effects of Climate Change

There is inherent uncertainty in predicting what the local effects of climate change are likely to be. The uncertainties generally fall into three categories: 1) Natural variability of the earth's climate; 2) Climate sensitivity (how the earth's climate system responds to increases in future greenhouse gas levels); and 3) Future greenhouse gas emissions.

To manage for these uncertainties, climate scientists use multiple models ("multi-model ensembles") that incorporate the estimated range of possible natural variability, climate sensitivity, and future greenhouse gas emission values when investigating climate-related change. The models typically generate a range of values for potential future air temperatures, ocean surface temperatures, sea level rise…etc., which naturally become increasingly variable the longer into the future the model predicts. This approach gives communities a range of projections to consider when developing climate change vulnerability assessments and adaptation plans.

Sources: Sharp 2012, Hawkins and Sutton 2009

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