An Estuarine Ecosystem Based Management Plan to the Spot Shrimp (Pandalus Platyceros) Resource in Prince William Sound with Reference to the Neva Estuary

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Abstract:
This paper is an effort to manage a specific resource within an Alaskan estuary by assessing its characteristics and trends. Spot shrimp (Pandalus platyceros), our species of focus, is a protandric hermaphrodite valued by various harvesters in the Prince William Sound estuary, which is an immense ecosystem in its own respect. However, recent issues (e.g. oil and gas exploration, demographic expansion, and climate change) threaten this biological community on many levels which may directly or indirectly affect the spot shrimp industry. A possible effect of such shifts is eutrophication, which has overwhelmed the Neva Estuary, located near the highly populated city of St. Petersburg, Russia. We selected this particular ecosystem as our object for contrast and comparison because it is a similar environment that is under rigorous management. The spot shrimp resource of this paper’s focus, on the other hand, is anything but stable and has waxed and waned multiple times in its past. The 1964 earthquake and 1989 Exxon Valdez oil spill both transformed its ecosystem. Our management plan encourages better collaboration to identify biological indicators as a basis for preparing for future change. It also targets maximum sustainable yield and tries to reconcile other mandates such as economy. Our dilemma is summed up in the following sonnet:

A Precarious Resource:
By Wesley Voley

Prince William Sound shrimp is quite unique
'Tis valued by many cultures worldwide
Defined by its brown hue and stark white streak
During the day it feeds, and night doth hide
   From Pollock, halibut, and other foes.
   It also switches from male to female
As larvae it drifts, to benthic then goes
Shrimpers catch masses; shrimp's being 'tis frail
As climate alters, food webs disrupted
Tourists, gaslines, garbage, and invasives
Shipping galore, industry erupted
More commercial harvest-management gives--
The shrimp: shall humans use or abuse it?
What future lies ahead? Fix it or sit!
Description of Prince William Sound
Prince William Sound (PWS), a semi-enclosed estuarine system of fiords in Alaska, sustains a complex ecosystem supporting strongly interrelated life. Exceeding an area of 9,000 square miles and reaching a maximum depth of 800 meters, the Sound contains geographic features such as Columbia Glacier, Montague Island, and the Chugach Mountains (See Figure 1). Its numerous resources, abundant wildlife, and stunning serenity make it a valuable asset for both Alaska residents and tourists. In all its immensity, a complete appreciation of this unique realm and sound management of its resources require an understanding of the combination of abiotic and biotic factors which govern it (Harwell NIH, 2010).

Nonliving Features
Numerous geographic and physical phenomena, ranging from minute to grand, work jointly to sustain the intricate relationships present in the Sound’s menagerie of life. Larger global processes such as the long term Pacific Decadal Oscillation and comparatively short term El Nino-Southern Oscillation (ENSO) interact with localized effects that include average rainfall and water circulation. Precipitation, along with glaciers and freshwater streams, circulate inside PWS before pouring into the Gulf of Alaska (GOA) at a rate exceeding the runoff of the Mississippi River. Upwelling and downwelling, examples of such circulation, convert iron (which dictates primary producer abundance) and other nutrients throughout the ecosystem. These natural water transportation processes are, in turn, influenced by the Sound’s intricate geographic and bathymetric features. Geologic activity also plays a role in its ability to shift the environment on a fundamental scale. The 1964 earthquake caused massive vertical displacement, landslides, tsunamis, and extensive damage to marine species such as intertidal zone inhabitants and fish. It disrupted the species balance by increasing sea mammal predation of mollusks. When combined, these variables can pose significant challenges to the management of marine species (e.g. pink salmon, spot shrimp) that depend upon them in a plethora of ways (Harwell NIH, 2010).

Fig 1) A physical map of the Prince William Sound estuary showing its fiords, islands, and glaciers. An immense ecosystem of both living and nonliving factors, it is home to the spot shrimp and a host of other assets.

Living Features
Living (biotic) influences in this environment are just as complex. The pelagic PWS habitat is occupied by interrelated organisms ranging in size from microscopic specks to colossal behemoths. For instance, primary consumers such as euphausiids (i.e. krill) and the spot shrimp devour phytoplankton (e.g. diatoms and dinoflagellates) and other primary producers. Higher on the trophic pyramid are carnivorous fish, sharks, and marine birds (e.g. gulls and guillemots) that consume shrimp and other invertebrates. However, to preserve self-awareness, one must not neglect the impacts of anthropogenic activity. One profound
example of how such an event can disrupt an ecosystem is the 1989 Exxon Valdez oil spill. This catastrophe threatened many species populations by dumping a layer of viscous crude oil across a vast area, thereby disrupting the transfer of energy across the food web. Other anthropogenic factors may include point source pollution, tourism, and species harvest, all of which can alter trophic structure (i.e. the predator-prey relationships among organisms) both directly and indirectly (Harwell NIH, 2010). Any given situation may be subject to multiple variables; hence, it is critical that we devote attention to the PWS ecosystem and its various factors to best manage one of its resources.

**The Neva Estuary of Russia**

Management of PWS spot shrimp can be boosted with insight of ecosystems similar to the one it inhabits. This provides a reference into such mechanisms as human development and its consequences. Our secondary ecosystem of focus, the Neva Estuary is an included inset of the Volga-Baltic Waterway and White Sea-Canal (Britannica Online, 2012)(See Figure 2). It courses from Lake Ladoga in the Republic of Karelia and Leningrad Oblast, Russia to the Gulf of Finland of the Baltic Sea. However, its freshwater supplement, the Neva River, branches into a delta in St. Petersburg, Russia, before pouring into the ocean. Russia, Finland, and Belarus are among the major countries bordering it. Since its formation around 1420-1250 BC from glacial activity, the Neva has comprised the third largest river in Europe in terms of water flow (Britannica Online, 2012). It runs 74 kilometers (i.e. 46 miles) and has an average width of 400-600 meters. The Neva Delta reaches a maximum breadth of 1,000-1,250 meters and contains an average depth of nine meters. Although the Neva Estuary is a unique realm, it exhibits not just biotic and abiotic contrasts from the Prince William Sound (PWS) ecosystem, but similarities as well (Vodohod, Nov 2012). The PWS and Neva estuaries both have cool waters due to their northern latitudinal positions. Thus, they support similar amounts of marine plant life. The Neva’s fish species, though sparse in diversity, may include smelt, voidance, and some seasonally present, or anadromous, salmon. Unlike Prince William Sound, the Neva freezes between December and April (Downtoearth, Nov 2012).

![Fig 2. The Neva Estuary lies at the eastern part of the Gulf of Finland near the industrious city of St. Petersburg, Russia.](image)
ecosystem, on which the Neva’s explosion of sport and commercial fishing depends heavily, to decline (Silfverberg, 2004). As we will later discuss, although it doesn’t impact PWS now, future outbreaks are possible due to changing demographics. A long-term generation of studies based in the Neva estuary works towards alleviating this ecosystem’s eutrophication and its consequences (Silfverberg, 2004). The Neva’s environment and ongoing research can serve as a reference for our management plan, both in the context of an ecosystem and a specific species.

**Shrimp**


The Spot Shrimp (*Pandalus platyceros*), characterized by a reddish brown color and conspicuous white spots on the abdomen (Spot Shrimp Profile-ADFG), is an important element included within the diverse Prince William Sound ecosystem (See Figure 3). The species’ overall presence, extending from the Aleutian Islands to California and encompassing multiple water depths, is widespread (Spot Shrimp Profile-ADFG). Although the influence of its PWS populations on trophic mechanisms is somewhat minor (Spot Shrimp Alaska-Blue Ocean, 2012), the spot shrimp connects to sources of both prey and predators. For example, it migrates to the surface during the night to consume euphausiids, diatoms, detritus, mollusks, worms, and sponges. During the daytime, it returns to the benthos to escape predators, which include cartilaginous fish, Pacific cod, rockfish, harbor seals, Walleye Pollock, flounders and salmon (Spot Shrimp Alaska-Blue Ocean, 2012)(Spot Shrimp Profile-ADFG).

The species’ life cycle is unique due to its tendency as a “protandric hermaphrodite” to convert gender from male to female during the second or third year of its lifespan (Spot Shrimp Alaska-Blue Ocean, 2012). This transition may occur before or after physical maturity. Capable of reaching a length of 12 inches (Spot Shrimp Profile-ADFG), but PWS spot shrimp exhibit an annual median growth rate of 3.2 mm per year at a length of 28.5 to 42.5 mm.

Harvest of the larger females, each which produce a mean of 3,900 eggs, can negatively affect future shrimp populations. These, in turn, are fertilized externally and hatch coinciding with plankton blooms (Spot Shrimp Alaska-Blue Ocean, 2012). Spawning typically occurs at depths of 500 to 700 feet (Spot Shrimp Profile-ADFG). Multiple habitats are occupied by the spot shrimp during the course of its lifecycle (Spot Shrimp Alaska-Blue Ocean, 2012). In Prince William Sound, these include intertidal, pelagic, and various coastal settings which differ on the basis of salinity and temperature (Harwell NIH, 2010). The spot shrimp is planktonic during its larval stages but resides in shallow water amongst kelp as a juvenile. After traveling to rocky areas inhabited by coral reefs, it practices vertical migration as an adult (Spot Shrimp Alaska-Blue Ocean, 2012). The entire lifespan of spot shrimp inhabiting PWS may range from seven to eleven years (Spot Shrimp Profile-ADFG).
The spot shrimp is widely demanded by restaurants (Harwell NIH, 2010). The species’ harvesting industry in PWS has developed strongly since its beginnings during the late 1950s (Harwell NIH, 2010) to early 1960s (Kimker, 1996). It remained a valuable asset up through the 1980s (Harwell NIH, 2010). Likely owing to tightened regulations, annual yields soared sharply between 1968 and 1976. Among these harvests, spot shrimp comprised the vast majority. A 1963 to 1966 study on shrimp populations in Unakwik Inlet, which involved the tagging of about 10,000 specimens, was conducted from the vessel Montague. The area was selected for the study due to its sheltered environment and abundance of shrimp. In addition to repossessing about 1000 of those tags, the team used a limit based model to assess shrimp growth, which was measured to an annual rate of 3.1 mm/year. Their findings were also consistent with the minimum lifespan of seven years. Recorded yields declined beginning in 1987 and plummeted during the 1989 Exxon Valdez Oil Spill (Kimker, 1996). The shrimp harvest was suspended in 1990 due to low numbers but was restored in 2010. Currently, the GOA shrimp fishery is healthy due to regulations, user demand, and coherent management strategies (Harwell NIH, 2010). However, no status of management plan is perfect, and many alternative strategies must be considered to optimize the resource. A dedicated program must incorporate an in-context understanding of a target species, its environmental background, and the issues testing our ability to sustain it.

**Management-(Overview of Issues)**
To improve the status of a resource, areas of concern or weakness that can hinder the future development should be considered. As a biological entity, the PWS spot shrimp is subject to both living and nonliving impacts that combine to create a wide spectrum of possibilities. Such potential problems are best understood in complete context.

**Oil and Gas Exploitation**
The state of Alaska is abundant in natural resources, which include hydrocarbon fossil fuels present in Cook Inlet, the Kenai Peninsula, and the North Slope. Continued oil and gas extraction could quite likely herald the establishment of more pipelines, shipping exports, and infrastructure. With the management of shrimp, the health of an ecosystem and status of the economy must be reconciled; therefore, sustaining our target species requires a detailed understanding of this industry.

The history of Alaskan oil exploration began with the utilization of claims near Homer in 1890. Another deposit at Katalla expanded into a local industry and continued for 20 years until 1933, when a fire forced officials to abandon the system. The 1920 Mineral Leasing Act enabled the free exploitation of oil throughout the United States; however, due to Alaska’s scarcity of large lucrative deposits, the state’s industry waned. The mandate for petroleum during World War II prompted the building of a TransCanada oil pipeline that was finished in 1944. In the 1950’s, the moderate-sized Swanson Oil field on the Kenai Peninsula attracted many entities and (AK History Course, 2004 – 2012) established Alaska’s potential. The state’s value was secured by the Kuparuk field (Resource Development Council, 2009). The Middle Ground Shoal oil field near Cook Inlet, developed in 1967, has since yielded 1.3 billion barrels of oil and 5 trillion cubic feet of natural gas; it has also contributed to population and economic growth in Southeast Alaska. The discovery of a massive oil field in Prudhoe Bay by the company Richfield Oil in 1967 was followed by the 1974 construction of the Trans-Alaska Pipeline System, which entailed territorial and environmental concerns. To this day, 10 million barrels of oil have been extracted and transported from the deposit. In the 1980s,
declines precipitated job and income losses (Alaska History and Cultural Studies - Modern Alaska, 2004 – 2012). The northern part of Alaska is estimated to contain a recoverable 22.2 billion barrels of oil and 124 trillion cubic feet of natural gas. Continental shelves bordering the Beaufort Sea and Chukchi Sea are believed to conceal hefty amounts of fossil fuels and have potential. Oil taxes comprise 85 percent of Alaska’s revenue. In addition, transportation, education, public service, and other factors of the state’s economy benefit heavily from this resource. 13.2 percent of America’s domestic production stems from Alaska because of the state’s oil and gas production, which supports an excess of 40,000 in-state jobs. Despite this, the state's oil production has been predicted to decline as evidenced by a 63 percent drop since 1988. For instance, although Cook Inlet reserves still contain 863 billion cubic feet of natural gas, its industry is also bound to a steady decrease that will continue unless new reserves are tapped (Resource Development Council-Oil and Gas, 2009).

The Future...
Many investors and other entities have tapped into and continue to benefit from Alaska’s vast gas and oil reservoirs. For example, ConocoPhillips, ExxonMobil, and Chevron have operated in the state for decades. By contrast, Shell is a relatively recent player that conducts offshore drilling in the Beaufort Sea, where deposits are believed by some to hold more potential than Prudhoe Bay’s fields combined (Resource Development Council-Oil and Gas, 2009). Due to expanding opportunities, a group of comparatively small oil and gas companies, called independents, have sprung into action. Some (that include Pioneer Natural Resources Alaska and XTO Energy) explore reserves in Cook Inlet, while others (such as Armstrong Alaska and AVCG/Brooks Range Petroleum) investigate the North Slope (Resource Development Council-Oil and Gas, 2009). The industry has ignited proposals for a natural gas pipeline to distribute this resource (See Figure 4). Since some ideas entail shipping exports of liquefied natural gas, the outcome of this conflict could influence the future of Prince William Sound. The “All Alaska Gasline” proposal calls for an 800 mile long pipeline paralleling the current oil pipeline (TAPS) and with a planned spur from Glennallen to Anchorage.

The project also includes possible processing plants in Prudhoe Bay and Valdez. The objective of its founder, the Alaska Gasline Port Authority, is to use the vast amount of natural gas in Prudhoe Bay to benefit Alaska’s economy via state supplements, exports to Asia, and employment (Alaska Gasline Port Authority). By contrast, ExxonMobil and TransCanada’s Alaska Pipeline Project calls for the extension of a gas line (Alaska Pipeline Project) from 11,000 feet deep reserves in Prudhoe Bay (Resource
Development Council-Oil and Gas, 2009) to Calgary, Canada with predicted costs ranging from 30 to 40 billion dollars. In effect, it seeks to expand the natural gas resource in Prudhoe Bay to markets across North America. A stemming alternative to this is to extend a pipeline to Cook Inlet for liquid natural gas (LNG) export (Alaska Pipeline Project). As economical oil and gas proliferates, there are more specific concerns which we must consider in the ecosystem based management of shrimp. As more of Alaska’s vast hydrocarbon resource is uncovered and distributed, more tankers will likely assist in oil and gas exports. This will raise the possibility of disasters such as the devastating 1989 Exxon Valdez Oil. During this event, 11 million gallons of oil were leaked into the Prince William Sound ecosystem and spread across an estimated 10,000 square miles of area. As a result, populations of herring and other species plummeted drastically. Remnants of the discharged oil still linger within the Sound’s shores and benthic sediments (Prince William Soundkeeper-History, Culture, Economy, 2011). As will be discussed further, another potential impact is disturbances caused by increased shipping traffic in general. Because many species in this ecosystem (that include spot shrimp) are interrelated, a single incident could mean devastation to our target resource. Hence, management must consider the possible impacts of oil and gas tanker transportation if it is to be adequately effective. As will be discussed next, changes in population, a parallel issue, play a similar role in our obligations as stewards.

Demographic Change
As humans, we need to be self-conscious of our impact on the surrounding environment, which, if neglected, would render any management plan both frivolous and ineffective. As evidenced by the Klondike Gold Rush and Trans-Alaska Pipeline, population increase can stem strongly from the exploitation of natural resources (Alaska-Population). The state’s urban communities have recently flourished in demographics. For example, Anchorage’s population numbered 296,767 in 2010 and was predicted to reach 309,011 in 2014 (Punham, 2011). This calculates to a 4.13 percent shift. The general topic of demographic change can be subdivided into the three following influences when applied to the environment: Tourism, Waste Discharge, and Eutrophication. Each may stem from the need to stimulate economic growth, and be considered a possible consequence of the other. In other words, tourism increase in the state coincides with population growth, and both of these exacerbate waste discharge. In turn, this can lead to eutrophication, thereby generating other types of environmental stress. Although the final problem isn’t a direct concern in Prince William Sound, its effects are nevertheless dire and could burden the future if management isn’t conducted with enough discipline. This chain reaction of hemorrhages, if combined, could emaciate the spot shrimp industry; therefore, each possibility should be considered in more detail if we are to proactively counter it.

Tourism
Each year, through various means of travel, myriads of tourists flock to Alaska to appreciate its environmental and cultural wonders (Resource Development Council-Tourism). Whether this asset continues by expanding or declining, it must be understood thoroughly if we are to maximize shrimp management. For example, economic benefits associated with this growing industry must be reconciled with environmental effects. From 2008 to 2010, tourism rates declined 11.8 percent to 1.5 million people per year, partly due to tax increases and cruise ship rerouting. The year of 2010 also experienced a 14.5% decline in the specific sector of cruise passengers. The majority (58%) of 2010 tourists arrived at Alaska via ferry and a close minority (37%) by plane (Alaska QuickFacts from the Census Bureau, 2012). Tourism accounts for $2 billion in yearly spending and is an integral
booster of job growth. Increased taxes on both cruise passengers and companies were imposed in 2007 but alleviated in 2010, prompting future plans to attract and accommodate more customers. Tourism accounts for a considerable portion of Alaska’s revenue, which, on the basis of cruises, subsistence, and income, amounted to $138.8 million in 2009. In 2006, companies resorted to great lengths to create an elaborate and tightened system that conformed to, in part, environmental concerns such as the disposal of waste. Maintaining these precautions would ensure that the cruise industry stays connected with Alaska. The state’s economy benefits soundly from tourism in assets such as product spending, marketing, and construction (Resource Development Council-Tourism). As a human induced factor, tourism needs to be studied in depth to preserve the health of the PWS ecosystem and its spot shrimp.

**Waste Discharge**

Waste can be released into ecosystems through both intentional and accidental means. Although this concern is relatively stable one in PWS (due to Alaska’s sparse population density) its influence on certain species such as seabirds may pose an indirect impact to shrimp populations. As we stressed previously, an entire ecosystem must be monitored if we are to help sustain a specific species such as spot shrimp. Marine debris has been observed in Alaska as early as 1930. Such litter can collect existing toxic chemicals, such as pesticides, which are then conveyed to organisms ingesting it and magnified across the food web. Seabirds, which confuse floating plastics for prey, suffer from digestive tract obstruction. The entanglement of animals in plastics is also a problem (Prince William Soundkeeper - Ecosystem & Threats, 2011). Debris can also accumulate during natural disasters such as the recent earthquake at Japan. Boating, whether for recreational and commercial purposes, can lead to the discharge of oil, trash, sewage, and toxic substances such as antifreeze and solvents. The Whittier Harbor is docked more than 30,000 times per year and has expanded greatly in recent years. Although the Valdez Harbor is constantly occupied, the maintenance there is vastly inadequate for this explosion of activity. Management is certainly lacking in this category of environmental concern. In retrospect, Alaska’s vastness makes ecosystem management difficult and disjointed, which calls for more progressive strategies (Prince William Soundkeeper - Ecosystem & Threats, 2011).

**Eutrophication**

Although the concern of eutrophication is associated more with the Neva estuary than Prince William Sound, an extensive understanding of its causes and consequences can aid in preventing future outbreaks. Its effects are drastic, and we must prepare for ensuing possibilities to ensure the lasting health of spot shrimp’s ecosystem. Eutrophication is a process by which nutrients, discharged into an ecosystem by solid or atmospheric waste, generate profuse

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**Fig5** A profuse cluster of marine debris near Unalaska, Alaska. This type of waste can entangle animals, obstruct their digestive tracts, and gather toxic chemicals.
plant growth (See Figure 6). This can be indicated in a terrestrial environment by forest expansion, or, in an aquatic realm, as profuse algae, cyanobacteria, and other plants. As a natural process, it may boost species variety locally but tends to deplete it when encompassing a large area.

Eutrophication can also bring about invasive species population growth. Established plant growth communities tend to persist if the added nutrients remain in a given ecosystem and continuously cycle. In many instances, eutrophication may cause oxygen depletion and render a region to the states of hypoxia and anoxia (Finnish En-Eutrophication, 2012).

![Eutrophication Diagram](image)

**Fig6** Diagram of the mechanisms behind eutrophication, an end result of demographic stress. Pollution releases nitrogen and phosphorous based nutrients into an ecosystem, causing macroalgae to proliferate. As the algae dies, bacteria decomposes it, depleting oxygen in the process.

As evidenced by the Neva Estuary, the previously discussed issue of waste discharge can result in eutrophication. This particular ecosystem is a classic example of how the effects of this process can dominate. Littoral organisms in the estuary are threatened by eutrophication at the coast. In the 1990s, phytoplankton levels bloomed despite declines in nutrient content, to be followed by the dominance of macroalgae and cyanobacteria. Rapid blooms of macroalgae are attracted by the estuary’s stony and sandy shallow benthos, and appear to coincide with the severing of algal mats from their substrates, possibly due to the presence of storms. The absence or scarcity of oxygen (anoxia or hypoxia) in parts of the estuary coincides with the aggregation of freely floating algae. The problem (of eutrophication) could be attributed to the anthropogenic influence; these prominent changes in species distribution and biomass could be studied further for improved management of the estuary (Nikulina, 2011).

This deprived ecosystem represents a counterexample to the productive shrimp industry we seek to sustain. It shows quite radically how the PWS could be degraded by the anthropogenic influence if it extended uncontrollably. A rigorous and detailed movement of management would help prevent this problem from affecting the spot shrimp resource and its diverse supporting ecosystem.

**Current and Ensuing Changes to Climate**

Perhaps one of the most pressing issues facing the global ecosystem in the future is climate change, whose symptoms, which include ocean acidification and sea level rise, are progressing on multiple scales. Whether applied globally or locally, its impacts have proven to be radically transforming; in retrospect, climate change demonstrates how precarious mechanisms that include trophic structure can truly be. To best sustain a mere individual species such as spot shrimp for future generations, any management plan must devote serious weight and diligence to the cause.

Since 1850, the average global temperature has increased 1.3 degrees Fahrenheit. This trend is expected to accelerate with climbing emissions of carbon dioxide, methane, and other greenhouse gases (Johnson, 2009) (See Figure 7). Human utilization of coal, gas, and oil is believed to be a major contributing factor to climate change. The Prince William Sound
estuary, by geographic location, is extremely sensitive to this phenomenon, and therefore demands special attention in a global context (Climate Change and Prince William Sound). On the other hand, Alaska’s temperature increases at a rate which is double that of the remaining portion of the United States. This value is believed to climb a further 4 to 6 degrees Celsius by the next 100 years. As the trend continues, ecosystem balance will become more unpredictable as key ingredients such as circulation, aquatic temperature, trophic relationships, and chemistry are shifted collectively (Prince William Soundkeeper - Ecosystem & Threats, 2011). Also, certain concerns such as albedo reduction and permafrost melting could exacerbate climate change (Johnson, 2009) and pose a significant, however indirect, threat to the PWS ecosystem. Due to the intricate nature of food webs, climate change could also profoundly disrupt ecosystem balance. By consequence, the decline of a certain species may pose a direct or indirect impact to the various organisms connected to it. Some, such as ringed seals and salmon, are particularly vulnerable. The effects of climate change will encompass terrestrial and aquatic ecosystems alike (Ecosystems Impacts & Adaptation, 2012). For example, in the Neva Estuary, species such as the zebra mussel and other mollusks have flourished. Their presence poses a threat to the area’s native ecosystem (Panov, 2001). Climate change influences both the geographic distribution of species and their timed periodic instincts. Since predator-prey relationships throughout the food web are well attuned to these functions, ecosystem balance is becoming increasingly threatened. Because many species in a system may be interrelated, individual extinctions can taint an environment to a permanent extent. As organisms from lower latitudes expand northward, temperate natives (including the spot shrimp) will face competition from these species while also confronting the difficulty of surviving in changing habitats. This problem can influence not only aquatic realms but also terrestrial ones, as evidenced by the north-bound growth of shrubs in the Arctic, which counters albedo, or the deflection of sunlight past Earth’s atmosphere (Johnson, 2009).

Increase in mean temperature may also enable certain species to travel north or to higher elevations, thus raising concern for invasives (Ecosystems Impacts & Adaptation, 2012). For example, in the Neva Estuary, species such as the zebra mussel and other mollusks have flourished. Their presence poses a threat to the area’s native ecosystem (Panov, 2001). Climate change influences both the geographic distribution of species and their timed periodic instincts. Since predator-prey relationships throughout the food web are well attuned to these functions, ecosystem balance is becoming increasingly threatened. Because many species in a system may be interrelated, individual extinctions can taint an environment to a permanent extent. As organisms from lower latitudes expand northward, temperate natives (including the spot shrimp) will face competition from these species while also confronting the difficulty of surviving in changing habitats. This problem can influence not only aquatic realms but also terrestrial ones, as evidenced by the north-bound growth of shrubs in the Arctic, which counters albedo, or the deflection of sunlight past Earth’s atmosphere (Johnson, 2009).

The alteration of global climate may also herald the onset of spreading disease; for example the invasion of oyster parasite, *Perkinsus marinus*, throughout the East Coast of the United States has brought drastic consequences (Ecosystems Impacts & Adaptation, 2012). Climate change also poses fundamental effects on an ecosystem’s hydrology. For instance it has led to rapid glacier shrinkage. A compelling example is the 191 kilometer long Bering Glacier located east of Prince William Sound, whose profuse discharge of icebergs heralds its dramatic retreat (Climate Change and Prince William Sound). Due to the continuing ice melting and seawater expansion, sea-levels are
predicted to rise. Also, although precipitation is bound to climb, it will become more sporadic and difficult to predict as more intense rainstorms become coupled with heat waves and droughts (Johnson, 2009). As its bordering glaciers vanish precipitation becomes more erratic, Prince William Sound’s water circulation, a process which primary producers and littoral organisms both depend upon, could also undergo fundamental change (Prince William Soundkeeper - Ecosystem & Threats, 2011).

The increasing carbon dioxide levels in Earth’s atmosphere have caused many margins of shallow water to become more acidic; coral respond to this condition by expelling zooxanthellae in a phenomenon known as coral bleaching. When this stress is prolonged, coral become less resilient (Ecosystems Impacts & Adaptation, 2012). The tendency for cold, shallow regions of water to absorb carbon dioxide raises concern for ocean acidity in Prince William Sound, whose continental shelves contain suitable conditions for this to occur. Carbonic acid tends to dissolve protective shells in organisms such as coral, calciferous plankton, clams, and shrimp (Prince William Soundkeeper - Ecosystem & Threats, 2011). In effect, ocean acidification suppresses the growth of coral (Johnson, 2009). Because phytoplankton is integral to the food web and slow to recover, this problem could disrupt certain ecosystems such as PWS at a fundamental scale. If this occurred, entire economic boosting industries, such as Cordova’s fisheries, could collapse. To best resolve this issue, long term strategies must be developed and communicated to the public (Prince William Soundkeeper - Ecosystem & Threats, 2011).

**Proposed Solutions**

To resolve these issues most effectively, we must incorporate all necessary resources, research, and experience while considering the possible impacts of our interventions. Certain mandates such as economies and ecosystems need to be reconciled, and methods for indicating progress must also be employed. If we abandon our obligations as stewards, the spot shrimp resource may wax and wane as predicted, with no outside control on how it develops. However, reckless action could exacerbate negative trends. Therefore, it is critical that any management plan employs both ingenuity and balance.

**Oil and Gas:**

“Political will is a renewable resource”

— Al Gore

To ensure that our resource (PWS spot shrimp) is sustained, we must prepare for the likelihood of oil and gas development and its effects on our local environment and the PWS ecosystem. It is crucial that we develop our natural resources; however, to continue exploration of oil and gas, we ought to manage the natural environment and develop resources safely. As part of a recurring theme, we target collaboration between experts and community members as a means for resolving issues. Because local residents are closely connected with their surrounding ecosystem and its resources, we suggest encouraging them to become involved in all avenues of oil transportation and management. Taking advantage of every valuable social asset can provide for more elegant management.

With the current state of the economy, an increase in gas and oil exploration is projected. Currently, the United States is the greatest oil consumer in the world, using roughly 18,690,000 barrels each day (Consumption Oil Statistics, 2009), and is predicted to be the largest producer by 2017, surpassing Saudi
As extraction of oil and its byproducts expands, more exports will be needed. This raises the likelihood of tanker accidents and spills, which pose an immediate threat to the PWS ecosystem and its spot shrimp resource. Coherent solutions must be employed to alleviate this influence.

One current means for safeguarding our resource from such disasters is SERVS (Ship Escort/Response Vessel System), a world renowned organization that functions to enable the safe transportation of oil throughout Prince William Sound (See Figure 8). SERVS employs common sense requirements coupled with local involvement to respond to spills in a sensible but effective manner. Current precautionary measures include abundant spill response supplies at the Valdez Terminal, alcohol tests on captains, navigational briefings, and speed limits ranging from six to ten knots. SERVS regards prevention as a priority, as evidenced by its attention to detail, which will be in demand as the oil and gas industry grows, and with it, tanker traffic. While regulations are important, other means should also be addressed. One such possibility is to increase the presence of local assets in the process. Encouraging local residents to undertake professions dealing with oil management and transportation would provide more reliable connections due to familiarity with their surrounding ecosystem.

These employees would be driven not only by regulations, but the intrinsic value of PWS as well. The idea of training and hiring local Alaskan employees can be seen in Field Based Education for Alaska Native Teachers (FBEAN), which puts Alaska Natives through teaching programs in hope to insure education in rural villages (Barnhardt, 1977).

A “Prince William Sound, Alaska, Risk Assessment Study” taken following the 1989 Oil Spill was weak in substance but could inspire future solution strategies. Although well devised in its attempt to establish data from questionnaire, it lacked a sense of clear and consistent structure. In other words, it was bold in its approach but intangible due to its obscure treatment of methods. These apparent flaws were criticized by the National Research Council, which reviewed the study by expressed request. The effort was modeled by assessing risks and possible errors in addition using simulation. The data, however creatively presented, lacked a sense of variation and neglected factors such as changing vessel speed. Although certain values were compared to each other, information from outside of the Sound was sometimes relied upon despite no indication that it applied. This plan’s tactics were poorly developed but signified a good start and could be improved (Committee on Risk Assessment and Management of Marine Systems) Future management could incorporate some of the study’s ideas while using its detached approaches as a counterexample to using joint efforts to manage data.

Icebergs discharged by Columbia Glacier raise another potential threat. This becomes especially hazardous when their view is obscured by fog, in which case escort vessels are employed to ensure clearance within a half-mile radius (ANWR Technology-SERVS MISSION). A proposal considered by several entities (e.g. Coast Guard, Alyeska, PWS Regional Citizens’ Council) as of 2002 was to monitor ice flows with radar systems attached at
Bligh Reef, site of the Oil Spill in 1989 (Jones, 2002). As of now, the system will run on a trial and advisory basis. The information that is collected will be available to the Coast Guard and to mariners in the Sound. To improve our ability to address this concern, or any concern, we must foster collaboration in the process. Currently, owing to the Exxon Valdez Oil Spill in 1989 and pressure put forth by both environmental groups and the general public, changes have been made to ensure the safety of the PWS ecosystem. One of the most important resources is SERVS’s dedication to preventing accidents in Prince William Sound and advanced training for spill response.

Although our objective favors increased collaboration between those that ship through Prince William Sound, we affirm that this issue is being handled adequately. With a few minor adjustments, we feel PWS could become an even stronger, cleaner, and safer ecosystem for current and future generations.

Demographics:
“It isn't pollution that's harming the environment. It's the impurities in our air and water that are doing it.” — Al Gore

Due to increasing exploration of our state’s abundant supply of fossil fuels and recent economic downturns nationwide, the need to investigate potential demographic shifts through response is a crucial step in predicting Alaska’s future. It is expected that future job opportunity growth will stimulate population shifts from rural to urban areas, which could create more settlements bordering PWS. In the future, this might require us to carefully consider a viable waste management plan. Waste discharged at urbanized areas could cause nutrient buildup, which ultimately leads to eutrophication, as prevalent in the Neva Estuary. To prevent wholesale contamination, we suggest employing technology that converts waste into usable energy sources. Landfills, sewage plants, and other conventional means of waste disposal should be planned strategically. These could also yield to recycling, composting, and other eco-friendly alternatives. Instead of procrastinating, we should concoct good solutions in advance, since pressing issues beg immediate attention. But most importantly, we should avoid detaching ourselves to resolve issues, for a “house” of management “divided against itself cannot stand (Lincoln),” and true results require full-fledged collaboration.

Although tourism benefits the economy, it can pose a detrimental impact to ecosystem health that is currently being adopted into management possibilities. The issue lends itself to periodic human population fluxes which can shift, or possibly disrupt, ecosystem balance. This partly stems from its tendency to compete for natural resources such as land and species harvest. Also, travelers dispose waste that can leak into the environment through sewage plants, landfills, and erratic dumping. Accidents and laziness both may contribute to this general problem. One solution to this concern is ecotourism; this is an imposed practice that seeks to allow tourists to appreciate natural and cultural wonders but limit their direct influence on the environment (Anderson).
Waste can be managed using natural processes such as fermentation and artificial means that include landfills. Some may be public, others private or performed at home. Ecologically sound ones include the recycling (or reusing) and the composting (or natural degradation) of material. However, certain forms of waste, such as pharmaceuticals, can pose a hazard and must be dealt with properly. Landfills are by far the most frequent technique, although some countries resort to burning waste as an alternative. Because it transfers particulates into the atmosphere, this trade off does not necessarily reduce impact (Dray).
One unique example of a waste management technology is the Wastech System, which consists of a microprocessing unit developed by
the Florida based company, Eco Energy Management LLC (See Figure 9). The system recycles waste through conversion into either fuel oil, biogas, or carbon black char. To accomplish this, it employs advanced double pyrolysis steam injection technology to process the material at temperatures of 850 degrees Celsius at an amount of 50 tons per 24 hours. Wastech powers itself using the biogas it produces and is capable of contending any type of material waste, whether that be rubber, plastic, wood, food, industrial, or medical. The oil it produces, resembling diesel fuel, can be utilized for diesel generators or furnaces and contains little sulfur. The black carbon, by contrast, is bagged as pellets, which can be converted into ink, tires, and water and air filters. Its untreated state, biochar, can be used for fertilizer (Sims, 2011). By vowing to forge interests between community and research, we could adopt this method into management of PWS waste. It would pave the way for extending a stewarding hand into other concerns.

Eutrophication, caused by nitrogen and phosphorus buildup, can be artificially driven by wastewater, urban runoff, and air pollutants. Especially in urban and farming areas, atmospheric waste may include nitrogen dioxide. During this process, diatoms are replaced by flagellates, the blooms of which (red tides) pose a lethal threat to fish and mollusks. Stagnant, or poor flushing, water is usually where eutrophication is more prominent ("Eutrophication"-National Estuarine Research Reserve System). Wastewater/waste treatment plants are required to restrict discharge of materials that include feces and suspended solids. Bypassing waste from river can help alleviate amounts of present nutrients such as nitrogen, as evidenced by the Yemassee plant. In South Carolina’s ACE Basin, septic systems overload the estuary with significant amounts of both phosphorous and nitrogen. These elements, constituting the recipe for eutrophication, are also yielded by fertilizer, which leaks into ecosystems through runoff into streams. Although attracted by sewage, macroalgal growth is suppressed by murky (turbid) water. In “ACE,” efforts to manage land have enabled water nutrient densities to decrease.

A “Clean Water Action Plan” proposed by EPA and USDA calls for enforced control of water quality, with emphasis on the importance of watersheds ("Eutrophication"-National Estuarine Research Reserve System). We should consider cost effective strategies that include employing technology, pinpointing sources of nutrients, implanting nutrient absorbent soils, and administering vegetative buffers. Another possibility is to establish and strictly abide by limits for nutrient concentration (according to EPA, 0.1mg/l for phosphorus and 0.2mg/l for nitrogen). It is wise to alleviate the progression, or rate, of the problem, not the issue itself. Future actions should be planned strategically to ensure both efficient and effective solutions. For instance, what should be encouraged, and what should be constrained? ("Eutrophication." National Estuarine Research Reserve System). Decisive action towards managing for eutrophication could be enabled via joint efforts to pinpoint each variable stemming from it.
Although we do not currently have the perfect solution to demographic change, we should not procrastinate but, instead, work together to create lasting positive change. Our motives should be wise, creative, and open-minded. Whether they include tourism or eutrophication, noble efforts are needed to ensure both the well-being of spot shrimp’s industry and its ecosystem.

**Climate Change**

“Here is the truth: The Earth is round; Saddam Hussein did not attack us on 9/11; Elvis is dead; Obama was born in the United States; and the climate crisis is real.”

― Al Gore

Apart from being a contentious topic in debates, climate change presents many challenges to the health of Prince William Sound (PWS) and our target resource, spot shrimp. Our driving goal is to monitor shrimp (for natural responses to this issue) more efficiently and to help enact fairer regulations through cooperative efforts. A perfect exemplar of this situation is a partnership forged between SERVS (Ship Escort/Response Vessel System) and the community based PWSAC (Prince William Sound Advisory Council) to actively prevent and respond to oil tanker spills. This parallels what scientists, government, and stakeholders could accomplish through combined efforts to respond to dangers linked to climate change. Research should be smooth and regulations must be focused rather than erratic.

This process should encourage users with a comprehensive format and avoid discouraging them with ruthless constraints and politics.

Essential to our plan is a research database providing widespread access to relevant data; this embodies the importance of joining efforts through alliances to sustain ecosystem health. Tangible plans, not mountains of data and other undesirable alternatives, should be used. Orderly information is best attained through open interaction that allows repeated observation of trends in variables linked to climate change. For a deeper understanding, all relevant parties should collaborate to consider and compare long and short term trends. Connections and contrasts in information could inspire comprehensive models based upon time and location, thereby kindling our ability to bolster poor constructed data and predict change (Wilkinson, Campbell-Lendrum). For instance, exaggerating the climate change topic to the public only creates severe distrust and delays opportunities for viable solutions. Politicizing an issue obscures more than exposes its inner reality. Solid data, it seems, may be best obtained through interaction with parties most intimately connected with the resource, namely the Alaska Department of Fish and Game (ADF&G) and commercial fisherman. Meaningful relationships are more likely to bring close commitment, which, in turn, stimulates potent management of a resource. A question emerges: how would such a system operate?

When complex ecosystems (e.g. PWS) become the focus of monitoring, a wide array of elements can spring about (Wilkinson, Campbell-Lendrum). For example, the migrations of marine invertebrates and fish extend a much greater distance than those of plankton and, therefore, are much more difficult to track. Methods for measuring such behaviors include tagging adults, tracking genetic contrasts in large groups of organisms caused by movement, and isolation-by-distance models describing the dynamics of schools (Hoffman |Gaines, 2008). Although these given approaches are limited, recent efforts in technology are redefining the daunting task of monitoring. Such a large chore can’t be tackled by disjointed parties; regulators and users, both closely connected with the resource, should unite to manage spot shrimp with emerging techniques.

Present regulations for our target species, as
established by the Alaska Department of Fish and Game (ADFG), are quite orderly. The annual time period designated for the activity spans from April 15 to September 15 (Regulations - Prince William Sound Personal Use Shrimp Fishery). The purpose of this (and possibly other regulations) is to help preserve hatching periods. Also, shrimpers are required to obtain licenses and mark each pot deployment with a buoy (Spot Shrimp-Alaska, 2012) (Regulations). The maximum number of pots that can be distributed varies with each successive yield and number of users. For example, more boats would equate to a small number of allowed pots; less boats and high shrimp yields might mean a large pot number limit (Mark Hem (pers. comm.))(Prince William Sound...Updates). ADF&G requires each shrimp pot to adhere to certain design specifications and to indicate the user’s identity (Regulations). A set of domains the state designates for shrimp fishing are periodically revolved; for instance, during 2011 areas surrounding Port Valdez and Whittier were closed to all users, while Port Wells and a southern portion of the Sound were entitled to commercial shrimp harvesters (Mark Hem (pers. comm.))(PWS...Updates). Excessive effort is undermined by the closure of areas in which certain quantities of shrimp have been harvested (Spot Shrimp). Regulations do carefully consider ongoing spot shrimp trends (and their various contributing factors) and should continue enactment through collaboration with research throughout the coming future. However, preventing the shrimp industry from collapse requires that closely connected parties employ expanding technologies, not countless limitations, to overcome obstacles.

Regulations should be efficient, not grueling. Despite previous population setbacks (caused by the 1989 Spill) in PWS that closed harvest for a certain period of time, the spot shrimp resource is presently at maximum sustainable yield (MSY) and has recently increased; but estimates projected for some Alaskan coastal regions, including that nearing Cordova, suggest long term decreases (Spot Shrimp). Pot traps can impose physical damage to habitat. Natural recovery is slow and efforts to manage this issue are sparse. This can be prevented by attaching short extensions called longlines to pots (Spot Shrimp). If we abstain from action this concern could worsen potential effects of climate change on benthic communities. However, this problem could be easily covered with well devised regulations. Another subject of attention is the possibility of stray pots trapping shrimp, which can be mitigated by constructing them from “rotten cotton,” a biodegradable material (Mark Hem). Any strategy we devise to monitor spot shrimp and prepare it for the coming future must involve joint cooperation to ensure that every measure is logically sound. Provided that this is a reasonable step, how do we ensure that information is tangible? Although decisive control can help to enrich an industry, excessive power can restrain it. Therefore, we must craft these current efforts into a system that encourages various users to cooperate rather than shunning them. For instance, these can be improved by training shrimp fisherman to measure species yields, health status, and other details relevant to monitoring. Clearly laid out procedures for obtaining the information could reduce the need for users to bear extensive expertise. Also, certified experts could assist them in the task. Instead of bogging down shrimpers with a barrage of rudiments, regulations could require them to input simple but effective measurements. Users collaborating willingly with government could forge a firmer step towards reliable management of spot shrimp.

The issue of climate change demands collaboration among various professions to track and identify organisms effectively (See Figure 10). This can be easily accomplished through technology, which applies not only to
flashy electronics but biology as well. Many recently developed approaches in genetics address this and involve techniques such as DNA barcoding, ecogenomics, and DNA microarrays. The first method (DNA barcoding) compares a species’ genetic makeup to a collection of segments, each containing up to 648 base pairs (Hoffman |Gaines, 2008) (Consortium for the Barcode of Life (CBOL)). Although convenient and adopted by many scientific groups, the technique is still disputed for its accuracy in discerning similar species. Ecogenomics, by contrast, analyzes genes on a larger scale to provide insight into microbe diversity and (with the aid of mapping) species community health. DNA microarrays use microscope slides to observe how individual genes adapt to environmental factors such as temperature increase. Such a method could lend clarity to shell composition changes due to ocean acidification, coral bleaching driven by heat stress, and other processes. Another approach, genomics, involves probing into complete genomes. This may shed light into the role “physiology” plays in coral and other symbiotic relationships (Hoffman |Gaines, 2008). With combined efforts between experienced parties, these techniques could easily conform to a role within PWS spot shrimp management.

More traditional approaches focusing on larger scales (namely tagging, otolith tracking, and data loggers) could help better management of spot shrimp through joint efforts. Tagging is a probability-based population-counting strategy. Despite being inexpensive and basic, it requires the capture of many specimens. However, an improved digital tag system, that imbeds itself in organisms, also measures vital functions (and sometimes migration check points), which can be directed to a computer for interpretation. With the aid of mass spectrometers, otoliths (fish ear bones) can indicate age (from concentric rings) and migration routes (from relative composition). This can be cross-referenced with tagging to cover ambiguities and presents valuable insight into management (Hoffman |Gaines, 2008). Decisive spot shrimp tagging should be conducted more regularly and embrace some of the technologies presented here. Fish predators of this species (e.g. Pollock and halibut) could be tagged and sampled for otoliths. Data loggers placed on organisms (e.g. mussels) can monitor health factors such as body temperature and compile trends. In addition, observatories use cameras and underwater vehicles to provide limited glimpses into ecosystems (Hoffman |Gaines, 2008). Regardless of a strategy’s ingenuity, no given solution will succeed in sustaining PWS spot shrimp unless we vow to combine knowledge and efforts elegantly. The process should warmly encourage users, not detach them with complex limitations. Requiring them to use technologies such as DNA barcoding and implanted tags would be a worthy substitute for menial restrictions. However, before shrimp catching areas are designated, researchers should observe various locations for potential yields. Willing collaboration among closely connected groups to monitor spot shrimp with these emerging techniques would signify a promising step in the right direction.

Climate change is a thorny issue indeed. Complex ecosystems are difficult to manage during times of change and uncertainty. To ensure stable management in times of instability, we need to collaborate by combining our entire research into an interpretable database; we should also monitor and regulate spot shrimp jointly. Our course of action may very well determine the fate of this resource and its intricate ecosystem.

**Conclusion**

Each of us live in locations and environments that have made us who we are, and have enriched our lives in an immeasurable way. To this end, we propose changes and options that will help ensure the places we love and enjoy are preserved. We believe that the Prince
William Sound is one of these places and the spot shrimp inhabitants are important resources that demand attention. If some of the proposals made in this paper are enacted, we would be well on the way to protecting this abundant ecosystem and its resources.

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<https://maps.google.com/maps?hl=en&q=where+is+the+neva+river&ie=UTF-8&hl=en&gl=us&ei=vriuUPekCYL2iwKXgoGwCg&ved=0CCwQ8gEwAA>.  


Figure Citations (in order of appearance)


