
The Continental Drifters

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The Nushagak Estuary: Salmon Resource, Potential Threat and Management Plan

Abstract
Estuaries form an interface between marine and freshwater systems and are parts of the larger ecosystems, either directly via water flows or indirectly through the exchange of fauna. In addition to the biota that the estuaries support, they provide a range of goods and services to the inhabitants of the various regions. The disturbance of the estuary can affect the ecological balance that exists between the biotic and abiotic factors within the environment hence its sustainability needs to be addressed by some form of management plan. On this premise our study focuses on the threats to the resources of the Nushagak estuary. The Nushagak River estuary has abundant aquatic and terrestrial resources and is the world’s largest salmon fishing area. The watershed is also environmentally untouched by development, making this estuary an essential freshwater and salt water resource for the organisms who dwell there. The Nushagak River estuary drains out into Bristol Bay, a region where it is potentially threatened by the proposed construction of the Pebble Mine, which could pollute waterways. The Nushagak estuary alone with the neighboring estuaries of Bristol Bay have 33 fish species essential to the community’s economic, cultural and commercial needs. Approximately 42.42% are anadromous, 12.12% are marine/estuarine and 45.45% are resident. Among the anadromous species, the 5 types of salmon contribute to the top Alaskan fish resources. The sockeye salmon alone gives 10,865,690 total harvest out of the state average total harvest of 42,699,402 in 2006-2008 (Dann et al, 2009). Studies have shown that the salmon life is already severely stressed by the impact of climate change, causing degradation of the freshwater and estuary salmon habitat. What would happen if the mining operation will be implemented? The discharge of mining wastes would increase the particulate load of the estuarine water, hence the sediment loaded estuary causes deceleration of the flow velocity of the river waters which consequently results in siltation. The Nushagak estuary will be certainly be at risk. As a point of reference, we studied the impact of the 40-year mining industry at the Mpenjati estuary in South Africa. Severe disturbance of the riverbed, removal of bottom habitat and associated organisms, siltation, river bank degradation, water and noise pollution are among the numerous effects of the mining operations. Consequently the Mpenjati management plan is repair and rehabilitation. In contrast our management plan to protect the Nushagak estuary is preventive.
Introduction

Bristol Bay is located in the southwest part of Alaska, east of the Bering Sea. Many rivers drain out to Bristol Bay. These rivers are Cinder, Egegik, Igushik, Kvichak, Meshik, Nushagak, Naknek, Togiak, and Ushashik. Of all these rivers, the largest estuaries are the Togiak, Nushagak, Naknek-Kvichak, Egegik and Ugashik. These river drainage systems are environmentally connected to other neighboring and intersecting rivers, streams, lakes and ponds that make up the Bristol Bay watershed (Figure 1).

The Nushagak Bay is a large estuary that is included in the Bristol Bay watershed. Among this area, the largest community is Dillingham, AK, while there are other surrounding communities located on and around the Nushagak River. The Nushagak River watershed is composed of mountains, mixed forests, tundra, lakes, and rivers. The dominant terrestrial vegetation is tundra, mixed coniferous/birch forest, and willow/cottonwood/alder riparian corridors (Nushagak-Mulchatna Watershed Council, 2007).

The Nushagak estuary supports a large salmon run of five species of salmon that both Bristol Bay and Nushagak estuary residents value for both subsistence gains and commercial profits. The Nushagak estuary is only one estuary that is included in all of Alaska’s estuaries. Any disruption of the Nushagak estuary, such as ocean acidification, climate change and the newly potential threat- the proposal of the Pebble Mine can affect the species that inhabit the area as well as the physical characteristics which can ultimately spread not only in the Nushagak estuary and it’s neighboring estuaries and bays, but also throughout the rest of Alaska.
General History

In a report by the Nushagak-Mulchatna Watershed Council (2007), it was stated that the Nushagak River watershed was formed by repeated Pleistocene glacial advances and retreats ending about 12,000 years ago. The modern shoreline of Bristol Bay was created in the same period when sea levels rose, inundating the Bering land bridge and creating the Bering Sea. This area encompasses the entire Nushagak drainage and all of Nushagak Bay (Figure 2).

During the time of the Bering Land Bridge, nomadic people have crossed into North America from Asia. Among these people were the Yupi’k Eskimo’s that have inhabited the western region of Alaska. Some of these Yupi’k Eskimos habituated the Nushagak region for centuries, up until the influence of Western culture when the Russians first started exploring Alaska. Since then, the people have relied on the watershed for food, specifically salmon.

Commercial and Subsistence Importance

Pacific salmon is the most valuable commercial and subsistencial fish in the Nushagak estuary. Since the Nushagak estuary is located in Bristol Bay, it is included that it is part of Alaska’s richest commercial fishery. In the Nushagak estuary and the other neighboring estuaries alone, the 2008 harvest of all salmon species was approximately 29 million fish, and the value of the 2008 commercial catch topped $113 million (Figure 3).

Although the Pacific salmon may be an important commercial value for fishery, it is also important for the the indigenous people who have inhabited the Nushagak estuary region as well as the rest of Bristol Bay. These people, as well as other terrestrial mammals have relied on Pacific salmon as a subsistencial resource of food and survival for thousands of years.

General Resources of Nushagak Ecology

The Nushagak watershed is considered one of the richest areas in Alaska for its abundance in natural resources. This watershed situates the Nushagak estuary with ecological relationships which when well protected and maintained would always be the
healthy pathway of the anadromous fish species, more specifically the five types of salmon, when their smolts are ready journey from the freshwater to the oceans. On the terrestrial connections, there are mountains, mixed forests, and the vast tundra enclosing lakes and rivers. Tundra is the dominant resource for terrestrial vegetation. Large tidal marsh exists at the mouth of the Nushagak River – tidal mudflats, sandy and gravelly shorelines and bluffs of glaciofluvial material up to 200 ft high. The 5 species of Pacific salmon spawn in Nushagak River. Other freshwater fish plus wild animals like moose, caribou, water birds, berries and medicinal plants thrive also thrive in the area. Our resource aim is toward the aquatic salmon species.

Fish Species

There are 33 known species that are distributed within the Nushagak estuary system. Out of the 33 species, 14 are known to be anadromous, 4 are both marine and estuaric, 16 are residential and 1 specie is known to be both anadromous and resident (Figure 4). Although there are a majority of species within the Nushagak estuary system, 5 are the most dominant, which are the coho (silver) salmon, Chinook (king) salmon, sockeye (red) salmon, chum (dog) salmon and pink (humpy) salmon.

Coho Salmon

The coho salmon (Oncorhynchus kisutch), or “silver” salmon have an appearance of dark metallic blue or greenish backs with silver sides and a light belly. These coho salmon have a life history that is straight-forward; Smolts migrate to sea in spring of their second year, spend 16-20 months rearing in the ocean, then return to freshwater as three-year-old-adults. A returning adult may measure more than two feet (61 cm) in length and weigh an average of eight pounds (3.6 kg), but can weigh as much as 35 pounds (16 kg).

Coho salmon adults migrate from oceans into freshwater streams and rivers of their birth in order to mate. They spawn only once and then die. Spawning males develop a strongly hooked snout and large teeth. Females prepare several redds where the eggs will remain for 6-7 weeks until they hatch (Oregon Natural Resources Council, 1974).
According to the U.S. Fish and Wildlife Services, Fairbanks Fish and Wildlife Field Office, Coho salmon around the Nushagak River Estuary and Bristol Bay spawn in the Alagnak, Kvichak, Nushagak, Ugashik and Egegik Rivers.

**Chinook Salmon**

The chinook salmon (*Oncorhynchus tshawytscha*), or “king” salmon, are the largest of any salmon. Adults chinook salmon can expand to about 40 pounds (18 kg), but individuals over 120 pounds (55 kg) have been reported. The chinook salmon appear similar to coho salmon with blue-green backs with silver flanks, but differ in size with small black spots on both lobes of the tail, and black pigment along the base of the teeth.

The life history of chinook salmon are similar to other marine salmon species. Adult chinook salmon reach their spawning areas between July and September each year. They choose to spawn in streams that are shallow, clear, and cold with upwelling of water through the gravel. The female digs a redd, consisting of several pits, and deposits in the stream of gravels. The spawning areas in Bristol Bays estuarine river systems include the Nushagak River, where the largest chinook salmon run is in Alaska. When the redds of these chinook salmon are hatched, they become fry, which are found along the sides of pools and near the cover of over-hanging banks. These fry grow to become juveniles, where they occupy different streams in the fall and winter. The juveniles then grow into smolts, where they remain in an estuary for a short time before moving farther offshore. Alaskan chinook salmon remain at sea between 3 and 4 years.

**Sockeye Salmon**

Sockeye salmon (*Oncorhynchus nerka*) are one of the smaller species of Pacific salmon, measuring 18 to 31 inches in length and weighing 4-15 pounds. The appearance of the sockeye salmon have silver flanks, a white belly, and a metallic green-blue top, giving them their "blueback" name. Some fine black speckling may occur on the back, but large spots are absent. Sockeye salmon are prized for their firm, bright-orange flesh. As sockeye salmon return upriver to their spawning grounds, their bodies turn red and their heads take on a greenish color. Breeding-age males develop a humped back and hooked jaws filled with tiny, visible teeth. Juveniles, while in fresh water, have dark,
oval parr marks on their sides. These parr marks are short-less than the diameter of the eye-and rarely extend below the lateral line. Sockeye salmon spawn in the Kvichak, Alagnak, Naknek, Egegik, Togiak, Wood, Igushik and Nushagak Rivers in the Bristol Bay. Sockeye salmon runs in these river estuaries, specifically the Nushagak River estuary, is the world’s largest salmon run, producing up to 70 million each year.

**Chum Salmon**

The chum salmon (*Oncorhynchus keta*) average around 8 (3.6 kg) to 15 pounds (6.8 kg), but some chum salmon individuals have been reported up to 3.6 feet (1.1 m) and 45 pounds (20 kg). Chum salmon are best known for the enormous canine-like fangs and striking body color of spawning males (Figure 5). Females are less flamboyantly colored and lack the extreme dentition of the males. Ocean stage chum salmon are metallic greenish-blue along the back with black speckles. They closely resemble both sockeye and coho salmon at this stage. As chum salmon enter fresh water, their color and appearance changes dramatically. Both sexes develop a "tiger stripe" pattern of bold red and black stripes.

Chum salmon feed on insects and marine invertebrates while in rivers. As adults, their diet consists of copepods, fishes, mollusks, squid and tunicates. Age at maturity appears to follow a latitudinal trend in which a greater number of fish mature at a later age in the northern portion of the species' range. Most chum salmon mature and return to their birth stream to spawn between 3 and 5 years of age, with 60 to 90 percent of the fish maturing at 4 years of age. The species has only a single form (sea-run) and does not reside in fresh water. As the time for migration to the sea approaches, juvenile chum salmon lose their parr marks (vertical bars and spots useful for camouflage). They then gain the dark back and light belly coloration used by fish living in open water. They seek deeper water and avoid light; their gills and kidneys begin to change so that they can process salt water (Office of Protected Resources, NOAA Fisheries, 2012).
Pink Salmon

The pink salmon (*Oncorhuchus Gorbuscha*) or “humpy” are the smallest and most plentiful of the pacific salmon. It has the shortest lifespan of all the pacific salmon, and spends the least amount of time in the fresh water areas. The pink salmon can be up to 30 inches long and they can weigh up to 14 pounds, but most fish weigh up to 2-7 pounds more typical. The pink salmon have steel blue to blue-green backs, silver sides, and their bellies are white. They have large oval spots on their backs, adipose fin and both tails. The spawning fish have streak on their sides, and spawn between late June and mid-October. The males have a strong snout, very sharp teeth. The pink salmon is also known as the “humpy” because of its very pronounced, laterally flattened hump which develops on the backs of adult males before spawning (Figure 6). Pink salmon are important in many Alaskan coastal fishing communities because of its importance to commercial fisheries and local economies. Pink salmon also contribute substantially to the catch of sport anglers and subsistence users in Alaska (Alaska Department of Fish and Game, 2012).

Environmental Stress to Salmon Life

Studies have shown that climate change is greatly affecting salmon life – a culturally and economically significant resource-across all life stages, both in freshwater and saltwater, as a result of changes in the timing and volume of streamflow and ocean acidification. Projected increases in winter flooding, decreased summer and fall stream flows, and warmer summer water temperatures will further degrade freshwater and estuary salmon habitat. The duration of periods that cause thermal stress and migration barriers to salmon is projected to at least double and perhaps quadruple by the 2080s for most streams and lakes. This will increase the rates of pre-spawn mortality for chinook salmon and steelhead trout. These changes will cause severe problems for our already stressed salmon stocks, including federally protected stocks listed under the Endangered Species Act and will likely lead to widespread violations of water quality standards adopted under the Clean Water Act. Although salmon have been able to adapt to great
changes in climate and environment in the past, maintaining diversity in salmon populations will be key to the survival of the species.

**The Threat of Mining Operations**

The mining methods of interest are the open-pit mining method for the proposed Alaska-based Pebble West and the underground mining method for the proposed Alaska Pebble East. Open-pit mining, open-cut mining or opencast mining is a method of extracting rock or minerals from the earth by their removal from an open pit or borrow. This form of mining differs from extractive methods that require tunneling into the earth such as long wall mining. Open-pit mines are used when deposits of commercially useful minerals or rock are found near the surface: that is, where the overburden (surface material covering the valuable deposit) is relatively thin or the material of interest is structurally unsuitable for tunneling (as would be the case for sand, cinder, and grave). For minerals that occurs deep below the surface—where the overburden is thick or the mineral occurs as veins in hard rock—underground mining methods extract the valued materials. A haul road is usually situated at the side of the pit, forming a ramp up which trucks can drive, carrying ore and waste rocks. Ore which has been processed is known as tailings. This is pumped to a tailings dam or settling pond, where the water evaporates. Tailings dams can often be toxic due to the presence of unextracted sulfide minerals and often cyanide which is used to treat gold ore via the cyanide leach process. This toxicity can harm the surrounding environment.

**The General Impact of Mining**

Mining is hazardous to the surrounding environment and even controlled mining sites release dangerous toxins, chemicals and pollutants around the mining region which then, in turn find their way to damage the ecosystem, which can affect the social health of the marine inhabitants, as well as humans. Impacts of sand mining can be broadly classified into three categories, physical impact, impact on water quality and ecological impact (The Ojos Negros Research Group, 2012) Physical impacts includes the large-scale extraction of streambed materials, mining and dredging below the existing streambed, and the alteration of channel-bed form and shape.
leads to several impacts such as erosion of channel bed and banks, increase in channel slope, and change in channel morphology. These impacts may cause: (1) the undercutting and collapse of river banks, (2) the loss of adjacent land and/or structures, (3) upstream erosion as a result of an increase in channel slope and changes in flow velocity, and (4) downstream erosion due to increased carrying capacity of the stream, downstream changes in patterns of deposition, and changes in channel bed and habitat type. Impacts on water quality is subjected by mining and dredging activities, poorly planned stockpiling and uncontrolled dumping of overburden, and chemical/fuel spills will cause reduced water quality for downstream users, increased cost for downstream water treatment plants and poisoning of aquatic life. Ecological impacts are subjected by mining which leads to the removal of channel substrate, resuspension of streambed sediment, clearance of vegetation, and stockpiling on the streambed, will have ecological impacts. These impacts may have an effect on the direct loss of stream reserve habitat, disturbances of species attached to streambed deposits, reduced light penetration, reduced primary production, and reduced feeding opportunities.

The Proposed Pebble Mine

The Pepple Project is copper-gold-molybdenum porphyry deposit in the advanced exploring stage. The project is located on the stage land in the Bristol Bay Region of Southwest Alaska. In 2007 the Pebble Partnership (PLP) was formed as a 50:50 partnership between a subsidiary of Anglo American and Northen Mitsubishi Corporation. The Pebble Mine consists of two contiguous deposits. Pepple West is near surface resource of approximately 4.1 billion metric tons that, if developed, would likely be mined by conventional open-pit mining techniques. Pebble East is significantly deeper then Pebble West and contains generally higher grade ore. Its size is currently estimated at 3.4 billion metric tons. If developed, Pepple East would probably be mined via bulk tonnage underground mining methods. PLP is currently conducting an exploration drilling program to further explor the Pepple deposits and upgrade its resource classification.
Potential Threat of the Pebble Mine

If the proposed Pebble mine is accepted, the first step of it’s process would be the detonation of the surface, causing waste from rock to form an acid mine drainage. The detonated surface, underground mine shaft or any other openings can result as chemical hazard. The openings result as a chemical hazard because the exposed lithosphere rocks can react with the atmosphere, liquid substances or other chemicals associated with mining to create an acid mine drainage. The next process of the mining operation would be milling. The mineral ore is processed to remove the unnessesary minerals to collect the desired sediment, in which the Pebble Partnership, would be gold. Chemicals such as cyanide and sulfuric acid are used to remove the ore. These chemicals become mineral waste which produces toxic metals that produce sulfuric acid as they degrade. These hazardous toxins pollute the surrounding environment. The mining industry continues today to be the number one creator of toxins in the United States. If the Pebble Partnership proposed mine is accepted, it is no doubt that the Nushagak estuary’s essential sockeye salmon (main resource) will downgrade it’s salmon population. The Nushagak estuary as well as the other estuaries in Bristol Bay would become endangered if the mining operation is built. Not only will the mine release toxins, but overtime siltation will occur and increase to the Nushagak estuary. Since sockeye salmon are anadromous species of fish, the blockade of the estuary will prevent them from making their annual spawn, as well as the juveniles that are supposed to be habituizing the Nushagak estuary, before going out to Bristol Bay. This effect would reduce the sockeye salmon population over time, drastically.

Furthermore, according to Murphy (2012), the Environmental Protection Agency is warning that plans for massive mine in the hills above Bristol Bay in Alaska, home of the biggest sockeye salmon fishery in the world, could have devastating consequences for the rivers and streams and wipe out habitat for fish.

A study that represents the federal government’s first significant scientific assessment of the proposed Pepple mine site concludes that extracting billions of pounds
of gold, copper and molybdenum from the region could result in the direct loss of up to 87 miles of steams and nearly seven square miles of wetlands.

Although the Nushagak River estuary and its surrounding river estuarine systems located in Bristol Bay have salmon resources that are valuable for both commercial, subsistencial and recreational fishing, a potential threat to the marine environment and biological ecology in under-going proposal to create a mining operation near the headwaters of the Nushagak River (**Figure 7**), as well as surrounding rivers near Bristol Bay. If approved, the environment around that area, as well as the surrounding areas will be affected greatly.

**Mpenjati Estuary-South Africa: A Point of Reference**

The Mpenjati Estuary is located in the KwaZulu-Natal south coast, some 165 km south west of Durban, between the small towns of Trafalgar and Palm Beach. The estuary and its small catchment area, fall within the boundaries of the Ugu District Municipality and the Hibiscus Coast Local Municipality (HCM). The system is naturally functional and in exceptional ecological heath in comparison with most estuaries along the coast line. In the early 1980’s, the relatively undisturbed forest land and palm trees surrounding the Mpenjati River and the water body itself, were recognized for their conservation value and recreational opportunities. As such, the lower half the estuary forms an integral part of the proclaimed protected area, the Mpenjati Nature Reserve, which protects a diversity of coastal habitats associated with the estuary; including estuarine and floodplain marshlands, endangered coastal dune forest and grassland, and open coastline and managed by Ezemvelo KZN Wildlife. The Mpenjati Estuary is unique in that is one of the few estuaries and wetland areas in KwaZulu- Natal afforded formal protection (the only system south of Durban) and it is directly linked with the adjacent Trafalgar Marine Protected Area(MPA). However, the Mpenjati Estuary is not with our various anthropogenic impacts. From 1969 to 2008, the system was subjected to sand and stone mining, peaking in the 1980’s which accumulated in the development of a brick making factory alongside the estuary. Mining operations severely and inevitably affected the natural sediment patterns, hydrodynamics and depth of the system as well as disruption of bottom estuarine habitat. The upper reaches and nearby catchment of the estuary are
bordere by agricultural plantations, predominantly sugar cane and banana, with the likelihood of resultant nutrient enrichment of the system. In addition, a rubble servitude was built across the upper reaches of the estuary to provide access to the farmlands to the south, which constricts freshwater flow into the estuary and limits the extent of the estuarine functional zone. The Palm Beach Waste Water Treatment Works is also located within the food plain, and currently discharges treated waste water into the system, which for the most part is compliant with water quality standards, however potentially constitutes the primary source of nutrient enrichment. Portions of the river banks within the reserve have been transformed into parkland recreational areas. All issues mentioned above contribute to the deterioration of the estuary and are of particular concern given the status of the Mpenjati Estuary as one of the core set of estuaries required to meet the biodiversity targets of the provincial and national conservation planning programmes.

The Mpenjati Estuary has been subjected to extensive sand and stone mining for approximately 40 years. While such operations no longer occur in the system following the eviction of operators from within the boundaries of the Mpenjati Nature Reserve in 2008, an application to conduct sand mining in the upper reaches of the estuary has been lodged with Department of Mineral Resources. The impacts of sandwinning include severe disturbance of the river bed and removal of bottom habitat and associated organisms, water and noise pollution, river bank degradation, invasive alien plant encroachment and poor visual aesthetics. Needless to say, the recommencement of sand mining in the Mpenjati Estuary is in complete opposition to regional estuarine ecologists, local conservancies and the aspirations of Ezemvelo to extend the protected area. Along with other factors, like climate change, the Mpenjati estuary is also impacted by soil erosion, beach degradation, loss of vegetation, damage to infrastructures, sea level rise, flooding and therefore affecting human health, and biodiversity. Needless to say, the recommencement of sand mining in the Mpenjati Estuary is in complete opposition to regional estuarine ecologists, local conservancies and the aspirations of Ezemvelo to extend the protected area.

So a broad rehabilitation management plan for the Mpenjati estuary has been proposed but its implementation faces the high demand for funding (Figure 8).
Management Plan

The threats to the Nushagak estuarine locations emanate from the threats to the Nushagak River. These are caused by commercial development, community development, recreational subdivisions, recreational activities, mining, roads, and global climate change. The effect of these threats are starting to manifest like the results of the commercial and recreational development are already having a noticeable impact implying that serious harm could happen if action is not taken to prevent more serious environmental harm. Mining explorations are occurring and if not controlled will pose serious damage to the environment. Sizable deposits of minerals have been discovered in the Nushagak watershed and could be an attraction for extraction by the mining industry.

We therefore recommend a strong management plan that can prevent the serious environmental harm and maintain the desirable quality of the Nushagak estuary. The anadromous salmon species harvested from Nushagak account for the highest economic and commercial value in Alaska. We do not want that Alaska, particularly its Nushagak estuary, would experience what environmental damages the Mpenjati estuary is presently experiencing. The Mpenjati estuary resources were impacted seriously due to the sand mining that caused severe disturbance of the river bed, removal of bottom habitat, associated organisms, water and noise pollution, river bank degradation, invasive alien plant encroachment and poor visual aesthetics. A moratorium on mining operations has been legislated. Other factors like climate change also affected the Mpenjati estuary by severe erosion beach degradation, loss of vegetation, damage to infrastructures, sea level rise, flooding and therefore also affecting human health, and biodiversity. Because of this, their management plan involves massive repair and rehabilitation of the area with the eviction of mining operators. The main culprit is the mining industry. It’s a serious stage of repair and rehabilitation, costing billions of dollars.

Our management plan is preventive. We propose three major activities for the next ten years and beyond: first, we propose for continuing research activities by experts and second, we also propose intense conservation movements involving all stakeholders by creating a state Task Force, third we propose for a strong representation of the
students in the process to train them to lead, spread and implement relevant activities in their own localities.

On the first plan, the research work shall be focused on water quality studies to determine the level of water quality indicators like temperature, pH, dissolved oxygen (DO), turbidity, biological oxygen demand (BOD), and metallic and non-metallic ions that can be threatening or toxic to the survival of the anadromous salmon, other fish species and organisms already identified thriving in the Nushagak watershed—42.42% anadromous, 12.12% marine/estuarine and 45.45% resident. The location of studies shall be the Nushagak estuary extending upstream for further extensive comparisons. Scientists conduct these studies and competent technicians trained for this type of work from universities, from health agencies like the Health department, the Alaska Department of Fish & Game, Environmental Protection Agency and from the Nushagak Nature Conservancy that was published in November of 2007. The community can also establish linkage with the university. The local school can integrate in the curriculum environmental studies that students can conduct. Training is an important part of this plan. Regular or periodic environmental impact assessment by EPA is also recommended. The involvement of students particularly from high school and college is vital to the continuity of the implementation of the plan. They can be given incentives to further their education while participating in research activities.

The second plan is on intensifying nature conservation movements. We know for a fact that there are already organizations that work on conservation. This idea has been a part of everyone’s awareness, but we propose to make it happen with more intensity by making every community member involved. It requires trained leaders to organize all stakeholders, ie, the community residents, the elders, the fishermen, the businessmen, the government officials, the scientists, the teachers and the students. A Task Force composed of representatives from all sectors of stakeholders shall be formed to identify structures, timelines, persons accountable and functions of identified specific groups. Such Task Force has a vision to hold on—like “Nature Conservation”, “Prevention is Better than Cure”, “No To Pebble Mine”

On the third plan, which is in the local or village scene, the model for Nushagak estuary management plan can be adopted. At Kotlik for instance, we are close to the
Bering Sea. The Kotlik River merging with the Yukon River flows down to the Bering Sea forming the Kotlik estuary. This Kotlik estuary is among the many other relatively smaller estuaries in Alaska that need environmental protection. As students and with mentors, we can participate actively in conducting research studies and conservation movements. Educational and monetary incentives for the students may be considered and would go a long way to advance the cause for environmental protection.

**Conclusion**

Our study has found out that the Nushagak Estuary has the abundant natural resources and topping it all is the five types of salmon. Our finding show that it is the top source for the 5 types of salmon, which are chum, pink, coho, sockeye and ... So far, no serious environmental harm has been identified yet but certain impacts of commercial and community development are beginning to be apparent. The high stakes potential threat is the projected mining operations to happen in Nushagak. Our focus of comparison is what happened in Mpenjati Estuary. The mining operations seriously damaged the valuable resources of the Mpenjati estuary.

In effect, we propose the 10-year and beyond management plan to protect the Nushagak estuary from environmental degradation by continuous research and monitoring activities to determine the water quality parameters and by organizing a strong Task Force legislated by competent authorities of Alaska to map out intense nature conservation movements involving all community stakeholders. Thus, making a model management plan that can be adopted in other estuaries of Alaska.

The data collected by research and monitoring activities shall be the basis to determine the environmental quality of the Nushagak estuary in order to safeguard the journey of the salmon from the freshwater to the saline waters.
Figure 1. Figure 1 shows the river drainages that meets Bristol Bay as well as the surrounding lakes and rivers.

Source: [http://www.aifma.org/about_aifma.html](http://www.aifma.org/about_aifma.html)

Figure 2. Figure 2 shows the Nushagak River Watershed outlined in red.

Source: Alaska Department of Fish and Game
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<td>Prospodium couleri</td>
<td>resident</td>
</tr>
<tr>
<td>round whitefish</td>
<td>uraruq</td>
<td>Prospodium cylindraceum</td>
<td>resident</td>
</tr>
<tr>
<td>coho (silver) salmon</td>
<td>qakiyaq</td>
<td>Oncorhynchus kisutch</td>
<td>anadromous</td>
</tr>
<tr>
<td>Chinook (king) salmon</td>
<td>taryaqvak</td>
<td>Oncorhynchus tsawytscha</td>
<td>anadromous</td>
</tr>
<tr>
<td>sockeye (red) salmon</td>
<td>sayak</td>
<td>Oncorhynchus nerka</td>
<td>anadromous</td>
</tr>
<tr>
<td>chum (dog) salmon</td>
<td>kantimeq</td>
<td>Oncorhynchus keta</td>
<td>anadromous</td>
</tr>
<tr>
<td>pink (humpy) salmon</td>
<td>amaqaayak</td>
<td>Oncorhynchus gorbuscha</td>
<td>anadromous</td>
</tr>
<tr>
<td>Arctic grayling</td>
<td>Culugpauk/Nakrullngpa</td>
<td>Thymallus arcticus</td>
<td>resident</td>
</tr>
<tr>
<td>rainbow trout</td>
<td>talaariq</td>
<td>Oncorhynchus mykiss</td>
<td>resident</td>
</tr>
<tr>
<td>Arctic char</td>
<td>Yugyak</td>
<td>Salvelinus alpinus</td>
<td>resident</td>
</tr>
<tr>
<td>Dolly Varden</td>
<td>Yugyaq</td>
<td>Salvelinus malma</td>
<td>anadromous</td>
</tr>
<tr>
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<td>anerrluaq</td>
<td>Salvelinus namaycush</td>
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</tr>
<tr>
<td>burbot</td>
<td>manignaq/atgiaq</td>
<td>Lota lota</td>
<td>resident</td>
</tr>
<tr>
<td>Pacific cod</td>
<td>Ceturtnaq</td>
<td>Gadus macrocephalus</td>
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</tr>
<tr>
<td>saffron cod</td>
<td>Ceturtnaq</td>
<td>Eleginus gracilis</td>
<td>marine/estuarine</td>
</tr>
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<td>quarruuk</td>
<td>Gasterosteus aculeatus</td>
<td>resident</td>
</tr>
<tr>
<td>ninespine stickleback</td>
<td>quarruuk</td>
<td>Pungitius pungitius</td>
<td>resident</td>
</tr>
<tr>
<td>coastrange sculpin</td>
<td>kayutak</td>
<td>Cottus aleuticus</td>
<td>resident</td>
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<tr>
<td>slimy sculpin</td>
<td>kayutak</td>
<td>Cottus cognatus</td>
<td>resident</td>
</tr>
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<td>naternaq/uraluq</td>
<td>Pleuronectes glacialis</td>
<td>marine/estuarine</td>
</tr>
<tr>
<td>starry flounder</td>
<td>naternaq/uraluq</td>
<td>Platichthys stellatus</td>
<td>marine/estuarine</td>
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</table>

**Figure 3.** Figure 3 shows all fish species known to be disturbed within the Nushagak River drainage study area. *Source:* Nushagak-Mulchatna Watershed Council (November, 2007)
**Figure 4.** Figure 4 shows a graph which shows the number of sockeye salmon harvested from the Nushagak Fishing District (oval on map) from 2006 to 2008. Colors correspond to colors on map. *Source:* http://www.adfg.alaska.gov/index.cfm?adfg=fishinggeneconservationlab.generalinfo_bristolbay

**Figure 5.** Figure 5 shows the a calico pattern, with the front two-thirds of the flank marked by a bold, jagged, reddish line and the posterior third by a jagged black line of the spawning chum salmon, in comparison of the young adult chum salmon which has a silver appearance, with not yet developed of the crooked jaw of a spawner.

**Figure 6.** Figure 6 shows a picture of a pink salmon, also known as “humpy”.
Figure 7. Figure 5 shows the area of the proposed mine, as well as the endangered river, that drains out to its estuary, the Nushagak estuary, as well as surrounding waterways.

Figure 8. Figure 6 shows the Mpenjati Estuary (NS7). A typical Natal South Coast temporary open/closed estuary. The estuary is within a protected area and links to the Trafalgar Marine Reserve. One of the few places where the land, an estuary and the adjacent marine environment are all conserved.

Source: (http://www.nmmu.ac.za/cerm/RTaylor/Bpenjati.jpg)
References Cited


