FALLOUT OF FUKUSHIMA:
A Monitoring Program to Preserve the Gulf of Alaska's Economy

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Cover image "Tiny Hatchetfish" courtesy of Ken Kostel, Woods Hole Oceanographic Institute

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Abstract

The 2011 earthquake and resulting tsunami at the Fukushima Daiichi power plant in Japan have created many environmental problems in the Pacific Ocean. Contaminated ocean plumes and marine organisms along with radioactive debris will eventually reach the Gulf of Alaska. Our program focuses on monitoring Alaskan waters for evidence of these factors to ensure the stability of the economy of the Gulf of Alaska.

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Introduction

The Gulf of Alaska (GOA) is crucial to the Alaskan fishing, tourism, and shipping industries which are cornerstones of the Alaskan economy. Currently, the GOA is a healthy and productive ecosystem which provides invaluable cultural and commercial resources; these resources are derived from a number of aquatic fauna that spend the majority of their lifespan in the GOA region. Knowledge of this ecosystem, before the advent of any negative ecological and economical impacts as a result of the Fukushima Daiichi disaster, is essential baseline information. This knowledge can be used to formulate a monitoring system to address radiation and debris from the power plant disaster as they cross the Pacific Ocean and reach the coast of Alaska. The goal of our research team is to develop a monitoring plan that identifies the effects of the debris and radioactivity on the environment and economy. A key piece to the proposed plan is the recognition that the GOA is a thriving ecosystem. The shipping, fishing, and tourist industries can provide indicators of the potential impacts from the Fukushima Daiichi disaster on the ecological and economic health of the state of Alaska.

Background

Location

On March 11, 2011, a 9.0 magnitude earthquake occurred off the east coast of Honshu, Japan, creating a large tsunami that devastated the Fukushima Daiichi nuclear power plant which is located 200 meters from the coast [Figure 1]. Japan is located on the edge of a subduction zone known as the Pacific-Philippine-Eurasian triple plate junction, an extremely unstable part of the earth’s crust. The earthquake and tsunami led to millions of tons of radioactive water being washed into the Northern Pacific Ocean. Just over two years after the disaster, the outer edge of the radioactive plume has reached the coast of California and is projected to reach the GOA around 2016 (Maximenko, 2011).

Radioactive Contamination

Shortly after the disaster, the seawater nearby the plant was reported to be contaminated with radioactive iodine-131 at levels approximately 15 million times the legal limit. In addition, the water contained 1.1 million times the legal limit of radioactive cesium-137 (Grossoman, 2011). While these levels have continued to fall as the radioactive debris is carried away from the site by the Kuroshio current, the government estimates that 300 tons (272,152 liters) of contaminated water continues to pour into the ocean by day (Kiger, 2013). “According to Russia's ITAR-TASS news agency, the safe level of radiation is 1-13 millisieverts per year; at Fukushima, however, the level of radiation is estimated at 100 millisieverts per *hour*” (Smith, 2013).

Radioactive cesium is a byproduct of nuclear fission in nuclear power plants. The half life for Cs-137 is 30 years and it decays with both beta particles and gamma rays to barium-137 (Bentor, 2013),while cesium-134 has a half life of 2.1 years (Environmental Protection Agency, 2013). When the radioactive isotope gets into the environment, it is very difficult to clean up. If ingested into the body it puts the person at greater risk for cancer. A study of sea life in the Atlantic Ocean found that when zooplankton and other microorganisms intake radionuclides, it can result in biomagnification through the food chain (Grossoman, 2011).

Studies have already shown that levels of radiation continue to remain high in bottom-dwelling fish near Fukushima. In January 2013, one of the most contaminated fish was caught in the port near the Daiichi power plant. Predictions of the effects of this cesium on organisms in the area will vary depending on the cesium discharged both from the plant and the interaction of the isotope with the ocean and the sea floor in the future. Buesseler found that the 'vast majority' of fish being caught off Fukushima and surrounding areas had radiation levels below the safe-consumption limit. However, forty percent of the bottom-dwelling species came in over that limit, which may be attributed that the levels of radiation in the ocean did not decline in the year following the accident. (Buesseler, 2012).

Radioactive Plume

Since the disaster in 2011, numerous scientists have developed computer modeling programs to predict the radioactive concentration levels and their projected marine pathways. As soon as the radioactive plume and debris entered the water from the disaster, it was picked up by the Kuroshio current off the coast of Japan and moved out into the Pacific Ocean. While this is beneficial, because it lowers the concentration, the power plant continues to leach tons of radioactive water into the ocean each day. The majority of this plume will continue to travel up the Kuroshio current and will be fed to the North Pacific current. Researchers believe the North Pacific current will continue to dilute and carry the plume the rest of the way across the Pacific Ocean as it travels eastward until it reaches the coast of California between 2013 and 2014. Some of the debris will stay in the northbound part of the North Pacific current and will head north, towards Alaska where the Alaska Current will pick it up and bring it into the GOA, reaching it around 2016. The rest of the plume will continue south down the California coast until it reaches the North Equatorial current which will take the plume westward across Hawaii and back towards Japan (Maximenko, 2011) [Figures 2 and 3].

Comparison

Located on the Northwest coast of England, the Sellafield Nuclear Plant has been experiencing very similar problems with radioactive waste as the Fukushima Daiichi power plant. This government facility, which has been dispensing radioactive waste into the Irish Sea since 1952, has contributed to the Irish Sea becoming one of the most radioactive bodies of water in the world. Sellafield also provides energy for one fourth of England, rendering it a vital facility (American University, 2013). Overall, there are eleven silos of radioactive nuclear waste in the Irish Sea, which is equivalent to 88 times more than what was discharged from Chernobyl in 1986. Two million gallons of radioactive waste are released every day during high tide. The current types of radionuclides being dispensed by the plant are cesium -137 and iodine-129, which are flowing into the Arctic Ocean and disrupting those ecosystems. As a result of the radiation in the Irish Sea, the aquatic flora and fauna have been hugely affected- various sea plants, fish, shellfish, and mollusks contain significant levels of radiation. The fishing industry in the Irish Sea has also been impacted by the abnormally high levels of radiation. For instance, many fishermen are catching fish that have severe mutations, which is hampering their fishing businesses (Cumbrians against a Radioactive Environment, 2013).

GOA Economy

A large part of the Alaskan economy is based on the commercial activities in the GOA. Stretching into the Pacific Ocean, the Alaska Peninsula and surrounding waters are home to approximately 50 fisheries, which create jobs throughout Alaska. In 2011, 5.35 billion pounds of fish and shellfish were harvested in Alaska waters. In 2009, 1.6 billion dollars worth of seafood was exported directly to Japan, China, South Korea, Canada and Europe. These exports will inevitably increase due to the shutdown of many Japanese fisheries. A total estimated ex-vessel value of Alaska's commercial harvest was 1.3 billion dollars. It is estimated that the seafood industry's 3.3 billion dollars in wholesale value generated an additional 1.3 billion dollars in direct and implied economic output, for a total contribution of 4.6 billion dollars and 80,800 jobs (Resource Development Council, 2013) [Table 1].

Tourism is the second-largest private employer in Alaska, and accounts for one in eight Alaskan jobs. The most recent data indicates that the tourism industry produces over 36,000 direct and indirect jobs, 8% of Alaska employment, and $1.1 billion in labor income (Resource Development Council, 2013).

Shipping is a vital part of Alaska's lumber industry, for example, in 2012, 151 million dollars worth of lumber was exported (United States Census Bureau, 2012). Since the tsunami, scientists at the International Pacific Research center have been trying to track the debris that threatens small ships and coastlines. Multiple computer models, based on currents and prior knowledge of debris movement, have been developed to predict the path the debris and radioactivity would take after the disaster. In fact, effective sightings of debris were reported by a Russian sail training ship, the STS Pallada, near the Midway Islands, precisely where the model predicted [Figure 4]. Debris found in major shipping lanes in the GOA may be detrimental to the industries' ability to maximize their profits because increased encounters will damage the hulls and/or propellers and increase transportation costs.

As seen in the Irish Sea, the effects of radiation can be detrimental to the fauna occupying the contaminated water. Because the Alaskan economy relies so heavily on the fishing, shipping, and tourism industries rooted in the GOA, deleterious effects from radiation on the ecosystem could greatly impact the Alaskan economy.

Monitoring Plan

Introduction

The goal of our research is to develop a monitoring plan to track the radioactive signatures released by the Fukushima Daiichi disaster as radionuclides and debris move into the GOA. The first step to this plan is to focus on the fishing, tourism, and shipping industries in the GOA and what these industries deem to be invaluable to their success. By identifying these cornerstones of their business operations, our management team will create a plan that targets the aspects of the ecosystem that ensure their success. Once we have identified these critical components, we can try to manage them in such a way that maintains their maximum productivity. In addition, we will develop a system to minimize any detrimental impacts which may result from the Fukushima Daiichi radioactive contaminants as they enter the GOA. While overall health of the ecosystem is important, targeting the parts that are key to the GOA economy will help us achieve our goal.

To monitor and mitigate the effects of any radiation and debris on the GOA ecosystem and economy, we must establish the sampling areas and/or information that we will utilize to make decisions about the system. The GOA is a vast region that contains a variety of habitats and economically viable resources. To monitor the entire region is implausible and not cost-effective. We propose the sport fishing, cruise ship, and sightseeing charters found in the Inside Passage in Southeast AK and Prince William Sound would represent the tourism industry. The commercial fishing fleet out of Kodiak Island will represent the fishing industry throughout the GOA, and the major cargo companies that transit through the GOA will represent the shipping industry.

Commercial Industries

Our monitoring system will utilize the abundance of information already collected by the individual industries and will couple this with ecosystem data that we plan to collect. To monitor the effects of radiation on the ecosystem and economy, a sampling plan must be initiated. In the fishing industry, one of the keystone species to the industry's success is salmon. In the state of Alaska, salmon are managed under the maximum sustainable yield principal, which means the fishing industries will harvest the maximum number of salmon available while ensuring future harvests. In order for this balance to be conserved, the health of the ecosystem must be maintained at its current level. As radioactive signatures begin to appear in zooplankton, the direct effect of biomagnification may begin to detrimentally impact the life cycle of salmon, eventually resulting in depletion in the quantities available to the fishing industry. The indirect effect will result in an imbalance within the ecosystem which will eventually impact all the economically viable resources. To monitor these gradually increasing levels of radiation throughout the ecosystem, a GOA zooplankton monitoring system will be established to track the entry of radiation into the system and determine whether or not the level observed may have long term effects on the ecosystem and industries that rely on them. In addition, we will collect data from local fishermen to address various aspects of the ecosystem's overall health. In addition, we will track harvest records.

In the coastal tourism industries, not only does the physical landscape of Alaska attract many visitors, but the fish and wildlife also play an important role. As radiation from the Fukushima Daiichi disaster begins to impact the ecosystem, a decrease in the abundance of wildlife and fish may occur which will indirectly affect the viability of the tourism industry. Information, such as passenger and sport fishermen numbers, successful fish landings/wildlife sightings, and the quality of their experiences, can be used as an indication of the ecosystem's health. For example, there is a direct link to the number of successful fish landings on sport fish charters to the abundance of feeder fish utilized by the targeted sport fish species (rockfish, halibut and salmon) (Savereide, 2013). These feeder fish, as well as the targeted species, rely on plankton and zooplankton as part of their life cycle.

The effects on the shipping industry are more direct. As larger debris from the disaster reaches the western part of the Pacific Ocean, the shipping industry is going to be negatively impacted because collision with debris, such as refrigerators, can seriously damage the hulls and/or propellers of commercial vessels. The shipping industry relies on large quantities of cargo and specific timelines to maximize their productivity and, subsequently, their profits. Shipping companies plan for maintenance and repair along their route, but the Fukushima Daiichi disaster has increased the amount of debris they would normally encounter. Collisions with debris typically cause a delay in shipment which leads to a domino effect within their system eventually resulting in a loss of profit.

Mitigation

Now that our team has found a way to monitor radiation levels in aquatic fauna as well as the physical debris in shipping paths, our management team has proposed a few possible solutions to minimize the negative effects that these contaminants may have on the ecosystem and economy. Although this is not part of our current action plan, it could be initiated in the future based on our data findings. To limit the impact on the shipping industry, we propose a system of small pilot boats to guide large shipping vessels through areas with large amounts of debris. These boats will pilot in front of the shipping vessel to safely guide it and, as needed, remove obstructive debris. Another proposed solution is to use a system of tow nets to collect and remove debris as it enters critical Alaskan shipping areas.

To counteract the effect radiation will have on the fauna in the GOA, we propose the use of salmon hatcheries and farms. By hatching the salmon fry in a reduced-radiation environment, it would remove the risk of deformities and death. From there the fish would be raised on a farm and fed radiation-free zooplankton to limit their exposure to radiation as they go through the critical stages of their growth. Once the fish grow larger and their diet no longer consists of only zooplankton, they will be released into their natural environment. Our hope is that because these fish will have had limited exposure to radiation in the beginning of their life, they will be more successful at reproducing. In addition, we hope that predatory animals, such as sea otters, will consume some of these lesser contaminated fish. This plan is not meant to replace wild salmon, but will hopefully help sustain the ecosystem until the radiation and its effects begin to disappear, and this plan will no longer be needed.

Budget

We propose a 10-year budget (2014-2024) to monitor the economically important waters of the GOA. This timeframe allows us to gather vital baseline information, develop a monitoring program, and design an action plan. The baseline studies will provide us with information about the current ecosystem and the industries, before radiation and debris enters the GOA. We will develop a monitoring program to evaluate the effects of radiation and debris while it is in the GOA system. Finally, if our data analysis shows the ecosystem is being adversely affected by the radiation and debris, we can design an action plan to possibly mitigate the negative effects on the ecosystem and the industries that rely on that environment. As we stated earlier, we will focus on three industries-shipping, tourism, and fishing-as well as radiation concentration in salmon and zooplankton. These areas will serve as indicators of the GOA's overall ecosystem and economic health.

Information about numbers of passengers, fishery harvests, quality of experience, number of collisions, days lost to repair, etc. are already collected by these industries and a number of other agencies throughout the state. However, to process this amount of information a team of two database managers will have to establish a GOA Radiation and Debris database that allows researchers to access the data needed to predict forecasts of the economic health of the industries being tracked.

Information from the zooplankton monitoring program will be collected at a number of strategically located sites throughout the GOA. Three 4-person crews, based out of Juneau, Kodiak, and Valdez, will visit a series of sites within each area three times a year to perform a series of zooplankton and salmon sampling surveys. The analysis of our data collected from these surveys should provide the information required to determine the impact that the radiation and debris may have on the GOA ecosystem and economy [Table 2].

The total cost for our 10-year monitoring plan is approximately 6 million dollars. This includes two full-time data managers, three 4-person sampling crews and their travel and lodging, surveying equipment, contracts with research vessels, and lab processing costs. The contracts with each research vessel will cover the cost of housing our technicians while they are conducting sampling activities. It is expected that the State of Alaska would be petitioned to supply the funds to implement our plan.

Conclusion

There are many environmental issues associated with the Fukushima Daiichi disaster. Our research team has created a monitoring program that will monitor ocean debris and radionuclide contamination in the marine life in the GOA. As lower trophic level organisms, such as zooplankton, become more contaminated, the potential damage to the GOA ecosystem increases. Fishing, tourism and shipping are crucial to the GOA, and provide cultural and commercial resources which come from the ecosystems in the ocean. It is crucial that information on the health of the GOA ecosystem is evaluated before the arrival of large amounts of radioactive material such as that resulting from the Fukushima Daiichi disaster. Evaluating this information will aid our management team in making decisions about how to mitigate the effects in ecosystems throughout the GOA.

Table 1: Average harvest, value, and permits fished for selected Alaska commercial salmon fisheries. Averages are for the period 1998-2002 (Woodby *et al*, 2005).

fishery	Harvest(fish)	Harvest(lbs)	Value[a]	Permits
Southeast and Yakuthe	72,052,177	315,357,810	$76,410,018	1,913
Prince William Sound	39,569,777	159,065,417	$44,920,066	694
Cook inlet	4,240,511	21,288,695	$13,001,875	1,052
Kodiak	20,728,977	83,820,140	$25,844,123	357
Chignik	2,788,447	16,222,507	$11,493,042	82
Alaska Pen. and Aleutians	9,816,129	45,005,559	$19,954,582	342
Bristol Bay	16,887,715	100,972,174	$64,988,392	2,511
Kuskokwim	394,342	3,052,759	$947,096	572
Yukon River	62,801	886,262	$2,159,909	617
Norton Sound	183,110	594,933	$155,752	59
Kotzebue	114,920	970,335	$546,511	48
Statewide	166,838,906	747,286,592	$260,421,366	6,334

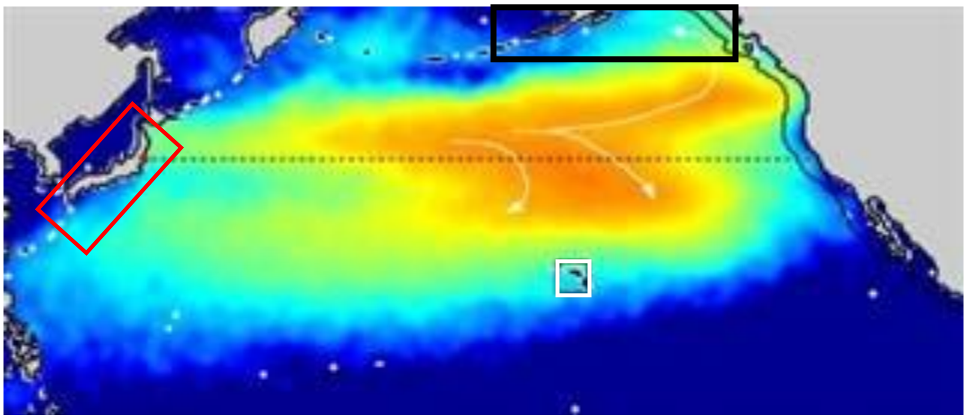
[a] Ex-vessel value of landed catch [b]No Yukon Fishery in 2001

<u>Table 2:</u> Our management team's estimated budget for the GOA ecosystem monitoring program.

	Quantity	Cost	Time Frame	Totals
Data Manager	2 personnel	$75,000/year	10 years	$1,500,000
Technicians	4 personnel in 3 locations	$5,000/month/ personnel	10 years	$1,800,000
Travel	4 technicians to Kodiak	$15,000	10 years	$150,000
	4 technicians to Juneau	$10,000	10 years	$100,000
	4 technicians to Valdez	$10,000	10 years	$100,000
Equipment	50 Geiger counters	$500/counter	10 years	$250,000
	plankton nets	$400/net, 6 nets biennially	5 years total	$15,000
	lodging for 12 personnel at 2 days/month	12 rooms at $200 per month	3 months for 10 years	$72,000
Contractual	5 boats for salmon and debris	$5,000/boat	10 years	$250,000
	45 boats for debris	$500/boat	10 years	$225,000
	1 boat per region at 3 regions for sampling	$25,000/boat	10 years	$750,000
	lab processing costs	$75,000	10 years	$750,000
Grand Total				**$5,962,000**

Figure 1: Map of Japan denoting the location of Fukushima Daiichi nuclear power plant (Google Maps, 2013).

Figure 2: Projected movement of the radiation plume from the Fukushima Daiichi disaster (Hsu, 2013). The red box surrounds Japan, the black box surrounds the GOA, and the white box surrounds Hawai'i.



Key:

Dark orange = highest concentration of radioactive contamination and debris

Light blue = lower concentration of radioactive contamination and debris

Figure 3: The major currents of the Pacific Ocean (NOAA, 2013).

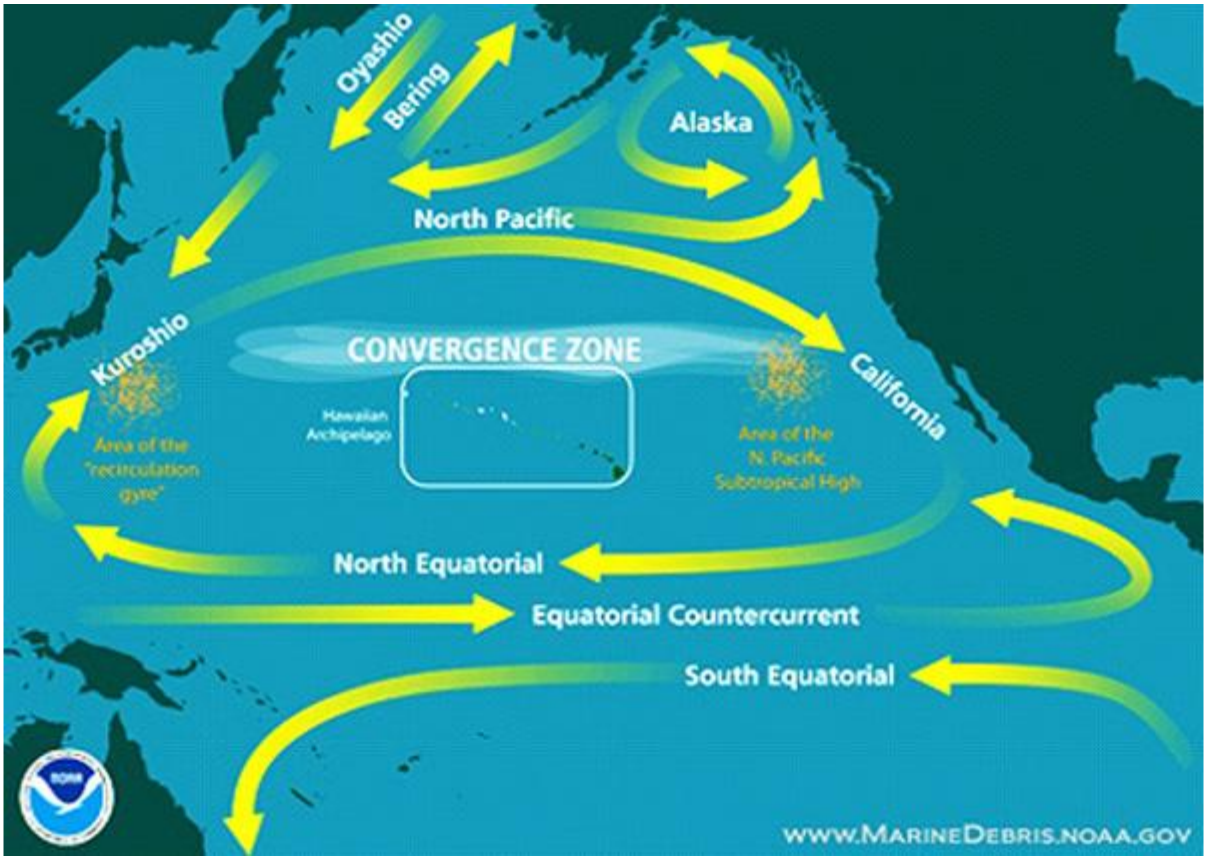
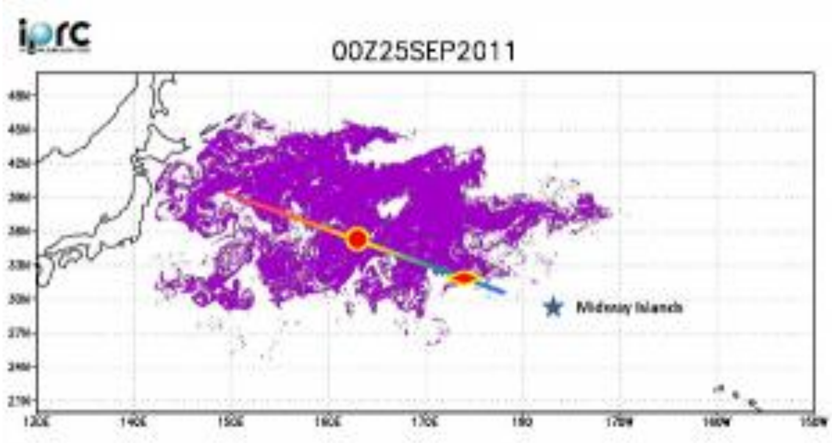


Figure 4: Location near Midway Islands where a Russian training vessel encountered debris from the disaster (University of Hawai'i, 2011).



Key:

Purple = computer projected model of radioactive contaminants and debris on September 25, 2011

Red circle = maximum debris density experienced

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