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The Mark of the Japanese Murrelet (Synthliboramphus wumizusume): A study of song and stewardship in Japan's Inland Sea

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I. The Sea of Miracles

For humans, the Japanese Crested Murrelet, *Synthliboramphus wumizusume*, is not a source of food. It holds no commercial value, nor is it economically significant. The murrelet does not compete with humans for nutritional resources, and it is not considered a pest. However, in the region of Kaminoseki in the Yamaguchi Prefecture of Japan, the lives of hundreds of people are hinged around the existence of this small seabird. This species of murrelet, which is known both as the Crested Murrelet in Korea and the Japanese Murrelet in Japan, lives within a highly restricted range, and is known to breed only on the islands surrounded by the warm, shallow waters of southern coastal Korea and Japan (Carter *et al*. 2002). Crested Murrelets face a variety of threats to their continued survival and is therefore listed as a Vulnerable Species by the International Union for Conservation of Nature (IUCN). Introduced predators such as the rats, cats, crows, and dogs that have colonized the rocky islands where they nest are major threats to murrelet populations (Otsuki & Nakamura 2016, Karnovsky *et al*. 2017). In addition to predation, development of and human interference in murrelet habitats has led to a dramatic decrease in population. In fact, population estimates posit that 8,000 individuals are alive today (Carter *et al*. 2002). The combined rarity and charisma of these seabirds has sparked notable attention in the international scientific community, and in 2017 scientists held a symposium designed to create a standardized protocol for monitoring murrelet populations (Otsuki *et al*. 2017).

One population of Japanese Murrelets lies above the rest as a subject of interest. The murrelet population in the Kaminoseki region sits at the center of a fierce battle between corporations, scientists, and communities. This conflict, which spans thirty-six years and concerns not only the struggle between corporations and conservationists but the polarizing

phenomenon of nuclear power in post-war Japan, is an incredible case study in the influence of local environmental stewardship, citizen science, and activism.

While the global population of *S. wumizusume* is estimated to be less than 8,000 individuals and Kaminoseki's colony of murrelets is much smaller, the role that these birds play in the future of Kaminoseki is immense (Carter *et al*. 2002). The potential impact of the conservation of Kaminoseki's Crested Murrelets ranges beyond the preservation of the ecology of the area and extends to the structure, economy, and way of life of Kaminoseki's communities and of the individuals whose families have lived off of the natural resources provided by the region for centuries.

Figure 1: Iwashima Island as seen from Tanoura Bay, Nagashima Island, Kaminoseki. Image credit: BrackWorry.

The natural landscape of the inland sea region surrounding Kaminoseki is a visually striking scene. Swedish botanist Carl Peter Thunberg noted in 1776 that the "mountains in several places resembled beautiful gardens" (Dusinberre 2012). Robert Fortune, another botanist visiting in 1860, described the area as a "beautiful landlocked harbor…two small towns were observed, pleasantly situated on the banks of the lake...hills filled the background, well-wooded in some parts, and terraced in others all the way up to their summits, showing that here the soil was fertile and productive" (Dusinberre 2012). The inhabitants of Kaminoseki and its surrounding communities have used the plentiful resources of both the land and sea to sustain their families throughout many generations. Tanoura Bay, an area of Nagashima Island just off the coast of Kaminoseki, is one of the more majestic views within the already impressive landscape (Figure 1). The cove is hugged on either side by lush, verdant hills and stands in stark contrast to austere rock formations that jut out of the surrounding Seto Inland Sea. The beach at Tanoura Bay holds relics of a past age—it is littered with arrowheads and pottery shards from civilizations over twenty centuries old, and the pathways carved through the area are lined with Satomaya forest, orchids, and endangered plants (Ankei 2003).

This idyllic spot, however, is the proposed construction site for a 275 megawatt nuclear power station. Since the proposal of this site by Chugoku Electric Power Company (CEPCO) in 1982, the residents of Kaminoseki, including those on Nagashima and neighboring island Iwashima, have engaged in relentless protest against the degradation of their land to both CEPCO and the Japanese Government (Figure 2). This struggle has persisted for almost four decades and has not yet reached a resolution; the construction plans are held in a deadlock as both sides fight for their interest. The role that Japanese murrelets play in this high-stakes situation is a product of the unique ecology and history of the region, and in order to conduct a

thorough analysis of the region and the participants involved in this conflict, I will examine both facets.

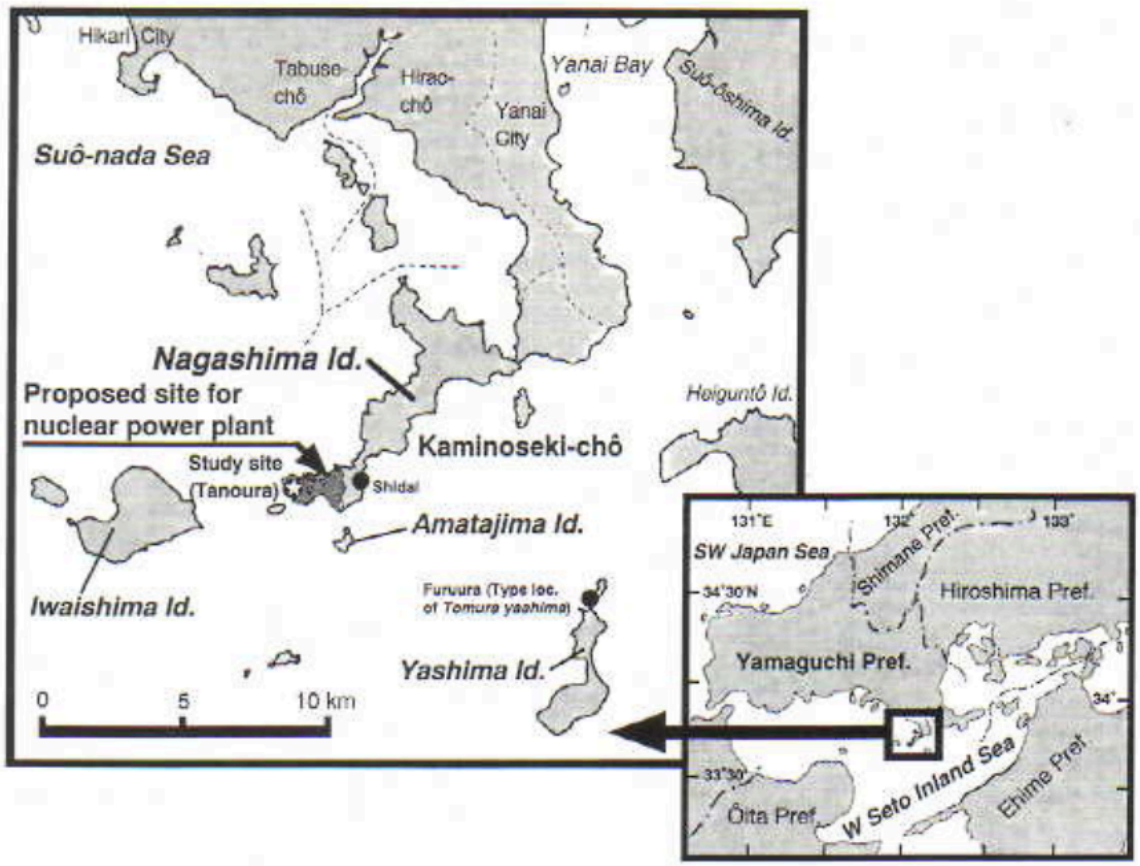

Figure 2: Region of the Suo-nada Sea including Kaminoseki, Nagashima, and Iwashima (Ankei & Fukada 2003)

The Seto Inland Sea is a body of water that separates three of the four main islands that make up Japan. Spanning 450 km from east to west and ranging from fifteen to 55km from north to south, the inland sea is the largest inland body of water within the Japanese archipelago (Ankei & Fukada 2003). In the past seventy years, the Inland Sea has experienced significant environmental degradation as a consequence of Japan's rapid shift towards industrialization. Since World War II, the Japanese economy has exploded as the nation has shifted to a more

industrial and manufacturing-based economic system as opposed to the agricultural system that dominated prior. However, the rise of this economy has resulted in the normalization of manufacturing processes that have severely degraded the health and quality of Japan's natural environments, including its bodies of water (Irizuki *et al*. 2018). Landfilling, dredging, and rampant pollution have inflicted considerable damage on the Seto Inland Sea; in fact, only 21.4% of the sea's natural shoreline remains untouched today (Ankei 2003).

Despite the environmental damage inflicted by the development and industrialization of post-WWII Japan, a small portion of the Seto Inland Sea continues to boast unique ecological features that have remained almost untouched by anthropogenic interference. The Suou-nada Inland Sea, which lies in the western portion of the greater Inland Sea, stands remarkably ecologically intact. In contrast to the Inland Sea as a whole, 75% of the shoreline along the Suou-nada region has not been interfered with by industrialization (Ankei 2003). In fact, this region possesses such impressive ecological biodiversity that it has been deemed a biodiversity hotspot by the many scientists studying the area. It is the only hotspot left in the Seto Sea, and therefore has the most species diversity of any shallow marine system in the entirety of Japan (Ankei 2003).

The Suou-nada region of the Seto Sea is a sanctuary for a wide variety of vulnerable faunal diversity. It is so biologically rich that it has been colloquially termed the "Sea of Miracles." The area, which experiences rapid seawater exchange from the warm Kuroshio ocean current, provides 9,500km^2 of intact habitat for a diverse assemblage of life that is unable to thrive elsewhere in the waters of Japan (Ankei & Fukada 2003). Finless porpoises, *Neophocaena asiaeorientalis*, are the smallest whales in the world. These porpoises have found a refuge in these warm waters despite declining populations elsewhere. Because of habitat destruction,

pollution, collisions with ships, and entanglement in nets, populations of finless porpoises plummeted drastically from 1976 to 1999. The crisis reached a crescendo at the end of the 20th century when only 750 individuals were counted, representing a dire 85% decrease in population size (Ankei & Fukada 2003). In the Suou-nada sea, however, there is evidence of modest increase in population size in the past decade. Because this is the only area where the population of porpoises is not decreasing, it is vital that this region remains unscathed from human impact. While the finless porpoise is an example of a charismatic species present in the Suou-nada sea, there are many other species of conservation concern present in the sea. The brachiopod *Discinica sperselineata* that lives in the Suou-nada sea is found nowhere else in the world except in the rocky intertidal zones of New Zealand (Ankei & Fukada 2003). The species *D. spereslineata* is known as a "phantom species", as it is a relic of the Cambrian era and provides insight into the makeup of the pre-human living environment of the region.

Additionally, the chordate *Branchiostoma belcheri* which is found in abundance in the Suou-nada region is near extinction in other parts of the inland sea. The Suou-nada area is also a habitat for an unusually rich grouping of mollusks, housing 183 species. The recent discovery of one of these species, *Tomura yashima*, is particularly significant to the scientific community because it provided a missing link in mollusk phylogeny (Ankei & Fukada 2003). Additionally, the gastropod *Ceratia nagashima*, is endemic to Tanoura Bay. (Karnovsky 2017).

The magnitude of biodiversity in this region has only become more pronounced as the plans to build a nuclear power plant in Tanoura Bay come closer to actualization. In a world facing a period of mass extinction due to climate change and other forms of anthropogenic influence, the areas that provide asylum for endangered species are increasingly few and

precious. It is of the utmost importance to protect these areas in order to ensure the best chance of survival for these vulnerable species.

II. Kaminoseki and Nuclear Power

In the years after World War II, Japan embarked upon an intensive conversion to an industrial economy; these changes were not only felt in large cities but in rural areas as well. Kaminoseki, however, is an exception to this overall trend. By 1998 the town did not have any major industries, and the island portions of the city remained deeply rural and isolated from the massive changes occurring in greater Japan. In fact, on the island of Iwashima, islanders tend to favor bartering to meet their needs rather than participating in a cash economy. According to Yuji Ankei, a faculty member at Yamaguchi Prefectural University who has extensively studied the Kaminoseki conflict with an emphasis on the efforts of Iwashima islanders, posits that islanders prefer to "exchange goods and services on the basis of gifts and general reciprocity, so that differences in their cash income do not become obstacles for egalitarian human relationships on the island" (Ankei 2012). As such, the economically isolated residents of Iwashima and Kaminoseki live off the resources provided by the land and sea, and most are subsistence farmers or fishermen.

At first glance, the island of Iwashima hardly seems like a bustling town. Many houses are empty, and rice paddies and vegetable fields are overgrown. Especially evident is the lack of children in the area. Indeed, there are such a distinct dearth of youths in the town that all of the elementary schools are closed. This issue is not unique to Iwashima—many villages in rural Japan are facing population decline as young people move to cities and older people continue to age and eventually die. Nonetheless, the magnitude of this phenomenon is striking in Iwashima

and in Kaminoseki as a whole. In the past thirty years, the population has decreased by a full 50 percent, from 6,773 in 1980 to 3,332 in 2010 (Yamaguchi 2011). Furthermore, the percentage of elderly in Iwashima is 46.4% and with an average age of 74 years, the population is the oldest in Yamaguchi Prefecture and one of the oldest in the entirety of Japan (Yamaguchi 2011).

The distinct demography of Kaminoseki is not the only notable characteristic of this small town. As readily apparent in the town as the advanced age of the majority of the population is the relationship between Kaminoseki and CEPCO, the nuclear power company proposing the construction of the reactor. As soon as one enters the town, they are greeted with signs advertising the presence of a nuclear power. One sign featured prominently on the island of Nagashima portrays two young parents and their child enjoying a picnic near a bay. Behind them, a path winding through a quaint village dotted with trees reaches its destination at a stately

Figure 3: (Dusinberre 2012): “Together with nuclear power, a lively town”, Nagashima Island.

power plant that looms tall on the horizon. Beneath the happy family, the sign reads: "Together with nuclear power, a lively town" (Figure 3).

Various similar signs pepper the streets of the town, all peddling the same message and general theme. One reads: "Bright and rich *furusato* making through a nuclear power station: bringing vitality to young people and comfort to the elderly," while another decrees "Through nuclear power, a *furusato* where young people gather and we have heart-to-heart communication" (Dusinberre 2012). *Furusato* in this context means hometown, and its use is emblematic of the discourse that CEPCO is attempting to communicate through these signs. One of the main arguments touted by proponents of the construction of the plant is that the reactors will enliven the town and create a strengthened sense of community for all residents. This rhetoric describes nuclear power as a tool to promote the idealized conception of a Japanese hometown.

CEPCO is highly aware of the disparity between the elderly population of Kaminoseki and the younger population who has left the area in order to join the industrialized society that is now so prevalent in Japan. The company profits from this disconnect by promising that the construction of the plant will provide incentive for young Kaminoseki emigrants to return to their home and connect with their elders and their natural landscape once more. The language in these signs, including "bright," "rich," and lively," conveys an image of vibrancy and vivacity that contrasts the subdued mood that permeates Kaminoseki. This divergence is also apparent in the visual component of the signs—the highly colored illustrations are oddly juxtaposed against the bleak backdrop of Kaminoseki's abandoned buildings. The signs present a stark example of the incongruence between the fantastical promises of the perks of nuclear power and the reality of Kaminoseki. There are also clear signs of a struggle in the town—the anti-nuclear posters and

fliers posted in the public spaces of Kaminoseki are evidence of systematic protest against CEPCO's plan.

However, CEPCO's attempts to associate nuclear power with a revitalized, bustling, ideal Japanese hometown is not limited to aesthetics and visual propaganda. For the past thirty years, the company has funded community projects that play into an idealized version of Kaminoseki; one significant example of this is the construction of a town bath. Daily baths are an integral component of Japanese daily life, and they are an ideal setting for community interactions and interpersonal relationships to develop. Thus, CEPCO is successfully embedding itself into the core activities and values of daily life in Kaminoseki. These attempts to convince residents that building the nuclear reactor is in their best interests are relatively transparent. Even more so is the fact that the Kaminoseki government has received 4.5 billion yen (~$40,000,000) from the central government and 2.4 billion yen (~$20,000,000) in "gifts" from CEPCO to support construction (Ankei 2012). Simply put, the financial boost is a blatant attempt to from both CEPCO and the government to put pressure on the Kaminoseki government and its residents to support construction efforts.

CEPCO has had a long time for its tumultuous relationship with Kaminoseki to develop. The power plant was first proposed by the nuclear company in October of 1982. The initial proposal yielded mixed opinions from different factions of Kaminoseki. Iwashima islanders, whose home is a mere 3.5 km from the proposed site at Tanoura, were strongly opposed, with only 10% of the island's 500 residents favoring construction. The opinion in the mainland town was less unanimous, but a strong faction of residents vehemently opposed the proposal. In 2000, a poll was conducted in the Kaminoseki mainland which determined that 47% of residents opposed construction and 33% favored it. The issue has remained a deeply polarizing one over

the years, and has divided families, friends, and other social groupings. Interestingly, the government of Kaminoseki has offered strong support for the project since its very first proposal. Mayor Katamaya, the government leader of Kaminoseki in 1982, initially offered a warm welcome to CEPCO and the implications of their arrival to Kaminoseki. Katayama's precedent has been steadily followed by his successors, as all subsequent mayors have expressed their support for the project (Ankei 2012). The turbulent opening of this conflict has only become more layered as time has passed and various factions have created obstructions to halt the plant's development.

III. Activism and Environmental Stewardship in the Kaminoseki Region

Since the very beginning, Kaminoseki and particularly Iwashima residents have thrown themselves into protesting the plant; in fact, their very lives have become intertwined with this effort. For the past thirty-six years, Iwashima islanders have conducted weekly anti-nuclear protests, which adds up to more than a thousand protests (Tabuchi 2011). Some particularly impassioned fishermen engage in daily protests from their fishing vessels and have endured personal taunts from CEPCO. Representatives from the company have responded to the protesting fishermen by saying that they will not be able to survive with fishing as their primary industry. This claim is incorrect, as Iwashima islanders have been doing so for as long as they have inhabited the island. Thus, the motive for their passionate defense of their island is as personal—rooted in the need protect their sense of identity and livelihood—as it is in protecting the environment (Tabuchi 2011).

One of the original Iwashima protesters is Mr. Ichio Isobe, an older fisherman, who has numerous connections to nuclear power. Mr. Isobe was one of 12 Iwashima islanders who

worked at the Fukushima Daiichi power plant in 1975 (Ankei 2012). While he was there, he witnessed contaminated water and wood being released into the surrounding environment. Of the dozen Iwashima residents employed at Fukishima, seven developed cancer and died (Ankei 2012). While the events of Mr. Isobe's life present an exceptionally personal and emotional connection between a Kaminoseki resident and nuclear power, they provide a salient example of the depth of passion that motivates these protesters to dedicate so much of their lives to resisting the development CEPCO's plant.

Another major local anti-nuclear activist is Mr. Taskashi Yamato. At 34 years old, Mr. Yamato is the youngest protester who consistency lives on the island. Mr. Yamato makes a living by selling loquat fruit, hijiki algae, and octopus, among other goods (Ankei 2012). In addition to this trade, he also spends time training young activists to plant vegetables as a way to promote sustainable, local agricultural practices for Kaminoseki and areas facing similar issues. The activist has high hopes for the resolution of the Kaminoseki conflict, and believes that sound environmental management practices and high-quality produce are essential components to ensure a promising economic future for Kaminoseki that does not rely on gifts from CEPCO or financial benefits from the proposed plant.

Mr Chiochi Ijumoti is a third active Iwashima protester. Mr. Chiochi's relationship with the plant has been contentious, as his father was one of the 10% of islanders to support construction. When his father died, Mr. Chiochi returned to Iwashima and immersed himself in anti-plant activism. Recently, he has focused on finding ways for the island to support itself, and has explored new agricultural methods that may be financially beneficial for the island. Incidentally, one of the techniques he used to clear agricultural fields for planting has garnered both attention and money for Iwashima. Mr. Chiochi used pigs to clear these fields, and in this process has

acquired high-quality pig meat. The quality of this meat is so so superlative that it has been purchased for a large sum by a French restaurant in Tokyo (Ankei 2012).

These individuals are only three of a powerful group of local activists that have worked tirelessly to defend their livelihood and environment. Their efforts have directly led to three of the four major blockages that are halting CEPCO from beginning construction. The first significant obstruction caused by activists is CEPCO's lack of fishing rights. Early on in the process, CEPCO attempted to pay the fishermen of Kaminoseki 12.5 billion yen in exchange for their fishing rights. This offer, which attempted to exchange money for lack of work, was essentially a tactic to buy out the fishermen so that they could no longer have a say in how the construction would influence their livelihoods and environment. Unwilling to accept financial incentives for their complicity in the degradation of the environment around which they had built their lives, the fishermen refused. In the 2011 lawsuit that followed this disagreement, fisherman Hisao Hashimoto provided this defendant's statement on behalf of the fishermen:

"(The) Nuclear Power Plant and this beautiful sea of lives can never co- exist. I have the right to live peacefully on Iwaishima Island, and to continue to maintain my life through fishing activities. We fishermen have the responsibility to conserve the Sea and to hand it down to future generations; CEPCO does not have rights to invade our life and the Sea of lives by urging local inhabitants with their powers. We are convinced to continue our non-violent, just activities against Kaminoseki Nuclear Power Plant Project until CEPCO abandons this project.'' (Ankei 2012)

The passion that ignites the Iwashima protesters is rooted in both social responsibility and environmental activism. Throughout this extended timeline, the islanders have banded together to complete various projects that emphasize the importance of sustainability to their lifestyle. In 2002, Iwashima residents built a house that looks over Tanoura Bay, the proposed construction site. This structure, which is powered by renewable solar energy, is called *Hitobo no Tsudoi no le*, the House for Interchange of Peoples (Ankei & Fukada 2003). The house represents a

physical manifestation of the concentrated efforts of the Iwashima protesters. As a bulding powered by renewable energy, the house is also a poignant symbol of the vigor of the anti-nuclear sentiment that permeates the region.

Religion is another factor that motivates Iwashima residents against the project and has resulted in serious delays in CEPCO's plan to begin construction. In the area of Tanoura Bay where reactor 1 is planned to be built, there is a sacred Shinto Shrine. According to Mr. H Hiyashi, the chief priest of Kaminoseki, the deities of Shinto are strongly opposed to selling the land for a nuclear power project. As a result, he has refused outright to sell the land on which the shrine resides. This has posed a major conflict for CEPCO, and combined with the refusal of fisherman to give over their rights, it is evident that the protesting actions of Iwashima residents have had a significant and direct impact on the 36-year delay in construction of the plant.

The fervent efforts of these residents have not gone unnoticed, and over the years the Kaminoseki conflict has attracted attention and support from outside activist groups. Many of these groups have had different motivations guiding their support of the people of Kaminoseki. Some are firmly rooted in anti-nuclear ideology, while others are more focused on preserving the rare ecology of the region. One group, the "Rainbow Kayaking Team," supported protesting fishermen by assisting them with blocking the construction site with their boats. The "No Nukes Yamagutchi Network" is another supporting group comprised of residents of the greater Yamagutchi Prefecture who reject the project (Yamaguchi 2011). Several independent filmmakers have become interested in the conflict and have visited Kaminoseki to make films supporting their cause and spreading awareness for their plight. Two documentaries, one named *Ashes to Honey* (2010) and the other *Holy Island* (2010) have been produced in recent years to circulate awareness, Additionally, the outdoor brand Patagonia recently funded a short

documentary called *Sea of Miracles* (2018) that focuses on the biodiversity of the Suou-nada Sea and the struggles of the people living there (Yamaguchi 2011).

One of the more impactful organizations supporting Kaminoseki residents is the Ecological Society of Japan, or ESJ, which became involved in 2000. The ESJ has been instrumental in halting progress of the project through a series of concrete steps focused on preserving the ecology of the region. In 1999, the Japanese government passed a resolution that mandated an environmental impact survey to be conducted at all proposed nuclear power plant sites. The survey that CEPCO conducted was perfunctory and omitted several of the most impactful effects of the plant on the surrounding area. In fact, the impact survey did not even mention Iwashima, the island that faces Tanoura Bay, or the significant influence that construction would have on the 500 residents of this small subset of Kaminoseki (Ankei & Fukada 2003). Most glaringly, the report did not include the presence of many of the rarest or most endangered species who thrive in the area, including Japanese Crested Murrelets, finless porpoises, lancelets (*Amphioxiformes*), and peregrine falcons (*Falco peregrinus*) (Ankei & Fukada 2003). The ESJ pushed hard against the lackluster report and urged the corporation for a reassessment. In doing so, the organization wrote a strongly worded resolution that highlights Japan's responsibility to respect this hotspot, which is the only one remaining in the Seto Sea.

The efforts of the Ecological Society of Japan did not go to waste. When the resolution reached the governor of the Ministry of International Trade and Industry in 2000, the governor was forced to recognize the notable diversity of the region (Ankei & Fukada 2003). He proposed another yearlong study to take into account the omitted species and to repeat the assessment in a more scientifically rigorous manner. Yuji Ankei, the scholar most closely associated with this conflict, worked with both the ESJ and another local group, the Association for Conservation of

Nagashima Island, during this time he became aware of the close relationship between the government and nuclear power companies, which is evidenced in both the leniency of the environmental impact assessment and the large sum of money gifted by the Japanese government to Kaminoseki to incentivize the town to support the project. According to Ankei, the government is interested in only on the impacts of the power plant on human health. He therefore urges that an outside organization must be the one to conduct environmental impact surveys in the future so that they can provide a more comprehensive and objective appraisal of the situation (Ankei & Fukada 2012).

IV. Ecological Impacts of Power Plant Construction

Even through the minimalistic lens of CEPCO's impact survey, the effects of the power plant on Tanoura Bay and the surrounding environment will be massive. Nearly all of the coast will be taken up by the site, and the two reactors will fill 300,000m^2. Half of this area will be dredged sea, which will be filled by approximately 170,000m^3 of local soil, and the boundary between the plant in the sea will be sealed by a concrete wall (Ankei & Fukada 2003). The massive reactors will need to be cooled constantly; to do so, the plants will draw in 190 tons of seawater per second, which amounts to 16.4 million tons of water per day, and this water will be a full 7°C degrees warmer than the surrounding seawater. Additionally, to avoid contamination, the pipes that draw in water will be lined with chlorides that prevent marine life from growing within them; estimates suggest that at least 70% of plankton and larvae growing in these areas will be killed (Ankei & Fukada 2003). This process will clearly have a deleterious effect on the abundant marine life in the region.

Despite the slew of impediments halting progress of the project, CEPCO began preliminary constructions on February 21, 2011. However, an event in March shifted the trajectory of the project for the next several years. On March 11, 2011, a magnitude 9.0 earthquake shook the area surrounding Tohuku, Japan. This event was one of the biggest earthquakes of the last 100 years, and its effects have continued to be felt throughout Japan in the following years. Immediately following the earthquake, a sequence of 5,000 aftershocks reaching 7.9 magnitude rocked Japan (Barclay 2011). The tectonic disturbance prompted a colossal tsunami, which wreaked just as much havoc as the earthquake preceding it and likely induced more long-term damage. As of 2017, 15,894 people were confirmed dead, and another 2,500 were still missing. Even now, about 50,000 evacuees are still living in temporary housing as the country struggles to repair the colossal damage (Oskin 2017). The powerful wave washed five million tons of debris into the ocean, some of which has been found on the shores of North American years later. The tsunami also had a terrible impact on avian life—over 110,000 seabirds were killed at their nesting sites at the Midway Atoll National Wildlife Refuge as the tsunami travelled across the Pacific. The direct cost of the disaster was estimated to be 16.9 trillion yen, or $199 billion dollars (Oskin 2017). Additionally, according to a World Bank estimate, the final cost of the disaster may exceed $235 billion, which would render the Tokohu earthquake the most expensive disaster in world history.

While the financial damage and the cost of human life alone are difficult to fathom, one of the most dangerous and long-lasting effects of the tsunami was its impact on the Fukushima Daiichi Nuclear Power Plant. The plant, which was not designed to withstand a tsunami so vast, was inundated when the major wave hit. The cooling system of the plant was compromised and rendered ineffectual, which then prompted a massive nuclear meltdown and a subsequent release

of 370,000 terabecquerels (a derived metric measurement unit of radioactivity) of radioactive material, including iodine and cesium, into the atmosphere and ocean (Barclay 2011). This is one of, if not the most noteworthy nuclear disasters since the explosion of the Chernobyl Power Plant in 1986, and its effects are predicted to be long-lasting and global in scale. In fact, in both 2014 and 2015, trace amounts of elevated cesium-134 and cesium-137 collected off North American shores have been traced back to the Fukushima disaster (Oskin 2017).

Japan's relationship to nuclear power tracks a long, complicated, and divisive history. The disaster at the Fukushima-Daiichi Plant has only served to fuel the bitter conflict between the government, who has supported the implementation and growth of nuclear power in recent decades, and many people within Japan who bear personal opinions against any use of nuclear power. One of the main arguments of those who support nuclear power is based on self-sufficiency. Japan has no significant natural resources—namely coal or oil—with which it can sustain its energy needs. In fact, Japan is only self-sufficient for 4% of its energetic requirements (Yamaguchi 2011). This conundrum has placed stress on the government to find ways compensate, and nuclear power is one of their most cost-efficient solutions.

However disastrous the impetus, the Fukushima disaster has brought to the fore the bitter conflict that has divided Japan for so many years. According to Tomomi Yamaguchi, the disaster has "highlighted the culture of secrecy surrounding nuclear weapons and nuclear energy that has long crippled public discussion of the issues, and raised questions about the rural/urban power differentials which have been amplified by the catastrophe" (Yamaguchi 2011). The event was so colossally harmful that the government was forced to put a halt on all nuclear power construction projects. The respite, although somber in mood, has given conservation associations valuable time to build a case against CEPCO that is based not only in anti-nuclear sentiment but

in specific regard to the unique biological features of the region. As of 2018, however, filling in of the inland sea has resumed, and it appears the construction is entering its next phase. The efforts of the conservation groups opposing construction are therefore now more important than ever.

The Kaminoseki Nature Conservation Association is founded by Midori Takashima, an outspoken activist who has dedicated her recent years to preserving the ecology of Tanoura Bay. Takashima has weighty goals for the project; the ultimate goal is to turn Nagashima into a UNESCO World Heritage Site, like Yakushima Island in Kagoshima Prefecture. If given this status, Nagashima will be protected indefinitely from any development, and CEPCO will be forced to abandon the project. The organization has also built a Center for the Biodiversity of the Suou-Nada Sea; this is a community-based center for environmental education that receives support from educators at the Malacozoologial Society of Yamagutchi Prefecture (Ankei 2012). If the immense efforts of these groups are successful, the continued existence of the finless porpoises, rare brachiopods, and molluscs of the Suou-Nada Sea will be secured. The survival of all of these species may be contingent upon one other species, around which the Ecological Society of Japan, the Kaminoseki Nature Conservation Association, international biologists, and other groups are building their case. The conservation value of *S. wumuzisume*, the Japanese Crested Murrelet, may be the deciding factor that tips the balance between the 4-decade long struggle between residents, scientists, governments, and powerful corporations. The very future of Kaminoseki may come down to the presence of just one small seabird.

V. *Synthilobramphus wumizusume*: Life History and Conservation

Japanese Crested Murrelets are a member of the family Alcidae, the Auks, which are colloquially known as the "penguins of the north." Auks have characteristically small wings that allow them to "fly" underwater, where they can dive up to 200m and eat both fish and invertebrates (Piatt *et al*. 1993). Auks are known to avian ecologists as reliable sentinels for ocean health; if something is amiss with an auk population, there is likely something occurring in the nearby ocean that merits further investigation and possible concern (Piatt *et al*.1993). Some members of the auk family are widespread and can be found on the coasts of several continents, while some are highly isolated. Of the eight auk species in the family *Alcidae* found in Japan, the Japanese Crested Murrelet is by far the rarest species, and their conservation has been the subject of vigorous efforts by international groups of scientists in the past several years (Figure 4). Due to their rarity, Japanese Murrelets have been designated as a "National Monument" in Japan, which affords them legal protection (Piatt *et al*. 1993). *Synthilopramphus wumisuzume*, can be found in 25 colonies across Japan. As of 1995 there were an estimated 7,500 individuals and 2,500 to 3,000 breeding pairs (Carter *et al*. 2002). Although the Biodiversity Center of Japan has completed some monitoring projects since 1995, population monitoring since this survey has not been conducted regularly, and there is a marked need for more rigorous studies to be done to assess whether significant changes in murrelet populations have occurred in the past twenty-five years. In Japan, the eight auk species can be found in different areas; however, the populations of each of these species have declined in recent years. These declines are direct results of anthropogenic changes such as the introduction of predators to islands, oil spills, changes in food availability, bycatch in fishing nets, and an overall trend of habitat destruction or degradation (Carter *et al*. 2002).

Mammalian predation is a particularly pressing issue for Japanese murrelets and seabirds in general. The introduction of small mammals such as mice, rats, and cats has become increasingly pervasive as humans have spread to islands around the world, and with these introductions, seabirds have faced major consequences. Nest predation, in which mammalian predators feed on seabird eggs or chicks, has had major impacts on seabirds worldwide (McCesney & Tershy 1998). Even seemingly harmless mammals, such as the house mouse *mus musculus* have been implicated in significant population decreases of seabirds, including the Tristan albatross, *Diomedea dabbenena*, and the Atlantic petrel, *Pterodroma incerta* (Wanless *et al*. 2007). As Japanese islands have become more traveled by humans, small predators have been introduced either inadvertently or intentionally to islands where murrelets live or breed, instigating substantial disturbance. Japanese murrelets make their nests by forming shallow depressions in under rocks or in the crevices between them ("Birdlife International" 2011). These nests are unprotected and therefore vulnerable to predation by a range of predators, both native and introduced. Predation of eggs is not the only concern relevant to Japanese murrelets. On Kozu island, there is evidence suggesting that introduced rats killed at least 145 adult individuals (Piatt *et al*. 1993). This event is corroborated by the finding of adult

Figure 4: *Synthilobramphus wumisuzume*, the Japanese Crested Murrelet. Image credit: Brock Worry.

carcasses on other islands, indicating that adult predation by rats is a widespread concern (Piatt *et al*. 1993). Murrelets also face predation pressure from other birds; raptors and corvids have been known to predate extensively on both eggs and adults (Karnovsky *et al*. 2017). On Birojima island, crows were implicated in preying upon 600 murrelet eggs in one year; this accounted for 40% of breeding failure in the Biro-jima colony in that year (Karnovsky *et al*. 2017)

There are several additional factors that contribute to the vulnerable status of the Japanese Murrelet. According to a study conducted from 1990-1991, 26 murrelet deaths were recorded in fishing bycatch from drift-nets intended to catch squid; extrapolations of this number estimate that between 93 and 417 Japanese murrelets were killed in drift nets in 1990, which represents between 1 and 10.4% of the global breeding population (Piatt *et al*. 1993). The volume of these deaths has been attributed to the migratory movements of the murrelets. After breeding season, murrelets overwinter in an area southeast of Hokkaido, Japan ("Birdlife International" 2001). This area contains a portion of the ocean where a confluence of major ocean currents exists, rendering it a critical area for fishing. Fortunately, the nations of Japan, South Korea, and Taiwan have placed rigid restrictions on harmful fishing techniques; in fact, large-scale drift-net fisheries have been halted completely in several critical areas ("Birdlife International" 2001). There are still some unrestricted zones within the range of Japanese Murrelets where drift-net bycatch still poses a risk, but since the cessation of large operations in the region where murrelets overwinter, there are likely significantly fewer mortalities now than there were in 1990.

Because Japanese murrelets number at only a few thousand in population and breed in only a few places, they are highly vulnerable to catastrophic events (Iida 2008, Iida 2010). Additionally, since they only lay two eggs per clutch and do not replace them if an egg is lost,

Japanese murrelet populations are extremely sensitive to stochastic mortality events and bottlenecks (Carter *et al*. 2002). In 1997, an oil spill off of Shimane Prefecture killed at least 1,315 seabirds, including several murrelets ("Birdlife International" 2001). In a more dramatic example, Izu Island, home to a major proportion of the global Japanese Murrelet population, was the site of a bombing target by the US Air Force from 1951 to 1952. Sanbondake Reef, the major nesting site on the island, was the localized target for almost a year, until the Air Force was informed of the damage they had inflicted and shifted their location ("Birdlife International" 2001). Fortunately, the population has been able to recover from these events and is still a large breeding population.

Japanese murrelets are particularly vulnerable to changes in their environment for a variety of morphological and behavioral reasons. Due to their small size, they have a particularly high metabolic demand; these murrelets must eat 90% of their body weight every day to obtain enough energy (Carter *et al*. 2002). Because of this requirement they are acutely sensitive to stressors that affect food availability. As the changing ocean climate is an ever-growing threat to the stability of marine food webs, these murrelets are increasingly vulnerable to these changes. The diet of Japanese murrelets are not definitively known, although isotopic analysis has suggested that their diet consists of the small pelagic fish and krill that makes up the diet of the closely related Ancient Murrelet, *Synthiloboramphus antiquus*. There is evidence that in recent years, changes in ocean currents have contributed to the depletion of fish stocks in the areas where murrelets feed ("Birdlife International" 2001). This trend is likely to increase in severity as anthropogenic climate change continues to effect massive shifts in oceanic and atmospheric circulation. *S. wumisuzume* also have highly restricted ranges and only rarely travel far from these sites. This makes the preservation of these small ranges tantamount; if a habitat is

compromised, it is likely that the affected murrelet colony will suffer dramatically (Piatt *et al*. 1993).

Japanese murrelet breeding takes place in the coastal subtropical waters of southern Korea and Japan. Ecologists have separated these breeding areas into three longitudinal zones. Kaminoseki happens to fall in the second zone; however, it is labeled as a "potential breeding site," as there is no concrete evidence so far that breeding takes place in this area. The two known main breeding sites are on Japan's Biro Island and Izu Island (Carter *et al*. 2002). Although Kaminoseki is not confirmed as a breeding site, it holds a special significance for the welfare of Japanese murrelets. Kaminoseki is the only site where murrelets have been known to stay all year long. This indicates that Kaminoseki is a roosting site for murrelets during their molting season, a period in autumn when they shed their feathers and are unable to fly. During this time, murrelets are particularly vulnerable to predators because they cannot escape in the air. Murrelets compensate for their lack of flight during this time by nesting in areas where food—mainly fish and krill—is abundant and requires minimal energetic expenditure to obtain ("Birdlife International" 2001). The evidence that the Kaminoseki nesting site is a refuge for murrelets during their molting season is a key discovery for the many biologists who have been closely studying the species in order to create better-informed management plans for their survival. This finding may also have prominent implications for the activists who are relying on the conservation value of Japanese Crested Murrelets to fight against CEPCO's proposal.

In recent years, important legislative measures have been created to protect populations of endangered plants and animals throughout the country. In fact, there are several sites in Japan that are now designated as National Wildlife Protection areas, whose main purpose are to serve as habitats for endangered species ("Birdlife International" 2011). In 2017, the Kaminoseki

Region of the Seto Sea was proposed as a contender for a future UNESCO world heritage site. Because only one site is chosen at a time, the selection process is competitive and requires defense. This proposal was supported by organizations operating within the region, such as the Kaminoseki Nature Conservation Association led by Midori Takashima, and outside organizations, such as the Pacific Seabird Group. In a letter to the UNESCO Association of Japan, the Pacific Seabird Group defended the selection of this site (Karnovsky 2017):

> "The Pacific Seabird Group and the Japan Seabird Group wrote a letter in 2011 expressing concern over the lack of information about the biodiversity of the region. Since that time more scientific research points to the fact that the Western Seto Sea is habitat for unique and rare species. For example, the KNCA have carried out surveys in the Kaminoseki region of the Seto Sea every year from 2008 to 2017. Each year they have found Japanese Murrelets during both the breeding and non-breeding season. There is no other place known to be used by Japanese Murrelets throughout the year. In addition, other unique species that have been discovered in this region such as *Ceratia nagashima*, a gastropod found only in Tanoura Bay, Kaminoseki. Furthermore, the finless porpoise (*Neophocaena asiaeorientalis)* of the Seto Sea is found there and is currently classified by the IUCN Red List as vulnerable. Not much is known about these rare species. For example, no complete survey of islands and rocks has thus far been carried out to find the location of the breeding colonies of Japanese Murrelets.
>
> Consequently, PSG feels protection from industrialization is warranted and critical to the ecological health for the shallow sea, and pollution will greatly impact the biodiversity that is in the early stages of being studied. We urge that this area gain protection by becoming a heritage site."

Despite the rigorous efforts of these groups, the UNESCO Association of Japan did not select the Kaminoseki Region as a protected site; instead, Okashima Island was chosen as a UNESCO site in July of 2017 (Karnovsky 2017). As of now, the Kaminoseki area and the biodiversity that exists there still faces the imminent threat of the construction of the nuclear power plant. However, activists and scientists are continuing to protest this construction by providing concrete evidence of the existence of the murrelets in the area. Recently, a team of both local and international activists and scientists placed song meters designed to capture the call of Japanese Murrelets at their nesting sites in various locations around Tanoura Bay and surrounding rocky structures. The data obtained from these meters will be used to construct a

map of the location of Japanese murrelets in the area, which will be given to local activist groups. Because Japanese Murrelets are a designated "National Monument," in Japan. they are legally protected by the government (Carter *et al*. 2002). Therefore, CEPCO will face pressure to shut down construction once their presence is confirmed. With this information, the organizations will be able to strengthen their case against CEPCO, with the ultimate goal of protecting the biodiversity of the region by naming the Kaminoseki area a UNESCO Heritage Site or Protected Wildlife Conservation Area.

VI. Acoustic analysis of the nesting sites of the Japanese Crested Murrelet (*Synthliboramphus wumizusume*) in the Kaminoseki Region

Abstract

The Japanese Crested Murrelet *Synthliboramphus wumizusume* occupies a limited range in Southern Korea and Japan and is considered vulnerable by the IUCN. There is strong indication of a colony of Japanese Murrelets located in Kaminoseki, Japan; however, no nests or individuals have yet been found. The is also evidence that murrelets make use of this habitat during their vulnerable autumnal molting season during which they cannot fly. This habitat is threatened by the construction of a nuclear power plant in Tanoura Bay. Construction of this plant would result in loss of nesting sites, food supply, and other components vital to the survival of the colony. This study attempts to detect the presence of Japanese Murrelets in Kaminoseki using bioacoustic monitoring of songmeters placed around Tanoura Bay. Preliminary sonograms created using the R package "Bioacoustics" did not yield conclusive results regarding the presence of Japanese Murrelets as the program captured background noise but did not pick up on bird calls heard during manual playback of the WAV files. Further research must be completed to refine the settings used in the program in order to conduct a more definitive analysis of the dataset.

Introduction

Vulnerability of the Japanese Crested Murrelet:

Synthliboramphus wumizusume, known as the Japanese Crested Murrelet, is highly vulnerable due to a variety of morphological, behavioral, and range-related factors. With a global population of less than 10,000 individuals clustered in relatively few colonies, Japanese Murrelets are susceptible to regional mortality events (Piatt *et al*. 1993). This vulnerability is compounded by their small size and high metabolic demand—a combination of factors that renders them vulnerable to stressors that affect food availability. Since these murrelets inhabit a small range in the subtropical waters of southern Korea and Japan, they are faced with the effects of shifting ocean currents as a result of climate change, and are frequent victims of drift-net bycatch due to the commercial squid fishing that is prevalent in the region (Piatt *et al*. 1993). On the small, rocky islands where they nest, murrelets and their eggs are vulnerable to predation by introduced

mammalian predators including rats and cats. There is also evidence that murrelets face depredation by avian predators as well (Karnovsky *et al*. 2017).

Japanese murrelets are vulnerable due to an array of morphological, behavioral, and range-related factors (Carter *et al*. 2002). They have a very small range of distribution: murrelets live in only about 25 colonies in Japan and never fly beyond 1,500km of Japan, even during the nonbreeding season (Yamguchi *et al*. 2016). Additionally, due to their small body size, Japanese murrelets have a high metabolic rate and must consume 90% of their body weight per day in food (Carter *et al*. 2002). These traits render Japanese murrelets vulnerable to the regions where they live. If food availability changes or severe environmental degradation occurs, they are therefore at risk of population decline or extirpation (Otsuki 2013).

Recent efforts to count Japanese murrelet populations have provided limited insight into the population dymanics of the species. In recent decades there has not been a standardized protocol in place for monitoring murrelet populations. In 1994-1995, the Biodiversity Center of Japan conducted a monitoring project and estimated that Japan has 25 colonies and 2,500-3,000 breeding pairs (Carter *et al*. 2002). Estimations were attained by counting the number of live birds or carcasses and eggshells found at a given site. A count of five birds or carcasses and one to five eggshells was extrapolated to ten to twenty-five breeding pairs. More than ten birds or carcasses or 6 eggshells indicated 25–50 breeding pairs. Twenty or more birds or carcasses and more than six eggshells indicated 50-100 breeding pairs (Carter *et al*. 2002). However, this method was not consistently implemented; for example, data for eggshell fragments were collected supplementarily and not by all study groups. There has been insufficient monitoring at any of the sites since 1995, and there is a complete lack of standardized monitoring as of 2018.

Therefore, there is a demonstrated need to explore new techniques into order to more effectively detect and monitor Japanese murrelet populations across Japan.

Bioacoustic Analysis:

For many taxa, acoustic signals are the most definitive indication of the presence of a species in a given location. For populations inhabiting harsh or remote areas, or for particularly elusive taxa, remotely analyzing acoustic signatures can be feasible alternative to observation (Brandes 2008). Sound analysis is therefore a highly effective method for monitoring a wide range of animal populations. The use of acoustic technology to detect faunal activity is a relatively recent development within ecology, having come to the fore in the past few decades, ant it already been used for several promising applications (Brandes 2008, Shonfield & Bane 2018, Oliver *et al*. 2018).

Automated recording units (ARUs) have proved to be an especially effective tool for the monitoring of avian species. The frequency of calls of a given species within a time period can not only confirm the presence of a species, but can compare relative abundance between populations (Cook & Hartley 2018). These data can be extrapolated to create an accurate species index that takes into account both composition and richness of the avian community of a given ecosystem. In the realm of avian ecology, sound monitoring technology has been used to decrease the frequency of bird strikes by aircraft and and wind turbines (Brandes 2008). ARUs can be highly useful tools for both small and large-scale research. At a small scale, ARUs can provide an accurate reflection of habitat use of individuals within their home range. On a larger scale, ARUs are one of the only noninvasive ways to track avian migratory pathways over a large expanse of time and space (Shonfield & Bayne 2018).

Bioacoustic networks have also been used recently to map phonological changes in avian taxa in relation to global climate change. In Oliver *et al*. 2018., researchers used autonomous recording units to remotely estimate the arrival dates of migratory songbirds to their arctic breeding grounds. As birds reach their breeding grounds earlier, which is a growing phenomenon linked to rising spring temperatures, breeding success may decrease (Oliver *et al*. 2018). Therefore, adaptations may arise to accommodate these climatic shifts. While these changes are population-specific, it is necessary to monitor them at a large scale in order to assess global trends in avian phonological response to to climate change. Automatic recorders provide an inexpensive way for these analyses to be conducted across wide spatio-temporal scales. Additionally, the large-scale data compiled by autonomous recorders are one of the most effective ways to track changes in meteorological conditions, extreme events, or variability in climate such as El Nino Southern Oscillation, in relation to avian species and their ecosystems (Oliver *et al*. 2018).

However, there is a variety of drawbacks associated with ARUs; firstly, if a unit fails or breaks, a large amount of data is lost. Additionally, the amount of audio data collected by ARUs is massive and can be overwhelming for many analytical systems (Shonfield & Bayne 2018). This is one of the most critical hindrances to the advancement of ARUs. According to Oliver *et al*. 2018, automated recorders "have yet to be widely deployed because bioacoustic data are complex and, despite significant advances in automated analytical methods, comprehensive toolsets remain largely undeveloped." There are therefore major limitations to widespread usage of this methodology and consequently a dearth of access to support for analyzing bioacoustics datasets.

Objectives:

In this study, autonomous recording units are used to detect the presence of the Japanese Murrelet in a region of Japan's Yamaguchi Prefecture in the Seto Inland Sea. While murrelet calls are heard frequently and fishermen have seen murrelets in the nearby sea, no nests or individuals in Kaminoseki have been concretely located. Their habitat here is imminently threatened due to the proposed construction of a nuclear power plant in Tanoura Bay (Ankei 2012). This threat is particularly troubling because Kaminoseki has been cited as the only area where Japanese murrelets are known to be heard year-round (Karnovsky 2017). This indicates that the murrelets use Kaminoseki as a nesting site during their molting period in autumn. This is a time when they are particularly susceptible to harm because they cannot fly; they therefore spend this period in a place where food is abundant and they can seek safe refuge from predators (Carter *et al*. 2002). It is critically important to substantiate the indicators of murrelet presence in the region in order to protect them from the harm caused by the construction of the plants. This study utilizes biacoustic tools to determine the presence of a population of *S. wumizusume* in the rocky islands surrounding Tanoura Bay that will be disturbed with the construction of the nuclear power plant. I hypothesize that Japanese murrelets are present in the region, and predict that the calls of Japanese murrelets will be heard on the songmeters in areas that correspond to where environmental degradation will occur as a result of construction of the plant.

Methods

Study Site:

Kaminoseki is a small town in the Yamaguchi Prefecture of Japan on the coast of the Suo-nada Region of the Seto Inland sea. This region is ecologically distinct in that it is virtually

undisturbed by the anthropogenic influences brought on by the rapid industrialization of post World War II Japan that characterize most of the ecosystems within the Seto Inland Sea (Dusinberre 2012). In fact, the Suo-nada region is widely recognized as a biodiversity hotspot, as it provides a habitat for many rare taxa, including, *Neophocaena phocaenoide*, the finless porpoise, cornirostrid gastropods, and *S. wumizusume*, the Japanese murrelet (Ankei & Fukada 2003). Songmeters were placed on the small rocky islands that surround Tanoura Bay, the proposed nuclear construction site on the island of Nagahsima, an island portion of Kaminoseki.

Songmeter Deployment:

Autonomous Recording Units were placed at six locations around Tanoura Bay and surrounding rock formations (Table 1, Figures 8-12). All six songmeters were deployed on 3/31/2018. Five meters were collected on 4/21/2018, while meter one was collected on 6/17/2018. Meter six was re-deployed on 4/21/2018 after its batteries were replaced and was retrieved on 6/11/2018. Meters two through five were therefore deployed for thirty days, while meter one was deployed for 71 days and meter six for 51 days. In all cases, songmeters remained active until their battery ran out.

Table 1: Locations of Songmeters

Songmeter	Location	Longitude	Latitude
1	Han-do	33°46’51.75”N	132°10’06.58”E
2	Uwashima Northeast	33°44’14.91”N	132°01’51.27”E
3	Uwashima Southeast	33°44’11.18”N	132°01’35.02’’E
4	Hijiro South	33°43’55.33”N	132°00’50.06E”
5	Hijiro North	33°43’59.71”N	132°00’52.34”E
6	Kanojima	33°49’25.68”N	132°02’17.77”E

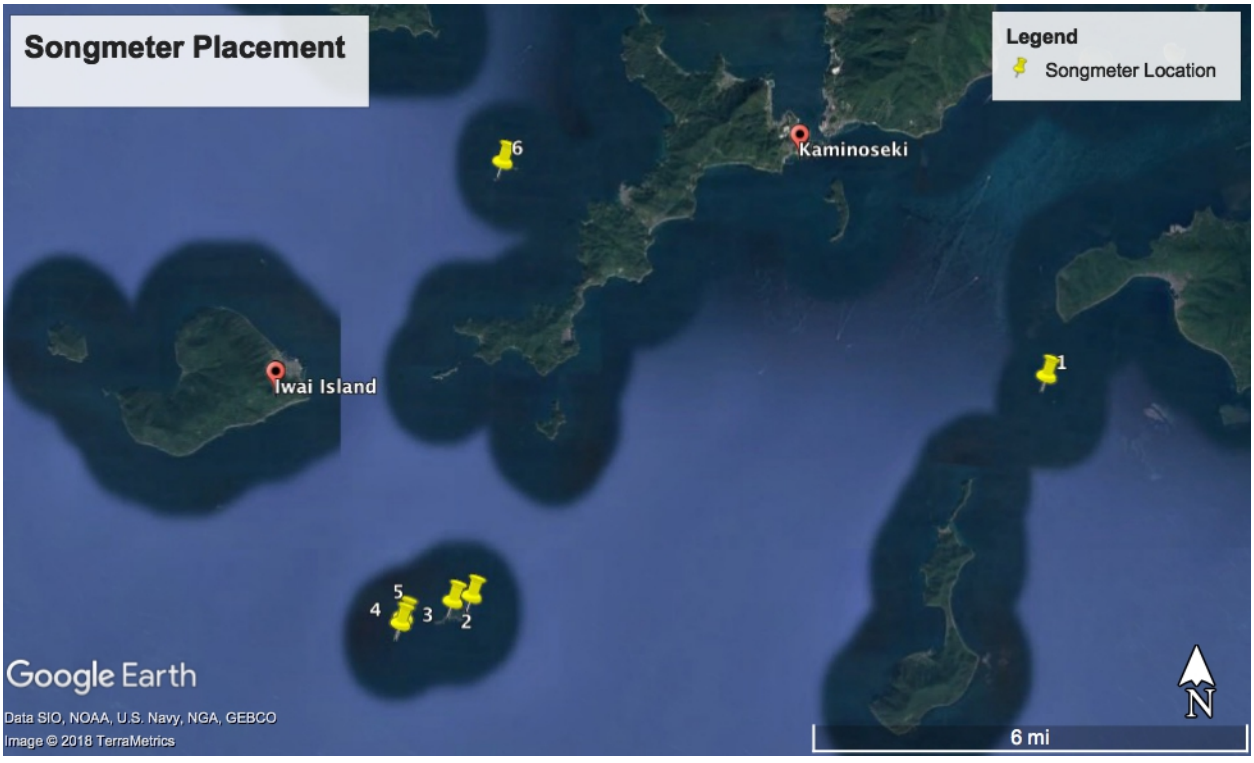

Figure 6: Map of songmeter locations. Iwai Island, or Iwashima, lies directly across from Tanoura Bay on Nagashima Island.

Songmeter 1: Han-do

Songmeters 2/3: Uwashima

Songmeters 4/5: Hijiro

Songmeter 6: Kanojima

Figure 7: Aerial view of the rocky structures of possible nesting sites where songmeters were placed.

Figure 8: A team of researchers sets out to deploy the songmeters.

Figure 9: The deployment team positions a songmeter.

Figure 10: Team members scale a cliff to place a meter in a useful position.

Figure 11: A songmeter sits on a rock.

Figure 11: A songmeter is positioned in a tree.

Figure 12: A member of the deployment team uses a GPS to attain coordinates of the location of a songmeter.

Bioacoustic Analysis:

We conducted analysis using the R Package "Bioacoustics". For each songmeter, we uploaded WAV files of fifteen-minute increments to R and analyzed through the "Bioacoustics" package. The standard settings of this package are designed to analyze bat sounds and were therefore modified to apply to analysis of bird vocalizations. The High-Pass filter was converted from 16000 Hz to 1000 Hz. Time resolution was changed from the default setting of 0.1milliseconds/pixel to 2ms/px for bird calls. The start amplitude threshold for audio event extraction was changed from 40dB to 20dB, and the end amplitude threshold was modified from 20dB to 30dB. The SNR threshold was placed at 8dB and the angle threshold at 125°.

For each WAV file, ocean background noise was extracted and a spectrogram of the remaining sounds was created. This spectrogram was then compared to a sample spectrogram of the vocalizations of *S. wumizusume* (Figure 13).

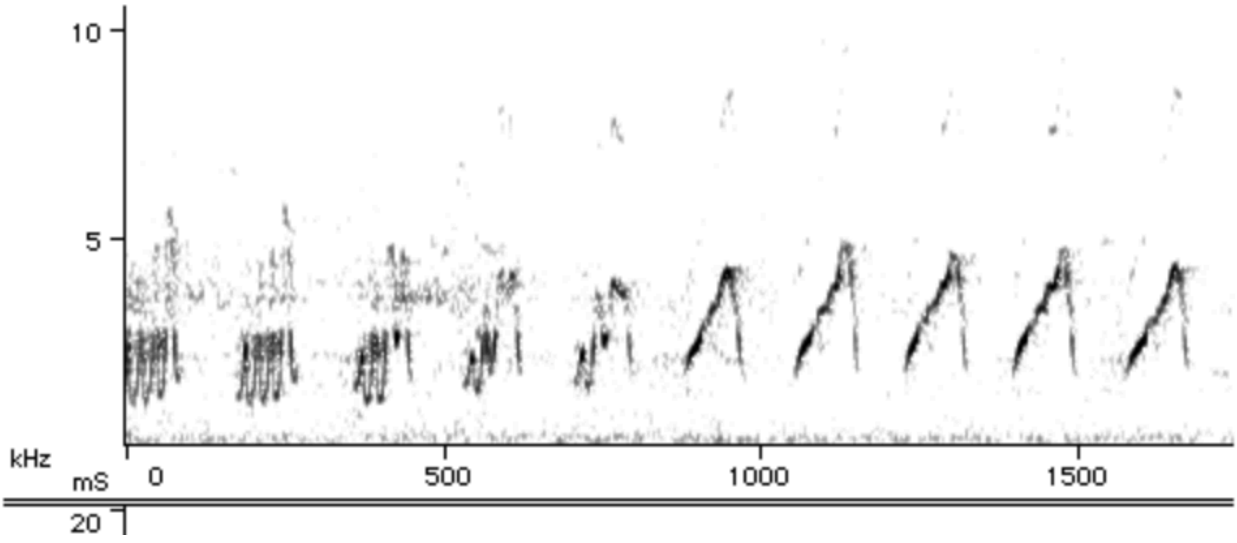

Figure 13: Sonogram of a Japanese Murrelet vocalization. Recorded by Hideo, U. (1996).

Results

There were substantial limitations to the scope of analysis conducted within the time limit of the study period. During the time allotted to the study it was difficult to learn how to use the Bioacoustics package in order to successfully manipulate the WAV file data into a readable sonogram. The most pressing issue was the inability to filter out loud, low-frequency background noise—composed mostly of ocean and wind sounds. Consequently, the program was unable to register the softer, higher-frequency sounds of bird calls on the files. Manual playback of a selection of files from each songmeter confirmed the presence of bird calls, but these calls cannot be definitively identified as the calls of Japanese murrelets.

A series of sonograms created from a selection of 15-second intervals from songmeter 2 shows the presence of constant, low-frequency noise, which is in this case the ocean (Figure 13). However, manual listening to the selected intervals also confirms high-frequency bird calls during these intervals. The fact that the program is unable to pick up these calls indicates that the settings are not correct for this type of analysis. It is therefore necessary to continue adjusting the settings so that more relevant sonograms will be produced. When the correct settings are configured, it will be possible to systematically review the files and effectively scan for the presence of Japanese Murrelet calls.

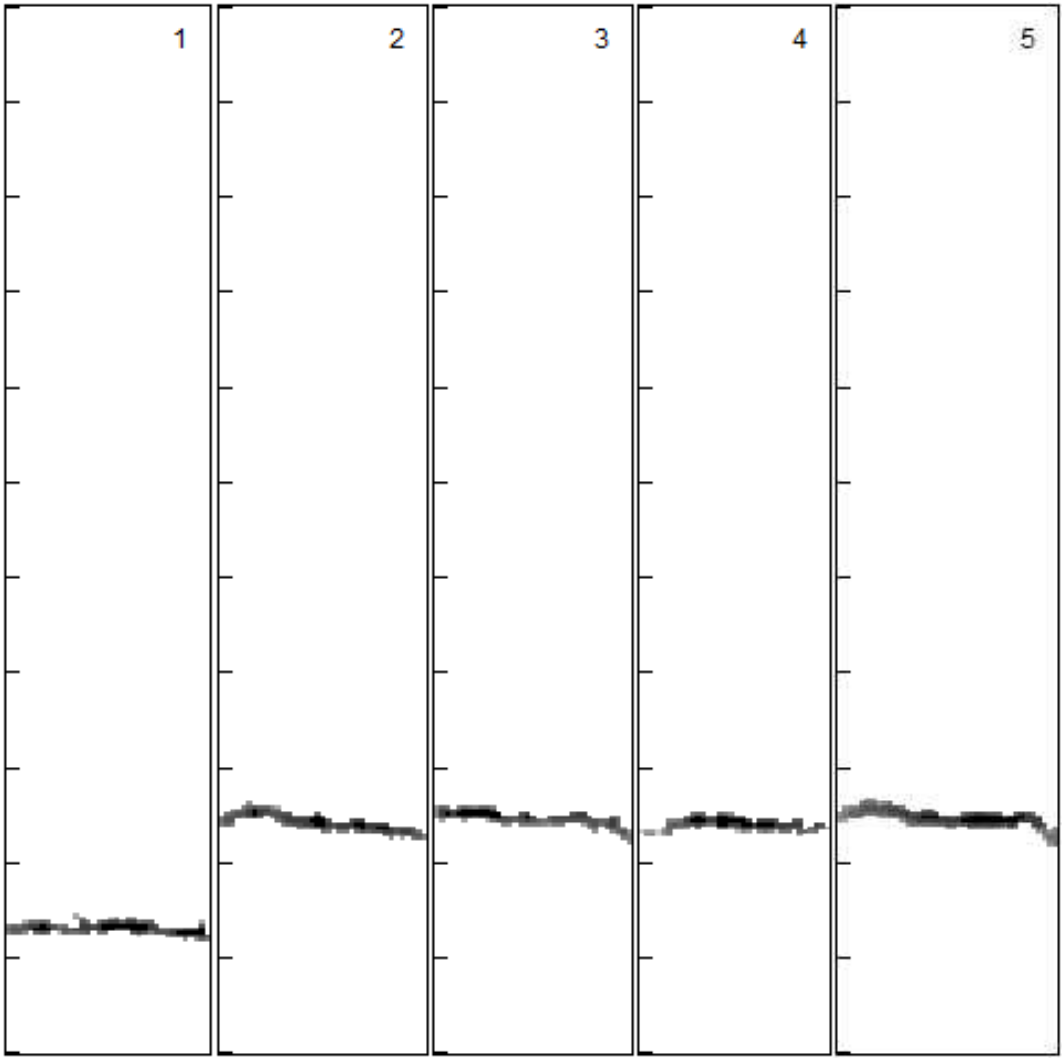

Figure 14: Sonogram from sound recordings of songmeter 2 in 15-second intervals. The y-axis indicates the frequency of the sound. Since all sound frequency is low and concentrated, it is likely that no bird sounds were picked up by the program despite the fact that manual listening confirms bird calls during the during these time intervals.

Discussion

Preliminary efforts have not yielded any definitive results regarding the presence of *S. wumizusume* in the Kaminoseki region of Japan. However, the dearth of results is due to a lack of experience with bioacoustic analysis methods that may be rectified upon further research and time spent adjusting the system with which we analyze the raw data. There is no conclusive evidence that suggests that Japanese murrelets are not present in the region; it is therefore recommended to continue analyzing the dataset until more conclusive results are found.

The difficulty experienced in analyzing the dataset speaks to the complexity of bioacoustic analysis. While the results of this study are inconclusive, there are several takeaways associated with the use of bioacoustic methods that may inform further undertakings in this field. Firstly, the songmeters were effective in recording sound. However, the noise of the wind and ocean are so loud in many of the files that it is extremely difficult to filter out these frequencies in a way that isolates bird calls. It may benefit future songmeter studies to research ways to minimize the uptake of background noise by automated recording units. Secondly, the amount of data acquired from the songmeters was very large. The duration of this study was about one month for most of the songmeters and over two months for songmeter 6. This resulted in a very high volume of data and a laborious analysis process. The large amount of data and the time-consuming nature of analysis indicates that automated recording units may be a more efficient method over a short temporal scale (Brandes 2012).

Because the murrelet colony in Kaminoseki is imminently threated by the construction of a nuclear power plant, it is necessary to continue working with this data set to work toward the goal of elucidating the presence of Japanese Murrelets in this region. These birds have a highly restricted geographic range; they live and breed in only about 25 colonies in Japan (Piatt *et al*.

1993). If even one colony is compromised, the global population of Japanese murrelets will plummet significantly. The evidence that murrelets rest in Kaminoseki during their molting season further enhances the significance of this area to the Japanese murrelet as a species. In order to confirm that murrelets use Kaminoseki as a place of rest during molting season, it would be beneficial to run the songmeters during autumn, which is when they are known to molt. Additionally, since Kaminoseki is labeled as a possible breeding site for murrelets, it would be helpful to repeat the study during breeding season (Carter *et al*. 2002). The results of these studies will clarify whether or not murrelets are indeed present year-round.

The construction of a power plant in Tanoura Bay has disastrous implications for the ecology of the region (Ankei & Fukada 2003). The population of Japanese Murrelets who live in this region are at particular risk, since both their nesting sites and the abundance fish and krill they rely on for sustenance will be deleteriously impacted by the construction of the plant (Ankei & Fukada 2003). Therefore, the survival of this colony is contingent upon the cessation of construction of the power plant. In order to protect this population, it is essential to prove their presence in the region. In this preliminary bioacoustic analysis of songmeters placed around Tanoura Bay, we have not achieved any conclusive results. However, this ambiguity can be rectified by further analysis of biacoustic methods. The dataset will continue to be studied until we are able to definitively assess the presence or absence of the Japanese Murrelet in the Kaminoseki region.

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