I. Statement of Problem and Overview

Suisun Bay stores a rusting fleet of over fifty retired Navy ships. They have been held by the Maritime Administration (MarAd) with the original intention of being available for emergency recommissioning or transportation. Yet now, after over seventy years, it is clear the obsolete ships will never see the open ocean again. Not only are they taking up space and becoming an eyesore, they are polluting the bay. The San Francisco Regional Water Quality Board in California recently announced its plan to sue MarAd for pollution from these ships (Zito 2008). With the recent pressure to deal with this long-ignored environmental problem, alternatives to the inefficient scrapping and recycling process are receiving more attention. For years, groups of divers and ecologists have advocated the conversion the ships into artificial reefs by sinking them in the ocean. Proponents of the plan envision this as a potential solution to two of California's environmental problems: reducing waste and creating marine habitats.

This paper examines two major points of environmental concern tied to artificial reefing. The first involves the hazardous materials present on the ships and their proper clean-up. The second questions the ecological benefits of these artificial reefs. Finally, these points will be considered in the context of California's ship problem.

II. Introduction and Background

Ships are constantly decommissioned by the Navy and stored for either future use or future dismantling and recycling. Over fifty of these have ended up in the Suisun Bay for decades and will remain there for decades more. The queue for recycling is backed up due to the lack of available scrapping yards, causing a yearly net accumulation of ships. Their fate is an issue that must be addressed since they contain hazardous materials. A recent study on the

Suisun Bay mothball fleet indicates that their paint contains high concentrations of toxic metals, including copper, zinc, lead, and chromium (R&M Environmental and Infrastructure, Inc. 2007). About a quarter of this paint has already chipped off and these chemicals have been found in the sediment at the bottom of the bay. According to the San Francisco Regional Water Quality Board, these ships have already discharged an estimated 19 tons of mercury, lead, and copper into the bay (Zito 2008).

Action must be taken to clean up this environmental mess. A research group called the RAND Corporation identified four options and estimated their costs (Hess et al. 2001). The proposed options are overseas recycling, domestic recycling, indefinite storage, and reefing. Each of these will be discussed in further detail.

Overseas Recycling

At the predicted price of $170 million, sending the old ships abroad to be recycled is the cheapest option (Hess et al. 2001). Years ago, this was a popular method because struggling people in developing countries are willing to disassemble the ships for the valuable scrap metal. Environmental standards and human health cannot be assured when sending these ships abroad due to ignorance or disregard of the hazards of the ship materials, according to Alastair Iles, a professor of Environmental Science, Policy, and Management at the University of California, Berkeley. (A. Iles, pers. com.). Many developing countries have loose environmental and worker safety laws, making them desirable destinations for these old ships by cheapening the disposal process. Recent controversy has surfaced due to investigations into the health surrounding one of these shipyards in Alang-Sosiya, India (Kanthak and Jayaraman 2001). The multilateral environmental agreement known as the Basel Convention attempts to halt the unjust transfer of hazardous wastes, including ones like PCBs found on old ships, to poorer countries by restricting its trade. Yet there are loopholes for the shipping of recyclable materials and this trade still occurs (Basel Action Network 2008). In 1999, the U.S. Government closed this loophole for its exports with the Toxic Substances Control Act. Now overseas recycling is no longer an option and all recycling must be done domestically.

Domestic Recycling

This option is projected to cost $1.9 billion dollars, much more than overseas recycling (Hess et al. 2001). Part of the stark price difference stems from costs of complying with stringent environmental standards and giving workers fair wages. Also, the scrapping yards must be certified (D. Long, pers. com.) and the country only has seven certified scrapping yards, meaning only fourteen can be recycled a year (Hess et al. 2001). The inconvenient locations of the shipyards relative to the storage areas demand extra costs and pollution from transportation. For instance, the ships in Suisun Bay must take a 45-day voyage to Texas scrapping yards (Peele 2006). Unless Navy or private funding supports the creation of more shipyards, this option is quite inefficient.

Indefinite Storage

According to the RAND report, this option would cost $4.9 billion (Hess et al. 2001). This cost includes decades worth of maintenance and docking fees (A. Iles, pers. com.). The maintenance is intended to keep the ship structure from deteriorating and the paint from wearing off and falling into the surrounding waters. Unfortunately, the ships in Suisun Bay have not been regularly maintained and have caused major pollution of the sediment surrounding the fleet

(Peele 2006). Though this is by far the easiest option, it leaves the ships to deteriorate indefinitely in our waterways. It delays a problem that must be dealt with eventually while externalizing the costs of ecosystem damage from deteriorating ships.

Reefing

The least utilized option is turning the waste into artificial reefs by sinking cleaned ships. According to the RAND report, at this would be the cheapest option for the Navy next to overseas recycling, which is no longer legal (Hess et al. 2001). This cost includes the same clean-up process as for domestic recycling. However, with sinking, the Navy does not need to pay for the extra transportation or labor-intensive dismantling required with recycling the scrap metal.

Artificial reefs also bring prospects of future revenue from the tourist economy associated with diving culture. The establishment of California as a popular diving destination could benefit local communities by attracting visitors. Looking to Florida's artificial reefing sites, supporters of artificial reefs find that increased recreational diving boosts the boating, gear, lodging, and retail sectors near the diving sites (Johns 2001).

A major setback to the reefs is the politics of obtaining ships for reefing. The process for getting ships owned by the Navy and MARAD is complicated. According to Dick Long, a man personally involved with the sinking of a retired ship off San Diego, California requires eleven state agencies including the California Coastal Commission and California Fish and Game regulate different aspects of the approval process (D. Long, pers. com.). The process is not streamlined through a single department and this bureaucratic red tape is a barrier to reefing ships. California is particularly cautious about what goes into its coastal waters, so it is tougher here than in other locations around the country, where more reefing has occurred (A. Iles, pers. com.).

In addition to the economics and politics, there are also environmental considerations relevant to artificial reefing. The major two are toxic waste and marine habitat effects.

Toxic Waste

Hazardous materials were used in parts of old ships before their harmful properties were understood. Now that the Environmental Protection Agency monitors discharges of chemicals like PCBs and asbestos, proper cleaning of contaminants prior to sinking is necessary. It is difficult to be certain what materials are onboard the ships or their potential environmental effects. The EPA has developed guidelines for proper clean up, but these are not enforced on the federal level.

Marine Habitat

The sunken ships would become a part of the marine ecosystem, the effects of which are complex and unpredictable. Examples from prior artificial reef projects show that the solid structure provides a surface upon which benthic reef organisms can colonize (Pitcher and Seaman 2000). Also, larger organisms could utilize the cavities for protection from predators and a safe place to spawn offspring. Many hope that this effort at artificial reefing could beneficially increase populations suffering from natural reef depletion. Yet some scientists fear that these ships could interfere with the stability of natural reef habitats, worsening the problem and destroying other conservation efforts. This uncertainty of the effect of artificial reefs is referred to as the attraction-production debate.

These environmental impacts are crucial to the artificial reefing debate. The benefits reaped by such a program could be negated by increased pollution of the ocean or harm to natural ecosystems. The impacts of the ships on the water quality and the nearby organisms determine whether reefing ships effectually removes pollution or simply shifts it out of sight.

III. Major Questions

1) What must be done to detoxify ships prior to reefing? Can the ships be sufficiently cleaned to prevent toxic discharge into the ocean?

2) Are the ships a suitable and productive habitat for marine life?

3) Do California's ship reefing advocates acknowledge these environmental concerns?

IV. Findings

What must be done to detoxify ships prior to reefing? Can the ships be sufficiently cleaned to prevent toxic discharge into the ocean?

The discovery of dangerous chemicals onboard old ships has halted the recycling processes here and abroad due to human health hazards in the handling of the ships materials (Hess 2001). Therefore, improperly cleaning ships before sinking them essentially introduces these harmful contaminants into the environment. To properly identify and remove these pollutants, some sort of regulation is required. The most useful level for such regulation would be at the federal level to create consistent nation-wide standards based on the best science (A. Iles, pers. com.).

The U.S. Environmental Protection Agency (EPA) would be the best agency to carry out this purpose. However, there is no national reefing program and the national environmental agencies do not enforce any organized clean-up plan. Although their jurisdiction encompasses almost all of the pollutants found on ships, regulations on the specific pollutants fall under different laws, providing piecemeal coverage on the issue. Current relevant laws include Clean Air Act, Clean Water Act, Superfund Act, Comprehensive Environmental Response, Compensation, and Liability Act, the Federal Insecticide, Fungicide, Rodenticide Act, the Marine Protection, Research and Sanctuaries Act, the Resource Conservation and Recovery Act, and the Toxic Substance Control Act. A whole other set of regulations could cover permitting, but no particular group is designated for that purpose (U.S. Environmental Protection Agency 2006).

It is currently up to individual states to produce and enforce vessel preparation laws. In California, this process is also not streamlined through a particular agency. For a sinking project in San Diego, the approval of eleven agencies was required (D. Long, pers. com.). None of the groups are experts on this issue, which makes it particularly difficult to ensure that the proper measures are taken to fully clean the ships (A. Iles, pers. com.). The sole document providing detailed cleaning procedures to decontaminate Navy vessels for reefing is provided by the EPA. *National Guidance: Best Management Practices for Preparing Vessels Intended to Create Artificial Reefs* was written in conjunction with national agencies with jurisdiction over the state of the ocean – including MarAd, the National Oceanic and Atmospheric Administration, U.S. Corps of Engineers, U.S. Fish and Wildlife Service, U.S. Coast Guard, and U.S. Department of the Navy. The resulting report lists dangerous materials that must be removed from ships before reefing. It includes the effects toxic chemicals found on most old Navy vessels, their locations within the ships, and proper removal methods. The main materials of focus are oil and fuel, asbestos, PCBs, paint, and larger solid debris (U.S. Environmental Protection Agency 2006).. Yet is it merely an informative resource with no legal authority and California maritime regulators have the option of whether or not to guide their decisions with this document.

Alastair Iles describes this document as a "reasonably comprehensive list of things to be cleaned-up" but is concerned about the exclusion of unlisted items onboard. Also, it does not distinguish between the types of vessels or the differences in models over the years. Fortunately, the Navy keeps an inventory of the materials used to build their ship (D. Long, pers. com.). Unfortunately, the Navy does not keep records of how their ships are retrofitted, making it unclear what could be on a ship when it is decommissioned (D. Long, pers. com.). With changing technologies and information about toxics, materials used on Navy vessels have changed over the years. For instance, the Navy promoted the use of asbestos-containing insulators on its ships from the 1930s to 1970s (Anonymous 2007). However, after the proliferation of studies on the harmful respiratory effects of asbestos, their use was lessened but not entirely discontinued. There are no records indicating the alterations, which produces uncertainty for those attempting to clean up the ship and regulators ensuring the ships are safe to sink.

Here we will look at the toxicity of the main substances highlighted by the EPA:

<u>Oil and Fuel</u>

Despite several decades in storage, many ships stored in the Suisun Bay still contain fuel (A. Iles, pers. com.). Oil is a generally undesired addition to the ocean because it poisons organisms upon exposure (U.S. Environmental Protection Agency 2006). In addition, oil is persistent in the water and is difficult to clean up. The EPA suggests thoroughly draining and flushing all portions of the ships that could contact fuel. Included is a detailed list of the items to be cleaned – pipes, tanks, engines, gauges, hydraulic systems, bilge areas and grease reservoirs. For some items in contact with oil, complete removal is recommended for precaution.

Paint

Before the discovery of its toxicity, paints were manufactured with heavy metals, including lead compounds. Lead is now known to have adverse effects on humans, especially during developing years. In addition, it is poisonous to some marine organisms (U.S. Environmental Protection Agency 2006). The undersides of ships are coated in anti-fouling agents that include copper, organotin compounds, and zinc (U.S. Environmental Protection Agency 2006). These coatings contain biocides to prevent the accumulation of organisms on the ships, like barnacles, algae, and bacteria. By definition, biocides are harmful to organisms and should be removed from ships before using them at reefs. However, often by the time ships are obtained for reefing, the anti-fouling coat is considered gone (D. Long, pers. com.). The EPA assumes that the biocides are inactive after twelve years or sooner if algal growth is prolific. In that case, they recommend doing nothing. They also recommend leaving intact paints alone. However, the paint often includes other harmful chemicals and all of it should be removed because they could deteriorate underwater. Unfortunately, this is not part of the EPA's recommendation.

Asbestos

Asbestos refers to a group of fibrous minerals often used to insulate boilers, steampipes, and hot water pipes (National Cancer Institute 2007). When manufactured into products, asbestos-containing material can come in two forms: friable and non-friable. The friable type is the most dangerous because it crumbles into invisible particles. Upon inhalation, these asbestos fibers have been shown to cause cancer of the lungs, mesothelioma, and other types of cancer (National Cancer Institute 2007). Other non-carcinogenic effects are also possible, such as scarring and inflammation of the lungs. Asbestos is only an environmental risk when airborne, but the EPA suggests proper measures should be taken to prevent the escape of friable asbestos. Although the asbestos would be submerged in water, there could be potential drift to shore, where it could dry up and be reintroduced into the atmosphere (U.S. Environmental Protection Agency 2006). Therefore the EPA method includes the removal of any loose friable asbestos wherever it is located. Since asbestos can be anywhere on the ship, even underneath parts that would not normally contain asbestos, it is recommended to hire an asbestos expert for inspection before cleaning. The EPA recommends sealing up intact asbestos instead of removing it. This could be to prevent hazards at the shipyards resulting in extensive work with asbestos.

PCBs

The least visible of these toxics is a group of man-made chemicals known as Polychlorinated Biphenyls, commonly referred to as PCBs. In studies on their exposure to marine animals, they have been shown to induce cancer and effects on the immune, reproductive, nervous, and endocrine systems of animals (U.S. Environmental Protection Agency 2006). The international scientific community classified them as persistent organic pollutants (POPs) during the Stockholm Convention. POPs are dangerous chemicals that do not degrade over long periods of time, but rather accumulate in the environment and can be ingested by organisms. Thus this chemical becomes a concern for human health as well because trace amounts can add up in top-predator fish and other marine organisms, which are consumed by humans. The known adverse effects of PCB exposure for humans include "damage to the immune system, liver, skin, reproductive system, gastrointestinal tract, and thyroid gland" (Anonymous 2008).

They were commonly incorporated in manufactured items for the useful qualities of heat conductivity and non-flammability (U.S. Environmental Protection Agency 2006). On Navy ships, they are mostly found in the rubber around electrical wiring and in the liquid for transformers (D. Long, pers. com.). However, they can also be found in smaller concentrations in the paint, caulking, plastics, and other not-so-obvious places (U.S. Environmental Protection Agency 2006). EPA guidelines suggest removing all liquids containing any PCBs and only solid pieces with concentrations greater than 50 parts per million.

This checklist of items to be cleaned is typical of the EPA's style of command-and-control regulation. It is an effective resource because it consolidates information about the present materials, their environmental toxicity, and recommends the most efficient manner in which to remove them. However, not all ships are built the same and further research and analysis should be done into the specifics of each of the ships cleaned for reefing. There is a category of the EPA document entitled "Other Materials of Environmental Concern." This encompasses the items that do not fit under those grand categories above. It includes antifreeze and coolants, batteries, fire extinguishing systems, refrigerants and halons, mercury, lead, black and gray water, radioactive materials, and invasive species.

The EPA seems to have thoroughly investigated the sources of toxicity from Navy ships and developed a standardized method to remove them. Post-reefing research attempts to determine whether their recommendations are sufficient.

A very important consideration raised by Alastair Iles is the type of ship being converted. The advocates of artificial reefing in California are looking at the ships in the Suisun Bay, which include old coast guard, merchant, transport, and warships (D. Long, pers. com.). Warships are more complicated than merchant ships (Hess et al. 2001) and are more likely to be "severely contaminated," requiring a greater effort to clean (A. Iles, pers. com.). The Space and Naval Warfare Systems Center (SPAWAR) assessed the ecological significance of sunken warships (Johnston et al.). By testing the dosage of contaminants of concern in the wildlife living near the uncleaned sunken warships off South Carolina, they determined the worst-case scenario for PCB contamination. The research found higher concentrations of PCBs, lead, and cadmium in fish and invertebrate tissues but not in animals from higher trophic levels. According to their benchmarks, the toxicant levels in species were low enough to declare that "creating artificial reefs with former Navy vessels containing PCBs in solid materials will not pose an unacceptable risk to the environment" (Johnston et al.).

Since "items containing PCBs may be found throughout a ship and are not always easily identifiable or readily accessible," it is close to impossible to remove all materials that contain PCBs (U.S. Environmental Protection Agency 2006). However, this study by SPAWAR showed that "residual oils and greases in bulkhead insulation were the most important sources of PCB loading" and suggested a focus on the careful selection of materials with the highest leach rate (Johnson et al.). This is why the EPA suggests the removal of only solids with PCB levels of 50 parts per million or more.

Are the ships suitable habitats for wildlife?

Since one of the main arguments for reefing is the beneficial effect on marine ecosystems, how wild species interact with artificial reefs is a relevant concern. As it stands, development in California has depleted reef ecosystems, especially along the southern coast. The California Coastal Commission acknowledges this by attempting to fix this with artificially reefs made from concrete and quarry stone (Johnson 2004). Most artificial reefs have been observed to attract life within several hours of being sunk (Johnson 2004).

Yet the marine ecology community is still unsure whether artificial reefs earnestly increase species productivity. Their apparent vibrancy may just be due to the shifting of species from a natural habitat to the artificial reefs. The species could also be merely visiting as roaming species from other habitats. Neither of those cases really increases species populations. It is called “attraction” in the so-called “attraction versus production” debate (Pickering and Whitmarsh 1997). This is not a desired result because it takes fish away from natural habitats, altering food web interactions and making natural reefs more vulnerable to degradation. It could also make some species easier to hunt for predators or to catch by fishermen. To understand the problem more comprehensively, artificial reefs should be designated as no-take zones so biologists can effectually study them (Pitcher and Seaman 2000).

What ecologists hope for from artificial reefs is “production,” which would constitute growth in the populations. How could this be done? Much analysis has been recorded on the ecological significance of artificial reefs. Pitcher and Seaman look at various factors of the artificial reefs, such as size, complexity, location. Ships considered for study can be altered to these criteria for maximum ecosystem diversity. One approach is to strategically design the artificial reef to facilitate the survivorship of all or the most vulnerable life stages. Another method is locating the reefs where they can protect the necessary species or habitats and provide for complex food webs.

Life Stages

One of the most important findings of the analysis by Pickering and Whitmarsh was that most reefs designed for commercial diving only facilitate adult species. To positively impact population growth, artificial reefs must protect egg and juvenile stage survival as well. Several methods to encourage other life stages are possible. An idea by Dick Long is to include pieces of concrete on or near the ships with holes of varying sizes. This can create havens for smaller fish where their predators cannot enter or provide spaces to lay eggs.

Location

To support California marine life, the reefs should accommodate the survival of species that have lost habitat. In Southern California, the ocean floor is muddy and sandy with no surfaces suitable for colonization or sheltered structures to lay eggs (D. Long, pers. com.). Since artificial reefs produce (as opposed to attract) best in cases where the natural habitat is lacking (Pitcher and Seaman 2000), the Southern California coast has many ideal sites for artificial reefs and that would not interfere with natural reefs.

There are only a few examples of artificial reefing of ships in California, but several attempts at reefing have been tried with other items such as oilrigs, tires, and rocks. Their impact on communities has been monitored and recorded, mostly by volunteer divers. A successful example of promoting marine life is the system of oilrigs off Southern California. The helped increase populations of a depleted rockfish, the Bocaccio, by providing a surface for barnacles to live. The resulting barnacle mounds on the ocean floor were preferred Bocaccio nesting ground over the barren ground (D. Long, pers. com.). Although complex interactions like this are difficult to predict, ships could work out better than the oilrigs because they have more surface area and thus more potential to support a diverse habitat (D. Long, pers. com.).

Examining these two strategies to increase populations, it is clear that artificial reefs would have a positive impact on the Southern California coast. The natural habitats have been depleted in a historically species rich area (D. Long, pers. com.). Placing any structure down there will definitely attract some species, but it will eventually become a habitat to support the food and shelter needs of marine species. They can also be designed to target specific depleted species and vulnerable life stages.

Another concern is that once marine life has been attracted to these areas, they become easier targets for fishermen. This could actually deplete fish populations further instead of enhancing them. A solution would be to establish reefs as "no-take" zones, in which fishermen cannot remove species. However, the sizing of these zones is important since fish and many other organisms dependent on these habitats are mobile. A "postage-stamp sized" no-take zone would not successfully protect the reef habitats from over-fishing (D. Long, pers. com.).

Do California's ship reefing advocates acknowledge these environmental concerns?

Much of the debate over artificial reefing is concerned with the financial dynamics. Pro-reefing advocates predict economic benefits for local shipyards, the diving industry and other amenities for tourists, such as food and lodging. In many cases, this has proved true. Records of local economics in Florida demonstrate that artificial reefs boost business sales a substantial amount (Johns 2001). In addition, the RAND report on ship disposal options focuses primarily on economics. According to their metrics of analysis, reefing wins out at the cheapest, most efficient option. Therefore, it is not surprising that the California ships-to-reefs movement also takes this economic approach to gain support because all the numbers are in their favor. However, this framing casts a shadow over the relevant environmental problems. Dick Long, says that he tries to make reefing decisions "guided by science," but the political and public sentiments are guided by money. His ultimate goal is to promote wildlife on the ocean floor for the benefit of future generations and wants the ship clean enough to eat off before sinking it (D. Long, pers. com.).

These intentions are idealistic from an environmental standpoint. To examine if these goals actually impact concrete decisions and procedures, we can assess the status the Yukon, a warship from Canada that was reefed in 2000 near San Diego.

Toxics

The major organizer of the Yukon project was Dick Long, founder of the Diving Unlimited International. In an interview, he described the cleaning of the Yukon. His stated goal is to work with the best science to remove harmful toxicants from the ships. The ultimate purpose of reefing is to enhance biodiversity and poisoning the fish detracts from this goal.

Paint was removed from above the hull because it contained lead. Below the waterline, the antifouling paint was assumed to be inactive (D. Long, pers. com.). However, a study by the San Diego Oceans Foundation later found that the antifouling agent was hindering colonization of invertebrates and algae in some areas (Parnell 2005). All liquids, including fuels and PCB-containing transistor fluid, were thoroughly flushed. All electronics, which are covered in toxic insulating materials and contain heavy metals, were also removed.

Habitat and Ecology

To mark the ecological impact of artificial reefs and assess the outcomes of those goals, thorough monitoring of the environment was undertaken prior to and subsequent to the reefing of the Yukon. A report entitled *Ecological Assessment of the HMCS Yukon Artificial Reef off San Diego, CA (USA)* was released by the San Diego Oceans Foundation five years after the sinking (Parnell 2005). The controversy about whether the reef does more than only attract wildlife or effectively enhances population was not touched in this study because more comprehensive methods are required.

The report nevertheless showed that the reefs are vibrant with life. The reef has experienced a natural succession of colonizing species. The Yukon is part of a network of artificial reefs, which appear to work together as stepping-stones for mobile species. It has proven to be a successful recruiter of sheephead and Bocaccio, fish that are depleted from overfishing. Although kelp growth has been confirmed on the flat hull, the ship's surface is not suitable for firm attachment required by kelp forests. In total, the Yukon has lower species richness than natural reefs, but it has not yet reached its highest succession stage. Studies are continuing to monitor the progress of the artificial reef habitat.

V. Discussion

Some of the potential problems of artificial reefing are clear. Dumping dangerous pollutants and interfering with natural ecosystems are valid concerns. The findings conclude that these issues are currently addressed by regulatory agencies and reefing advocates in California. However, closer analysis of the situation is still warranted.

The toxic materials onboard are a deep concern for some opponents to the plan. Although the EPA has developed an easily accessible resource after much research, this is not necessarily comprehensive. It is possible that the EPA has not yet identified all the harmful chemicals or the proper cleaning methods. For instance, when the harmful effects of PCBs were unknown in the 1980s, PCB-containing materials were not removed from ships prepared for reefing (Johnston et al.). Currently, the EPA requires no action on solid materials below a certain concentration of PCBs. In addition, antifouling paint should be removed even if it is expected to be inactive because it negatively impacted Yukon colonization. Should future research dispute the validity of these recommendations, the current methods could promote environmentally damaging practices. It is necessary to update guidelines to ensure that new information is propagated as soon as it becomes available.

A California or national reefing program could be the medium through which a standard set of cleaning protocol could address the incorporation of new science. The ideal reefing program would ensure that cleaning standards are effective and enforceable without being too overbearing. Several existing state offices could take on the regulation of reefing, like the California Environmental Protection Agency, the California Department of Fish and Game, or the California Coastal Commission. Alastair Iles warns that those in charge of setting the standards and procedure for cleaning "should be independent of the Navy and the state agencies that permit the disposal of the ship." This distribution of duties would avoid potential misrepresentation of data because of biases while providing a system of checks and balances.

To best protect the wildlife living within a reef, it is important to restrict the fishing allowed in the area. By attracting fish, these reefs are a jackpot for commercial fishing, yet this could result in an effective decrease in populations instead of enhancing them. This would be a problem if depleted species are attracted to the habitat and thus become more vulnerable to overfishing. An effective solution would be to create "no-take zones" in which fishing is banned within a specified perimeter around the ship. The California Department of Fish and Game has the power to enforce a no-take policy. However, in the case of the Yukon near San Diego, California Fish and Game refused to make the area a no-take zone because of limited staff for monitoring purposes (D. Long, pers. com.).

There are considerations aside from the main environmental focuses of this paper. Practically speaking, those ships have wasted away there for decades because there was no incentive for faster action. Considering the historical trend, they would probably have continued to remain there for decades more if the San Francisco Regional Water Quality Board had not recently sued the Navy. Reefing provides a new option with exciting prospects for tangible economic benefits. This could motivate private and state actors into clean-up action much faster.

Since a current hindrance to artificial reefing efforts is funding, a reframing of the problem could help pay for the expenses. Considering that the ships leak toxins into their surrounding water environment, the recognition of these ships as hazardous waste could make them eligible as Superfund sites. This could provide money for those planning to clean up the ships and reef them. Another environmental protection law that applies is the Endangered Species Act. Designing and positioning artificial reefs to target certain species is a potential way to protect endangered animals. Therefore ships to reefs projects could receive federal backing for their application as conservation tools.

Artificial reefs can be beneficial to scientific research. Since artificial reefs are essentially a blank slate on an otherwise uninhabitable ocean floor, they are perfect for witnessing and studying succession stages and colonization strategies. Another potential funding source for ships to reefs projects could be the oceanography research departments of universities.

Although there are many potential ecological risks to artificially reefing ships, there also exist viable solutions. There are also additional benefits for the environment, including speedier-than-natural clean up of hazardous sites and information for scientific research. Funding for these interesting projects is limited, but untapped sources from government protection legislation and private businesses could be utilized. Hopefully a state or federal reefing program can streamline the process use our waste to create life on the ocean floor.

VI. Abstract

Retired Navy ships waiting to be disposed of currently pollute the waters of the Suisun Bay. Of the available options, artificial reefing is the most economically promising. From an environmental standpoint, the disposal of these ships bears the benefits of cleaning up toxic wastes in addition to enhancing wildlife. A setback is the presence of multiple contaminants on these ships, which would require thorough removal in the reefing preparation process. After an assessment of the toxic clean-up and ecological impact of other Navy vessels, artificial reefing was determined to be a safe and desirable option for these ships with a few concerns. Recommendations are offered to abate those concerns.

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