Short Sea Shipping: A Compatibility Model

Technical Analysis prepared for Friends of the Earth

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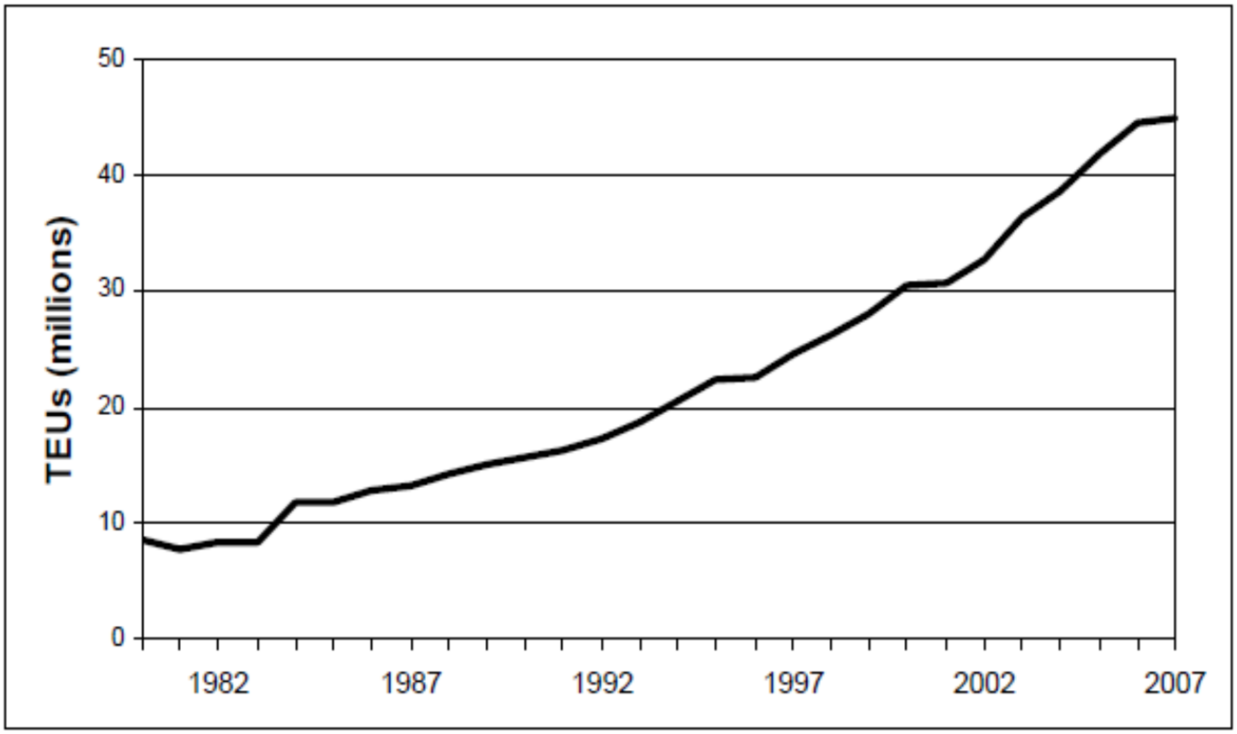
** The views expressed in this report are those of the authors, MPA candidates at San Francisco State University at the time it was written, and do not necessarily represent those of Friends of the Earth.*

I. Introduction

The transportation of freight is a vital component of our economy, as both an indicator of and a contributor to economic growth. Transportation networks facilitate the movement of goods and are an essential element of the level of prosperity present in society. The current trends of globalization over the past two decades have led to a significant growth of both international and domestic freight transportation. This increase of domestic cargo transportation in the United States has been carried out mostly by trucks, and this has caused environmental and social problems. Traffic congestion, air pollution, highway accidents, and increased energy consumption are all direct results arising from the transportation of freight by truck. In 2007, highway congestion alone cost an estimated $78 billion in wasted fuel and lost productivity (Schrank and Lomax, 2007). Trying to alleviate congestion on the road by expanding and building new roads would be far too costly to be feasible. The U.S. Federal Highway Administration estimates that the average cost of highway construction is $32 million per lane mile, without including the cost of interchanges, bridges, or factoring in the costs of environmental externalities (Denisis, 2009).

While freight traveling by truck is increasing, so is the amount of freight traveling by sea through America’s ports. As shown by Chart 1, container traffic through U.S. ports exceeded 44 million twenty-foot equivalent units (TEU’s) in 2007, and that number is expected to double by 2020 (Ibid.). This major increase in cargo flow has placed strains on the U.S. transportation network with major coastal ports operating near their maximum capacity.

Chart 1 – Container Traffic at US Ports



(Source: American Association of Port Authorities, 2008)

In the Bay Area, that increase in cargo flow is acutely felt at the Port of Oakland. The Port of Oakland is currently the 5th largest container port in the United States and the 3rd largest in California, after Long Beach and Los Angeles. (Cannon, 2009). Overall container growth grew 51.6 percent from 1998 through 2007, and is expected to double by 2020. This expected growth makes it clear that the impacts of emissions, pollution, and other environmental impacts of container shipping will be concerns for years to come.

To start with the basics, there is no clear consensus on the definition of short sea shipping (SSS), but the definition given by the U.S. Maritime Administration as “a form of commercial waterborne transportation that does not transit an ocean and utilizes inland and coastal waterways to move commercial freight” is the most widely accepted (Denisis, 2006, p. 3). The practice of using waterways for transporting freight has been utilized since the ancient times. In the United States, cargo is shipped along the Mississippi, Missouri, and the Ohio Rivers, and also within the Great Lakes. While SSS along these waterways was once extremely common, currently only 9 percent of total cargo by weight is being transported by water in the Mississippi River system and the Great Lakes versus over 60 percent that is being transported by trucks (Bureau of Transportation Statistics, 2006). As noted above, with highways operating at near capacity and environmental concerns becoming an increasingly large part of the discourse on transportation effects, an effort is underway to revive SSS as an alternative and sustainable mode of freight transportation.

This paper will examine possible direct and indirect effects of SSS, with a special lens looking at the proposed SSS routes between Oakland, Sacramento, and Stockton, California. First, the possible effects to marine animals due to the acoustic noise generated by SSS vessels will be examined. Second, the effects of possible SSS vessel collisions with sea life and the potential for aquatic non-native species (ANS) contamination caused by SSS vessels will be evaluated. Third, pollution caused by SSS vessels will also be investigated, with a comparison of the amounts of pollution caused by those vessels, railways, and trucks on the road. Fourth, the research completed on the effects of dredging to expand ports and waterways will be presented, and then an effort will be made to monetize all of these different effects together to try and determine quantitatively whether SSS is not only more environmentally friendly, but more cost-efficient than other forms of freight transportation. Finally, this paper will conclude with recommendations to Friends of the Earth for the position they should take on the specific SSS routes being planned between Oakland, Sacramento, and Stockton.

II. Acoustic Interference

San Francisco Bay is home to a wide range of marine mammals, including a significant number of North Pacific harbor seals, California sea lions, and North Pacific harbor porpoises

(California Seafood Council, 2010). Among the wide range of marine life in the San Francisco Bay, there exist several species of cetaceans that rely on echo-location and other forms of signaling for communication, breeding, and migration. Sounds produced by vessels (under the general category of human initiated, or anthropogenic noise), particularly in the 20-200 Hz range, are of concern for these animals, for some marine mammals communicate in this signal range. Shipping noise is a threat because it can interfere with some animals' ability to communicate (by masking noises important to animals' behaviors), and animals may change their patterns to avoid certain locales altogether if the noise produces too much stress (Tyack, 2008).

One effect of shipping noise on marine animals is increased compensation for masking by producing stronger or more frequent sounds, which can be dangerous if predators that would not normally hear these calls can locate signaling animals more easily. For example, from 1977 to 2000 the Southern right whale increased the frequency signal of its contact call from about 65 Hz to about 75 Hz and the North Atlantic right whale heightened the frequency signal of its contact call from about 65 Hz to about 95 Hz from 1956 to 2000; both shifts in call frequency are thought to emerge as a result of expansion in low-frequency shipping sounds (Tyack, 2008; see Chart 2). Over time sound exposure from shipping can lead to hearing loss, decreased habitat use, prey detection interference (although that particular effect of shipping noise has not been thoroughly researched (Ocean Studies Board, 2003)), and eventual relocation of environment. In addition, different factors affect an animal's susceptibility to stress, such as the duration of time an animal has to adapt to noise, time of year (animals may be more vulnerable during breeding season or stronger after having migrated and returned from a warmer location) (Tyack, 2008), environment (a stress study on a captive animal may produce drastically different results from an animal living in its natural habitat, plus laboratory studies are relatively short-term and cannot observe changes that may be produced over long periods) and age of animal (as stress produces a heightened response on the growing brain (Studds & Wright, 2007). Therefore a series of diverse studies analyzing different trends in the environment should be performed.

Chart 2, Right whale frequency model

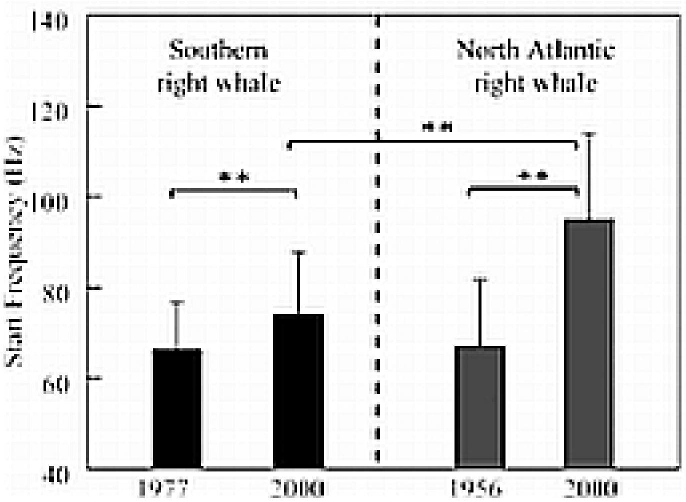


Chart 2 (From Parks et al., as cited in Tyack, 2008). Although 1977 and 1956 measures of frequency signals are roughly the same, over time signal ranges of right whales in the North and South Atlantic have increased, likely as a result of low-frequency shipping noise propagation.

For example, although shipping patterns may not differ drastically according to time of day (as some vessels operate all hours), the nocturnal patterns of animals can be quite varied from diurnal behaviors, so night and day noise impact studies would be advisable. It would also be practical to research effects in high and low activity areas (on account of both ship and animal behaviors) throughout a long enough observation period to account for differences in seasons (Southall, 2010).

Studds and Wright (2007) suggest that even a small amount of interruption in an animal's routine behavior can lead to significant and possibly permanent damage. Unfortunately, it may not be possible to know when an animal has been exposed to a dangerous level of stress (i.e. when the animal has been significantly harmed in some way by stress); since it may appear that an animal has acclimated to a situation when in fact it has not. For example, if an animal responds to noise interference with fatigue, it may not have the energy to swim away and will remain in a dangerous area, appearing to be tolerant of a threat even though it simply is too tired to move. Or an animal may respond to noise by leaving a highly noisy area or by stopping signaling to communicate altogether until the noise has ceased; a response particularly common to ambient noise disruptions in the ocean, where signals are lower. Sometimes animals may change the pattern or increase the frequency of communication in response to ambient noise (Studds & Wright, 2007).

Communication altering can be especially harmful to animals, such as baleen whales, that communicate over long distances, as an animal in one location may experience different ambient noise patterns and not recognize the signals from a mate surrounded by higher noise volume. Signal miscommunication can lead animals to be misled into believing that certain sounds are from prey, mates, or predators, when they are not and may cause animals to unnecessarily expend energy (Tyack, 2008).

How does the potential for damage inflicted by noise interference affect animals in and around the San Francisco Bay? The Bay is a marine sanctuary for many animals and shipping noise could be very damaging to marine life. Although there are several different types of marine mammals in the Bay, Southall (2010) suggests focusing on pinnipeds and fish chorusing in particular. Chorusing occurs when a large group of animals produce a cohesive sound emission, i.e. a call, and fish chorusing can heighten depending on time of day (e.g. chorusing can often increase at sunset) and year. Fish chorusing is a signal that is crucial to spawning, although the level of noise exposure and possible effects on chorusing from shipping has not been thoroughly researched (Ocean Studies Board, 2003). Pinnipeds, i.e. seals, sea lions, and walruses, are especially vulnerable to noise exposure, as they live both underwater and on land, and ships produce both underwater ambient sounds and emit noises above water. Ambient sound interference can be harmful to pinnipeds' abilities to gather food, navigate, and avoid predators, and loud noises produced by shipping vessels can be harmful to mother-offspring communication and breeding, both of which are dependent on sound signals. Both underwater noise disruption and sounds heard from land can cause problems related to hearing, particularly noise-related temporary threshold shift (TTS) (Kastak et al., 2007).

TTS is temporary hearing loss caused by noises that are not considered to be in the normal safe range of sound or can be induced by noises that would normally not be harmful, but are because they last too long (National Institute on Deafness and Other Communication Disorders, 2010). TTS causes assorted changes in sensitivity, and studies have shown that recovery from noise exposure may vary among species and individual animals (depending on several factors, such as original level of hearing before exposure to disruptive sounds, the amount of change in threshold level, age of animal, sex, and noise damage infliction an animal has already experienced) (Kastak et al., 2007). When studying the effects of shipping noise on pinnipeds it is important to note that pinnipeds can be separated into two categories in relation to hearing abilities. Otariids, or sea lions and fur seals, are susceptible to effects from sounds in a spectrum along the mid-frequency range, along 1 kHz to 30 kHz (as opposed to phocids, i.e. walruses, which hear at a lower to mid-sound range of 0.2 kHz to 50 kHz) (Southall, 2005). One option is to decrease noise created by ships in the range that is more sensitive for seals and sea lions, which would be beneficial to communication between animals and help them to avoid predators. However, the possibility of collision may increase as animals may not be aware of a ship's presence since the ship will be quieter; so striking a balance between avoiding strikes and preserving a healthy acoustic environment may be tricky (Bland, 2010, as cited in National Public Radio, 2010). If sound reduction is not immediately feasible, precise (at least as much as it is possible to be exact) measurements will be prudent to better understand how much damage is incurred on marine mammals due to noise interference.

Passive acoustic monitoring (PAM), a means of recording ocean acoustics, can be advantageous in careful observation of the direct effects noise has on marine mammals. Many research methods are sensitive to the environment and can only be performed in certain conditions and seasons, whereas PAM can be done any time of year, regardless of changes in light and weather. T-PODS are one type of passive acoustic monitoring used in the United Kingdom and consist of a self-contained recording system with a hydrophone, a filter and digital memory that measure the rates of echolocation clicks. T-PODS are helpful in noting short- and long-term changes in animals that rely on echolocation. The devices (Simon et al., 2010) can be used to record activity from porpoises, dolphins, and toothed whales and they can be efficiently utilized in regions with multiple types of species. In order to better comprehend the effects of ambient sounds and noises heard from land on the behaviors of pinnipeds, NOAA (2004) recommends expanding current auditory evoked potential (AEP) technologies. AEP research should be performed in both silent (i.e. controlled) and noisy environments, e.g. experimenting in areas prone to shipping noise exposure, meaning that studies should involve captive animals and those at sea (or in this case, the Bay) (Southall et al., 2005).

<u>III. Collisions with Marine Mammals</u>

Considering the mass of a shipping vessel in relation to that of any given marine mammal, planning a short sea shipping endeavor must account for the potential of animal strikes. Factors influencing the severity of impact in a collision are: the size of the ship, the direction the ship is going as it collides with an animal, the depth of contact a vessel makes with an animal, the vessel's speed and rate of acceleration, and the time span of the collision. In particular, lowering speed of vessels has been determined as a highly significant factor in reducing a ship's risk of striking mammals (Silber et al., 2010). Of course, persons financially invested in commercial shipping vessels may object to a forced reduction in speed (for the cargo will take more time to arrive at its destination) but fuel costs would be reduced and emissions would be lowered, as less fuel would be used.

Other countries have adopted measures to decrease the risk of vessel-mammal collision. For example, Greece has developed a program to propel research in the prevention of ship strikes on cetaceans in sensitive habitats. The Real-time Plotting of Cetaceans (REPCET) program is currently being tested in the Mediterranean as of December 2009 and involves testing a tracking system of activity between ships and marine mammals. The Pelagos Sanctuary for Marine Mammals is home to a high volume of ship traffic, so it is an ideal testing facility. The reporting of mammalian activity is bi-faceted: it involves observers who look out for whale activity and send reports via Iridium satellite to a server, and the server sends out a corresponding mass message to nearby ships (who are subscribed to the network) (Ship Management International, 2010). Perhaps the Bay can take similar (or employ a more technically advanced cellular network) measures to observe and report nearby whale activity.

In the summer and fall of 2010, there have been at least six ship strikes on whales along the coast of California: near the Farallon Islands, the Monterey Bay and by the Channel Islands. Even a small number of collisions per year can be extremely significant to threatened or endangered species. For example, Scripps is currently performing research, sparked by the 2007 deaths of two blue whales as a result of collisions with commercial shipping vessels, to better understand how whales respond to the presence of large cargo ships (Bowe, 2010). One of the researchers involved in the study, Scripps PhD candidate Megan McKenna, explains that a rate of even just two whale deaths resulting from collisions per year could seriously impact the survival of the already fragile blue whale species (Ibid.). Near the San Francisco Bay, the Gulf of the Farallones and Cordell Bank National Marine Sanctuaries are home to endangered whale species, so even if a small number were harmed by collisions, the future of the entire species may be at risk. Overall, decreasing the speed of cargo ships in the Bay along with the implementation of an observation/report system could be practical steps to take in the prevention of marine mammal collisions. It may be useful to further investigate and collaborate with groups in the Mediterranean in order to create suitable Bay models and studies. Additionally, aerial studies performed on the East Coast (via the efforts of several collaborators, including the National Marine Fisheries Service, New England Aquarium, US Coast Guard, US Navy, Florida Department of Environmental Policy, Gray's Reef National Marine Sanctuary and Georgia Department of National Resources) have proven useful in preventing shipping collisions with right whales (by managing ship traffic), but the National Oceanic and Atmospheric Administration (NOAA) has determined these studies to not be completely accurate in measuring the potential of ship strikes, so they should be utilized in combination with other strategies (NOAA, 2001).

IV. Potential for Aquatic Non-Native Species (ANS) Contamination

Ballast water is responsible for the vast majority of non-native species spread, especially along the coast, since organisms can more easily survive shorter trips associated with coastal transport (Simkanin et al., 2009). Unfortunately, there is not a large body of research focused on shorter voyages; rather most studies concentrate on longer distances within and between large oceans. However, there is a small amount of existing recent data analyzing the spread of aquatic non-native species (ANS) in four different West Coast ports: Puget Sound (PS), Lower Columbia River (LCR), Los Angeles/Long Beach (LA/LB), and San Francisco Bay (SFB), as provided by Simkanin et al. (2009). For the purposes of focusing narrowly on the effects ballast water could have (were short sea shipping to become a regular occurrence between various coastal ports and not limited to the ports of Stockton, Oakland, and Sacramento) on ANS distribution in the Bay, this report will not relate the findings concerning the three other ports unless they could significantly affect the spread of ANS in SFB.

The study took place throughout the 2005 calendar year and examined how many ships within seven categories (barge, bulk carrier, container, general cargo, ro-ro, tanker, and any others not applicable to those types) were responsible for expelling ballast water and their methods of expulsion. In their gathering of ANS data, which solely consisted of studying invertebrate species, Simkanin et al. relied on the Smithsonian Environmental Research Center's National Marine and Estuarine Species Information System (NEMESIS) (Ibid.). The researchers acknowledged several barriers to accurate data collection, namely that the number of ANS in any given area may vary and that prior research of ANS relative to ballast water is sparse, so collective knowledge in this arena is limited.

Of the ports studied, SFB had the least amount of ballast water discharged. SFB was home to the highest volume of traffic and therefore received the greatest ballast water distribution from other ports. The Bay was also unique in that it dealt largely with coastal, rather than overseas, ballast water, and tankers were the primary source of incoming vessels. Ninety-five ANS were found in SFB, out of the total one-hundred and thirty-three ANS discovered among all four ports in the study. The main source of ANS spread overall was found to be ship fouling, but in the case of one species uniquely observed at a single port in the study, the key source of vector contamination was ballast water. Since half of the species have been found to spread via ballast water distribution, regulatory means have increased in order to reduce further potential ANS spread to other ports. For example, the PS port was found to be a suitable environment for the mitten crab, which is highly present in SFB. Although ships traveling from SFB to PS were responsible for the expulsion of 47,520 MT of ballast water in PS, stricter ballast water self-management (per Coast Guard and US EPA regulations) has prevented the invasion of the crab to the PS port (Ibid.).

There are several challenges to estimating the actual threat and primary vectors (i.e. ballast water, ship fouling, etc.) responsible for transportation of ANS, primarily in that ANS move about the vectors in different phases. For example, it may be hard to measure the potential longevity of an invasive species if the organisms are only in their larval stage, as there is no certain means of knowing if the organism will continue to thrive as it matures in its new habitat. ANS must be continually observed from the point of introduction and throughout their colonization period in any given foreign aquatic habitat (Ibid.). Furthermore, it may be useful to apply anti-fouling agents to ships, but the risk lies in using environmentally-friendly chemicals as some, such as tributylin (TBT), are highly toxic (Krozer, 2003).

ANS, of course, is only an issue in the transportation of species over longer distances than would be relative to the short trips between the Delta, Sacramento and the Bay. However, it may be useful to acknowledge the potential for species spread if short sea shipping is further popularized and utilized more frequently between several different ports.

V. Pollution Caused by the Short Sea Shipping Vessels

Another issue to recognize when examining the effects of short sea shipping is the level of possible water pollution caused by the shipping vessels. Pollutants could include: oil, gas, or other maintenance fluids leaking into the waterways; on-board behaviors and potential accidents; and exhaust emissions from the vessels. Specifics would be difficult to discuss without knowing the exact type of vessels being proposed for use in the California Delta region. Whether the ship is a smaller Load-on Load-off (Lo-Lo) or a Roll-on Roll-off (Ro-Ro) will dictate some of the dangers that are specific to those types of vessels; therefore, this examination of possible dangers will lean towards the more general.

First of all, the possibility of fluid leaks from these ships could be devastating to the ecosystem of the California Delta. This is a risk that currently is present when looking at all ships traveling on the waterways around the world, but a major increase in vessels transporting goods within the Delta region would increase the possibility of fuel leaks. Nengye and Maes (2009) note that any increase in ship traffic will undoubtedly increase the amount of pollution in the waterways from those ships. These concerns could be alleviated though through the increased use of less toxic and/or organic fluids and lubricants. Also, to further reduce the amount of chamber waste that could be introduced into the ecosystems, regular engine maintenance must be performed, as well as the utilization of high grade lubricant (Krozer, Mass, & Kothuis, 2002).

Reducing the amount of waste that each vessel produces that then could contaminate the waterways can be both simple and cost-effective. For example, the use of gasoil in ships instead of traditional heavy oil can produce a 40 to 45 percent fuel savings (Ibid.). Generally, these methods require an initial investment, but reduce the amount it costs to actually run the ship over the course of its lifetime. Any push to legislatively mandate these types of environmental protections could run into cost arguments, but the overall cost saving rebuttal may be enough to make those arguments moot.

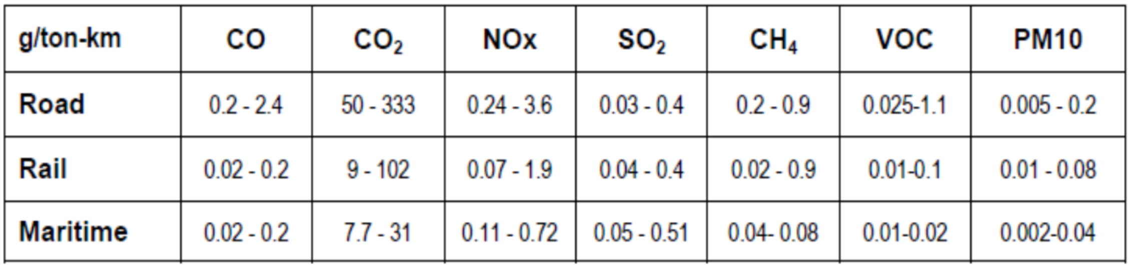
As with any activity involving humans, the potential for accidents and other unforeseen consequences must be examined. First of all, there always exists the possibility of operators, either through official acts of the company or the actions of a lone employee, illegally dumping or not carrying out proper environmental protocols. This has happened in other industries where the cheaper and/or easier way to dispose of some hazardous material is to simply throw it away.

Also, there exists the possibility of accidents that could cause fuel or other hazardous wastes to be spilled in the waterways. The *Exxon Valdez* oil spill in Alaska and the *Cosco Busan* fuel spill in the San Francisco Bay are both stark reminders of what can occur when inattentive captains and crew fail to carry out their duties to the highest level. Of course, it is necessary to note that these events were extremely rare and out of the norm. In fact, Paixao and Marlow (2001) note that the risk of traffic accidents for trucks carrying goods is much higher than the risk for short sea shipping vessels. That may be true, but they also note that the potential damage caused by an accident at sea in a delicate ecosystem could be devastating environmentally.

Another pollution concern of short sea shipping vessels is harmful air emissions. Psaraftis and Kontovas (2010) conducted a major study on CO_2 emissions, specifically comparing the emissions of trucks and container ships. They found that while ships may exhaust as much CO_2 as a truck does, the ship can haul up to 50 times more cargo, which means an overall decrease in the amount of CO_2 produced per unit of cargo shipped. Also, there are ways ships can further decrease the amount of air pollution they exhaust. For example, scrubbers can be installed on the exhaust system or the ship can simply operate at a slower speed (Nengye & Maes, 2009). Operation at speeds as high as 14 knots were shown to have an optimum effect on carbon emission reductions, and within the California Delta Region, this speed would probably be close to actual operating speed.

Oses and Castells (2009) conducted a report on the pollution impacts of short sea shipping compared to the road alternative. Their research found that the sea method of shipping can produce a definite cost and fuel savings, as well as reduce CO_2 emissions. Also, as shown by Chart 3, SSS has the lowest amount of emissions of air pollutants in grams-per-ton for all surface transportation modes. It is important to note that this information was obtained through a European study, and their regulations governing vessels may be more stringent than in the United States.

Chart 3 – Emissions of Air Pollutants in grams-per-ton for Surface Transportation Modes



g/ton-km	CO	CO_2	NOx	SO_2	CH_4	VOC	PM10
Road	0.2 - 2.4	50 - 333	0.24 - 3.6	0.03 - 0.4	0.2 - 0.9	0.025-1.1	0.005 - 0.2
Rail	0.02 - 0.2	9 - 102	0.07 - 1.9	0.04 - 0.4	0.02 - 0.9	0.01-0.1	0.01 - 0.08
Maritime	0.02 - 0.2	7.7 - 31	0.11 - 0.72	0.05 - 0.51	0.04- 0.08	0.01-0.02	0.002-0.04

(Source: Kamp, 2003)

VI. Dredging

In order to establish a short sea shipping route between Oakland and Sacramento, some dredging of the sea floor would inevitably occur. New docks would need to be constructed, current estuary waterways would need to be expanded to allow for increased ship traffic, and new routes would probably need to be developed and constructed. Levin et al. (2001) makes it clear the importance of having a stable level of sediment within ocean environments, and also notes that dredging kicks up sediment in the ocean that can disrupt sea life; therefore, it must be further examined.

In the San Francisco Bay specifically, a study on the effects of dredging on sea life was conducted by Jabusch, Melwani, Ridolfi, and Connor (2008) for the San Francisco Estuary Institute. Their study examined the impacts of dredging on the populations of five different types of fish present in the San Francisco Bay: Chinook salmon, coho salmon, delta smelt, steelhead trout, and green sturgeon. It also considered: (1) the potential presence of chemicals associated with plumes resulting from dredging and dredged material placement, (2) chemical processes affecting their potential short-term impacts on fish (e.g. reduced dissolved oxygen, decreased pH, chemical transformation reactions, changes in bioavailability), and (3) potential for acute toxicity or subacute biological effects on sensitive fish species resulting from short-term exposure to dredging-related water quality impacts (Jabusch et al., 2008).

They found that dredging has an immediate impact on the ocean environment, specifically that during dredging: (1) the particulate organic mater (POM) concentration in the water increases; (2) dissolved organic matter (DOM) bound pollutant concentration in the water column increases; (3) the total concentration of pollutant in the water increases; and (4) POM with different pollutant concentrations are mixed. While these effects will occur fairly quickly after dredging activities, it can take months to years for the water environment to reach its optimum equilibrium level again (Jabusch et al., 2008).

Ultimately though, they found that dredging has little short-term or medium-term impact on the sensitive fish species studied. The most likely contaminant of concern to exert short-term direct effects is ammonia, but ammonia sensitivity is very species dependent. Saltwater fish are believed to be more sensitive to ammonia than freshwater fish (Jabusch et al., 2008). Since most of the fish in the San Francisco Bay and the Delta System are saltwater fish, their susceptibility to the harmful direct effects of dredging in their habitats must be noted.

Besides the impact that dredging can have on the species of fish that live in the areas in question, the estuaries and critical transition zones (CTZs) that link land and freshwater habitats to the sea can be negatively impacted by dredging (Levin et al., 2001). CTZs provide essential ecological functions, including decomposition, nutrient cycling, and nutrient production, as well as regulation of fluxes of nutrients, water, particles, and organisms to and from land, rivers, and the ocean. These areas though are under constant threat from both natural and man-made activities (Levin et al., 2001).

Dredging specifically can have a major negative impact on CTZs. It can substantially modify the depth, direction, and velocity of water flows, as well as alter the transport and redistribution of sediment and other materials. Levin et al. (2001) found that dredging causes the loss of CTZs, which leads to less biodiversity. The dredging and increase of sediment in the water affects almost every type of living thing there, from the smallest organism to plants to fish. While its impact can be felt on all levels of life in the water, it is not a permanent situation, and how harmful it actually is to the life is difficult to measure. Levin et al. (2001) also found that water sediment levels and salinity will return to equilibrium after months or years.

One factor regarding the effects of dredging on sea life that Levin et al. (2001) and Jabusch et al. (2008) agree on is that more research must be conducted to further examine the indirect effects of dredging. While it is clear that dredging kicks up sediments in the water, they both found that actual measurements as to how harmful it is long term to aquatic life are inconclusive. At this time it is known dredging affects sea life, it is just not known whether that effect is serious in the long term. Also, Bray (2008) notes that generally the acute toxic affects of dredging are seldom seen in areas exposed to currents and waves, which is the situation in the San Francisco Bay Area.

VII. Monetization of the Potential Environmental Impacts

While actually monetizing the potential environmental impacts of short sea shipping is extremely difficult and subjective, some research has been completed that has attempted to do just that. For example, Kreutzberger, Macharis, Vereecken, and Woxenius (2003) conducted an analysis comparing the environmental impacts of intermodal freight transport (including short sea shipping) with a transit system that relies solely on all-road transport methods. They analyzed a mixture of transport methods and not just short sea shipping alone because most people agree that the addition of SSS methods within a region would not altogether replace road transport, it would simply reduce the number of trips completed by on-road transports (Ibid.). They examined a variety of external effects of both intermodal and unimodal transport that has already been discussed in this paper, such as: noise, pollution, and potential for unforeseen disasters.

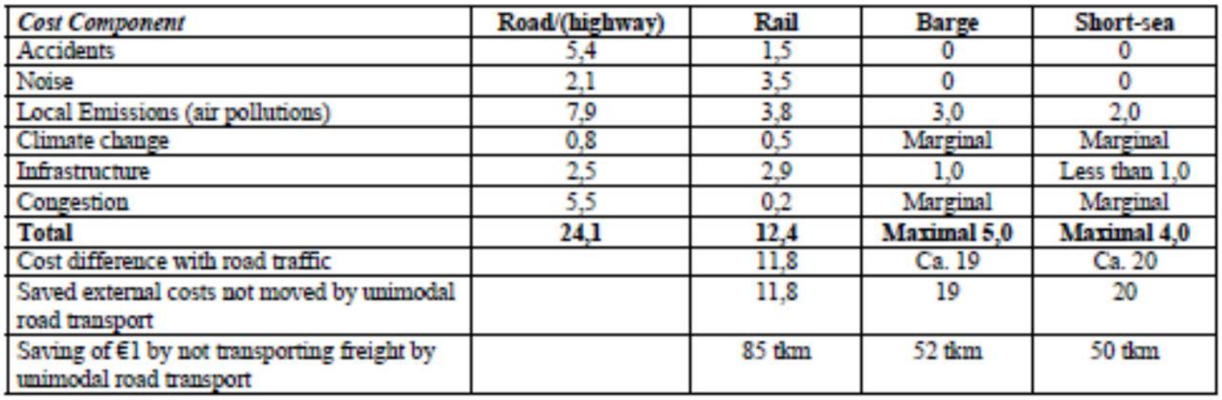
These researchers note that the field of measuring external transport costs is rather complex and largely depends upon the method used to actually attempt to measure them. Many aspects must be distinguished:

1. The focus of the study;
2. The economic approach;
3. The transport system aggregation level;
4. The system chain;
5. The range of external effects;
6. The external cost strategy;
7. The methods of effect and impact estimation;
8. The methods of impact valuation;
9. The instruments to realize the internalization; and
10. The modality analyzed.

All of these aspects must be recognized and serve as a checklist for future researchers when attempting to measure the externalities related to transport systems. The review of literature already completed on this topic was put through that rigorous checklist and they examined the seemingly simple research question: Is intermodal transport more environmentally friendly than all-road transport?

Overall, they found that intermodal transport is more environmentally friendly if only energy use and CO_2 emissions are taken into consideration, but is even more friendly to the environment if local emissions, accidents, congestion, and the noise effects on humans are included in the calculations. Furthermore, as exhibited in Chart 4, they found that when simply comparing short sea shipping methods to on-road or train transport, the transporting of goods by barge had the lowest external costs. It should be noted that their analysis did not factor in the costs of building and maintaining new facilities, the costs associated with pre- and post-haulage of the goods to the shipping terminals, or other cost factors that could be unique to the Oakland-Stockton shipping route which is the major focus of this paper. Even with those omissions from their research, the work of Kreutzberger et al. (2003) was the most complete and up-to-date analysis of the monetary costs associated with different transport systems. It must be noted though, that the Kreutzberger monetization model only takes into account the harm noise causes to humans, and not the potential harm to sea life. The damage from acoustic noise in the water must be examined separately.

Chart 5- External Cost per Transportation Method



Cost Component	**Road/(highway)**	**Rail**	**Barge**	**Short-sea**
Accidents	5,4	1,5	0	0
Noise	2,1	3,5	0	0
Local Emissions (air pollutions)	7,9	3,8	3,0	2,0
Climate change	0,8	0,5	Marginal	Marginal
Infrastructure	2,5	2,9	1,0	Less than 1,0
Congestion	5,5	0,2	Marginal	Marginal
Total	**24,1**	**12,4**	**Maximal 5,0**	**Maximal 4,0**
Cost difference with road traffic		11,8	Ca. 19	Ca. 20
Saved external costs not moved by unimodal road transport		11,8	19	20
Saving of €1 by not transporting freight by unimodal road transport		85 tkm	52 tkm	50 tkm

(Source: Kreutzberger et al., 2003).

Denisis (2009) expanded upon some of the conclusions presented by Kreutzberger et al. His work focused on ways short sea shippers could further improve their environmental performance by lowering ship emissions while at port, where most of their external costs occur. Through a thorough cost analysis, the conclusion was drawn that even though short sea shipping has high emissions with regard to certain pollutants and specific locations, such as at port, given the lower pollutant cost overall, its performance in terms of monetary impact on emissions is superior to unimodal transport systems. This fact, in combination with the extremely high energy efficiencies of short sea shipping and its congestion mitigation benefits, proves the superiority of short sea shipping to unimodal all-truck transportation in terms of lower monetized costs.

VIII. Conclusions

The preceding analysis has attempted to examine the varied potential benefits and drawbacks of short sea shipping in the Bay Area. As the above research has concluded, when externalities of different types of transportation systems are monetized and examined, intermodal transportation, especially short sea shipping, is a more cost-effective and environmentally friendly method of transporting freight in regard to emissions and efficiency. However, further research is necessary to better determine both the short- and long-term effects SSS may have on marine life, particularly mammals and their abilities to communicate and swim safely. Proceeding from here, scientists and government officials would benefit to collaborate in order to create an effective and harmonious shipping environment.

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