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An Environmental & Economic Analysis of Cruise Ship Discharges in California State Waters

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Introduction

In recent years, California has experienced an unprecedented increase in cruise ship traffic. For instance, in 2002 California ports handled over 700,000 cruise ship passengers, making it the second largest market (behind Florida) for the cruise industry in the United States. As a result, California received approximately 10% of the industry's direct spending, amounting to over $1 billion[i]. While these figures show that cruise ships contribute significantly to California's economy, there is concern that cruise ships may also be contributing to the degradation of California's coastal waters.

An average one-week cruise ship voyage generates more than 50 tons of garbage, one million gallons of graywater (wastewater from sinks, showers, galleys, and laundry facilities), 210,000 gallons of sewage (blackwater), and 35,000 gallons of oil-contaminated water[ii]. This wastewater discharge rate is roughly equivalent to the wastewater production of a municipality with a population of 2,000. The problems associated with these wastewater streams and their potential impacts on California's coastal resources could escalate in the near future, as the cruise industry is expected to expand by 8.5% each year for the next ten years[iii].

In an attempt to minimize the environmental effects that cruise ship discharges have on California's coastal resources, several state laws (AB 121, AB 433, and AB 906) have recently been passed. However, these new state laws fail to address blackwater and graywater wastestreams, two major components that could be affecting the health of California's coasts. In addition, the California Cruise Ship Environmental Task Force Report made specific recommendations to increase regulation of cruise ships. Consequently, new state bills will be proposed this year calling for further regulation of cruise ship discharges, including blackwater and graywater. However, there is a lack of scientific information on the effects of blackwater and graywater to the environment and marine communities, making it difficult to determine the appropriate level of regulation required to keep California's coast safe from degradation. Our project focuses on these wastestreams and attempts to identify some of the potential environmental effects of treated blackwater and untreated graywater discharges to California state waters. In addition, we attempt to value these environmental effects upon California state beaches through an economic analysis. Our main objective for this project was to supply stakeholders with information to assist them in effectively regulating cruise ships in California.

Objectives

1. **Identify potential environmental effects of blackwater and graywater wastestreams in California state waters.**
2. **Value the environmental impacts on California state beaches.**
3. **Supply stakeholders with information to assist them in effectively regulating cruise ships in California.**

Project Approach

Our analysis of the effects of blackwater and graywater wastestreams is accomplished with the development of four mathematical models. The first model (Bacterial Load Dispersion Model) considers fecal coliform as an indicator of the amount of bacteria reaching the shore, thus affecting beach water quality, tourism and human health. We attempt to value these effects with an economic analysis that uses the outputs of the Bacterial Load Dispersion Model to estimate a consumer's willingness to pay for an improvement in water quality at 13 California state beaches. The last two models consider metals and heavy pollutants, thus affecting marine organisms. One of these (Priority Pollutant Dispersion Model) calculates the concentrations of metals and heavy pollutants in the water column and the other (Sinking Load Model)

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estimates the concentrations of these pollutants at the sediment-water interface on the seafloor. The results of the latter two models are used in an ecological risk assessment employing species sensitivity distributions to examine potential effects to both pelagic and the benthic marine communities.

We analyzed the outcomes of these models under three regulatory scenarios (current federal regulations, Alaska state regulations, and regulatory recommendations made by the California Cruise Ship Task Force) in order to assess the effectiveness of each in protecting California's state waters. A summary of these scenarios is found in Table 1.

	SCENARIO 1:	SCENARIO 2:	SCENARIO 3:
	Federal Regulations	Alaska Regulations	CA Task Force Recommendations
Treated Blackwater	Anywhere*	1 nautical mile at 6 knots	Anywhere*
Untreated Graywater	Anywhere	1 nautical mile at 6 knots	3 nautical miles
Treated Graywater	Not Regulated	Not Regulated	Anywhere

*Unless state designated No-Discharge Zone

Table 1: Summary of Regulatory Scenarios

RESULTS AND DISCUSSION

Our Bacterial Load Dispersion Model examines the percent change in bacterial concentration reaching the shore under each of the three scenarios. This model is based on a mass-balance approach using Fick's Law of Diffusion and accounts for the turbulent nature of currents in the ocean as well as the extinction rate of fecal coliform bacteria. It is run under average weather conditions and extreme weather conditions.

The results show that under average weather conditions nominal amounts of bacteria reaches the shore. However, under extreme weather conditions, when the velocity of the ocean current is greater than average, considerably more bacteria reaches shore. More specifically, under the Federal Regulations scenario, 94% of the original bacterial concentration reaches the shore. In comparison, under average conditions in this scenario only 0.14% reaches the shore. The results also show that if graywater were to be treated to the same standards as blackwater the concentration of bacteria reaching the shore under both average and extreme conditions would be reduced by 99%.

Bacteria at the ocean shore, for which fecal coliform bacteria are used as an indicator, have been shown to adversely affect human health. In addition, when concentrations of bacteria in the water exceed the state level water quality standards, beaches are closed, thereby negatively impacting the local community and the state as a whole. For example, preliminary results from the Southern California Beach Valuation project indicate that closing Bolsa Chica state beach for just one day during peak summer months, would result in a loss of $7.3 million. This number includes the loss of revenue from projected beach spending, as well as the regulatory costs from both state and city employees involved in closing a beach[iv]. The results of this examination led us to agree with the Task Force Recommendations and conclude that cruise ships should be required to move at least three nautical miles offshore before discharging in order to reduce the pollution that reaches the shore during extreme weather conditions. We also conclude that in addition to moving further offshore before discharging, graywater should be treated to the same standards as blackwater to most effectively eliminate the possibility of harmful bacteria reaching the shore.

We then used an economic travel cost model to determine how the demand for beach recreation changes with a change in water quality. We calculated the travel costs for visitors, including the opportunity cost of time, based on survey data collected by the California state parks visitor services section. Utilizing a hedonic equation, we regressed the average total cost of visiting a beach against the characteristics of the beach (water quality, amenities, air temperature of the beach). As anticipated, our model predicted that as water quality increases, people would pay more to visit the beach, but the effect was not statistically significant.

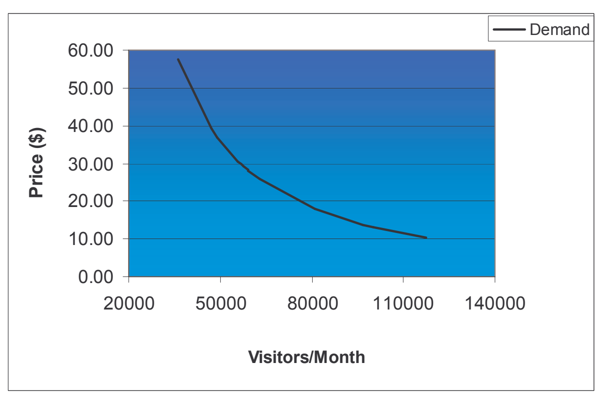

Figure 1: Demand for Beach Recreation

In order to account for simultaneity, the predicted cost from the hedonic equation was then inputted into a Cobb-Douglas demand equation. The demand for beach recreation was shown to be inelastic (See Figure 1). The results of this equation showed the effect of price on demand is negative, as expected, but statistically insignificant. Nevertheless, the effect of an increase in water quality from its impact on price can be traced through to its effect on visitation. For instance, the impact coefficient of water quality on price was \$0.09/MPN/100ml; therefore, if the water quality at Bolsa Chica State Beach was improved by 50 MPN/100ml, visitors would be willing to pay \$4.50 more to visit Bolsa Chica State Beach, a 43% increase from the predicted travel cost value.

Furthermore, we feel that the results could be strengthened by improving upon a number of factors, mainly the quality of the data available regarding beach visitation and beach water quality in California. In addition, California state beaches are not required to post water quality information, therefore it is possible that unless a beach is closed, visitors are not aware of the difference in water quality at various beaches. Consequently, water quality may not factor into a visitor's decision on where to recreate.

The Priority Pollutant Dispersion Model measures the average concentration of dissolved heavy metals along with other priority pollutants that are discharged one time from one average-size cruise ship. The pollutants remain in the water column over a period of five days, which is enough time to determine adverse effects on organisms. Heavy metals collect in living organisms and increase in concentration as they move up the food chain. This process is called bioaccumulation. In general, these pollutants are present at trace levels in uncontaminated waters, and in small amounts these metals are essential micronutrients for living organisms. However, if the threshold for the organism is exceeded by elevated levels of intake, heavy metals can: 1) seriously affect the respiration, photosynthesis, transpiration and growth of plants, 2) trigger important dysfunctions of the nervous system, blood and renal systems in animals, and 3) reduce growth and reproduction in animals.

In order to determine the concentration of these pollutants in the water column under each of the three scenarios, this model takes into account the characteristic length of diffusion of metals and the depth of the ocean at three main California ports: Los Angeles, San Diego, and San Francisco (See Figure 2).

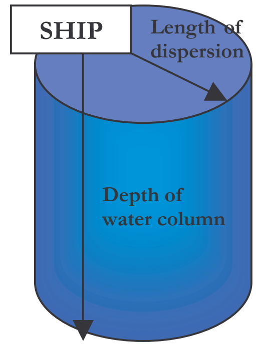

Figure 2: Schematic of Dispersion Model

The results of this model were compared to species sensitivity distributions for each of the pollutants that show the sensitivity of the marine community to increasing concentrations of the pollutant. The results showed that there is no effect to the pelagic marine community from the concentrations of dissolved pollutants released in a single discharge from one cruise ship. However, our model was unable to account for the accumulation of metals in the water column that would result from multiple discharges in the same area. Repetitive discharges have the potential to lead to bio-concentration in organisms, and bioaccumulation of these metals in higher trophic levels. Thus, these metals may negatively affect marine organisms even though the results of our model predicted otherwise.

The Sinking Load model measures the average concentration of heavy metals and other priority pollutants attached to particulate matter that sinks to the benthos. This model accounts for the area that metals will diffuse through given average turbulent conditions in the ocean and the depth of the pore water[v] at the sediment-water interface (See Figure 3).

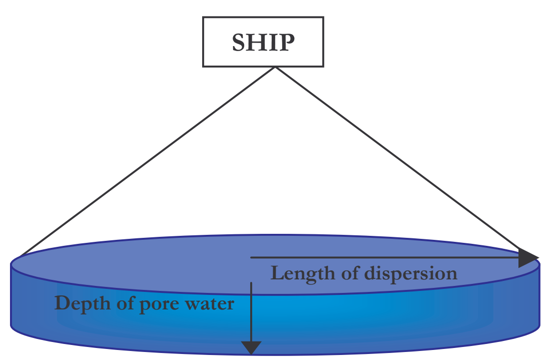

Figure 3: Schematic of Sinking Load Model

The results of the model were then compared to species sensitivity distributions for each of the pollutants, showing the sensitivity of benthic marine organisms to increasing concentrations of the metals. The results showed negative effects to 90% of the marine benthic community from the concentration of copper reaching the benthos. There were no negative effects shown for any of the other heavy metals analyzed. These results led us to conclude that future policies should consider the elevated loads of copper in cruise ship waste streams. It is also important to note that the data used to calculate these models came from ships required to use Advanced Wastewater Treatment Systems (AWTS). However, cruise ships in California are not subject to the same regulations, and therefore many ships may not have this wastewater treatment capacity. Ships without this technology could be contributing more pollution to the marine environment than those predicted by this model. Therefore, the results presented here can be viewed as a best-case scenario.

RECOMMENDATIONS

Based on the results of our project we have developed a number of recommendations regarding the regulation of blackwater and graywater wastestreams from cruise ships.

- We recommend that future policies require ships be at least 3 nautical miles offshore and away from critical habitats, such as marine sanctuaries. This would assure minimal impacts to coastal areas.
- In addition, we recommend that graywater be treated to the same standards as blackwater and that any standards applied to one wastestream be applied to the other since both wastestreams contain large amounts of bacteria and heavy pollutants.
- Due to the accumulation potential of heavy metals over time, as well as the likelihood of cumulative impacts of these constituents to the marine community, we recommend legislation that mandates the use of treatment systems that would remove these metal prior to discharge.
- However, if technology standards are not required by legislation, we recommend that depth be taken into consideration as a metric for determining where cruise ships can discharge. This would minimize the effects of pollutants on the marine community.
- Finally, we recommend further economic analyses on the adverse effects of cruise ship discharges in regards to beach closures, fisheries, and human health to bridge the gap in economic information regarding cruise ships in California.

Recommendations

1. **Require cruise ships to travel at least 3 nautical miles offshore before discharging.**
2. **Treat graywater to the same standards as blackwater.**
3. **Require the installation of treatment systems to remove heavy metals from discharges.**
4. **Consider depth as a metric for determining where cruise ships can discharge.**
5. **Conduct further economic analyses of the adverse effects of cruise ship discharges.**

[i] Business Research & Economic Advisors (2003). The Contribution of the North American Cruise Industry to the U.S. Economy in 2002.
[ii] Herz, M. and J. Davis (2002). Cruise Control: A Report of How Cruise Ships Affect the Marine Environment. The Ocean Conservancy.
[iii] Sweeting, J. and S. L. Wayne (2003). A Shifting Tide: Environmental Challenges and Cruise Industry Responses, The Center for Environmental Leadership in Business.
[iv] Pendleton, L. and H. L. Kite-Powell (2003). Coordinated Regional Benefit Studies of Coastal Ocean Observing Systems: California Region Progress Report. Woods Hole Oceanographic Institute.
[v] Pore water is defined as water filling the spaces between grains of sediment (Toxic Substances Hydrology Program (2003). Glossary. http://toxics.usgs.gov/definitions/pore_water.html, United States Department of the Interior.)