2015 COAST Summer Internship

State Lands Commission's Marine Invasive Species Program
Vessel Biofouling Management

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Research Project

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Introduction

As a cadet at the California Maritime Academy, the impact of the maritime industry is heavily engrained into my academic curriculum. Globalization of people and products has led to a significant increase in world-wide trade via water: 90% of the world's trade moves by ships in an ocean that covers 71% of the globe's surface (Shipping and World Trade, 2015). Globalization of trade and commerce has presented an eruption of vessel traffic via ocean highways. Just as these ships bring commercial goods, oil products, and international business interactions, they also bring the possibility of the introduction invasive species through a process known as biofouling. Organisms can stick to layers of biofilm that grow on the wetted area of a ship's surface, including several niche areas capable of hosting entire ecosystems, such as sea chests. Marine biofouling is a leading vector of marine introduced species on a global scale (Davidson, et. al 2014).

My summer research internship at the California State Lands Commission provides me with a broadened perspective on the negative impacts of biofouling, as well as a greater understanding on the practices to eliminate/reduce it on commercial vessels. The State Lands Commission's Marine Facilities Division (MFD) and Marine Invasive Species Program (MISP) are constantly reviewing and redesigning practices and regulations to fit the growing impact of worldwide shipping and the risks it brings to California. In working under MISP, my internship was divided into two separate, yet related, projects.

First, this research report will outline my expansion of the biofouling portion of the Ballast Water Management Database. This report will outline the methodology of my three goals: verifying the accuracy of anti-fouling coating biocides that had already been inputted, separating anti-fouling coating clusters, and populating the database through research and company outreach. I will discuss the difficulties, as well as the successes that I encountered while conducting this database expansion, as well as the benefits that it will provide me and the MISP.

Second, this research report will outline my waterline evaluation project. The report will discuss the methodology of determining which maintenance/operational practices are associated with the extent of fouling on waterlines. With these data, the report looks to assert which of these practices may be predictive of risks that would indicate priority vessels for MISP when related regulations are adopted.

The report will conclude with discussion as to how these projects will impact the State Lands Commission's Marine Invasive Species Program. My own personal experience and education gained will also be discussed, as well as further insights to improve similar projects for prospective interns.

Background

Biofouling is a colossal issue for many parties, including shipping companies, environmental advocates, local and international consumers, and regulatory bodies and

governmental agencies. Biofouling on ships has a direct impact on these parties, eventually affecting consumers and business-owners.

Shipping companies depend on regulated service, the ability to make a profit, and the ability to conduct business under (often strict) environmental and governmental restrictions. Biofouling impedes upon all of these decencies by skyrocketing fuel costs through increased drag. "Estimates of increases in fuel consumption from biofilm attached to the hull alone range from 8% to 12%, and from normal propeller fouling range from 6% to 14%" (Rompay, 2012).

The annual fuel consumption for a Panamax containership is 30-40.000 mt, equaling about 10 million US dollars a year.   Ships with a biofilm alone will incur approximately $800,000 additionally per year. For shipping companies, such as Matson, with 18 ships, that's in the range of $14,400,000 dollars lost each year, all from a thin layer of slime on the hull of a ship.

The environment pays the largest price, taking the direct impact of slower ships' increased fuel emissions and greenhouse gasses. Through the introduction of marine nonindigenous species, native species to a region may be forced out by new competition for finite resources.

Biofouling also has a direct impact on regulatory and government agencies world-wide. As global shipping continues to increase in correlation with more available shipping lanes and the drive of consumer and global demand for goods, the expansion of species introduction will likely follow suit. Regulatory agencies are forced to act accordingly through enforcement and education. The California State Lands Commission's Marine Invasive Species Program is the leading State-run body tasked with creating and enforcing new regulations to prevent the introduction of marine nonindigenous species, as well as to uphold current safety and procedure compliances for those ships discharging ballast and transporting oil. Just as the agency must enforce, they also aim to be proactive through education regarding biofouling and nonindigenous species for the maritime industry to practice.

Project 1: Database Population

Background

To discourage the settlement of microorganisms, bacteria, and animals, shipping companies utilize antifouling systems on the hulls of their vessels. There are four main forms of antifouling coatings: contact leaching paints, controlled depletion polymers (CDP), TBT free self-polishing copolymers (SPC), and foul-release. The Ballast Water Management Database contains these common antifouling coatings, as well as any other types that have been recorded on ships entering California ports since 2008. The database, however, previously needed information for several data fields related to the effectiveness of the coatings, including biocides, coating delivery mechanism, effective coating age, and effective vessel speed for the coating.

Methodology

The primary step to updating the coatings database was to verify the accuracy of all biocides inputted into the database. Because the coating database has been updated by multiple

parties, data was listened under different names (ie, one biocide would be listed as DCOIT, while another would be listed as Duracide, both of which are different names for the same chemical). I went through each of the 422 coatings and double-check the biocides for both accuracy and uniformity.

The secondary step was to determine and locate any clusters of coatings (such as the name of a series) that were combined into one coating name. I also determined which coatings were unusable (i.e. provided no company name). Raya Nedelcheva provided 22 clusters that could be separated in total. There were 56 additional coatings that would be unusable in database population.

Thirdly, if I was unable to find information on websites, I conducted outreach to the companies manufacturing and selling the coatings. I first emailed representatives of 22 domestic and international companies requesting product information about their coatings. If they were unable to reply by email, or did not reply by a deadline, I followed up with a second email and a phone call.

Finally, all data from each of the 422 coatings that I received from company's websites and representatives was manually inputted into the coatings database.

Results

Larger companies were the easiest to get in contact with via email and were more than happy to assist with my research project. Because Chris Scianni had already gained several contacts prior to my arrival at MISP, the process was additionally expedited. Of the 22 companies I originally contacted, 6 replied with information. While that number doesn't appear substantial, these larger companies produce and sell the highest numbers of coatings, which had a significant impact on our overall number.

# Found out of 343			
Delivery	**Months**	**Speed (qualitative and quantitative)**	**Biocides**
292	242	215	331
# Found out of 343 (as a %)			
Delivery	**Months**	**Speed (qualitative and quantitative)**	**Biocides**
85%	71%	63%	97%
Total Data Collected			
1080			
78.72% of total			

In removing the 69 coatings that were unusable or had been separated as a cluster from my final count, I was left with 343 coatings to analyze. 1080 separate data inputs were completed, 79% of all 1372 possible needed inputs for the Ballast Water Management Database.

Discussion

It was expected that there would be hesitancy from smaller companies to be open about their product information, which we encountered numerous times. There were also time change and language barriers that created complications in getting in touch with international companies. Another issue encountered was the automatic removal of coating information once a coating expired- companies we contacted would often have no information on a coating if they no longer sold it.

Overall, populating the database was more successful than expected- larger companies were fairly easy to get in contact with and were more than happy to assist in our data collection. By already having contacts available through Chris Scianni, direct communication with representatives from many companies was fairly simple. By updating the database, MISP has access to more thorough analysis for biofouling research. The update has also allowed for cohesive and accurate biocide information inputted by a single source, rather than multiple people over a span of time.

By participating in this project, I have gained valuable experience communicating with both domestic and international companies. By building connections with these companies, I have also gained knowledge and resources for obtaining coating data for future research. I have also gained basic knowledge of biocides and the appropriate coatings for commercial vessels, which can be used thoroughly as I continue my maritime-based career field.

## Project 2: Waterline Evaluation

Background

Accurate approximation of the overall fouling of a commercial vessel would be done by underwater divers to obtain a complete scope on the wetted surfaces where macrofouling could occur. However, often when there is fouling on the waterline of a ship, there will simultaneously be fouling on the bottom of the vessel. While what we see on the waterline may not always correlate with what is underneath, when there is fouling on the waterline, there is likely fouling below the surface.

With the proposed introduction of biofouling regulations, regulatory agencies will be responsible for enforcement and education in regards to biofouling on commercial vessels. This waterline evaluation project was intended to provide hints and trends that would simplify the process of determining which ships to screen for potential biofouling infractions.   In relation to the database population project, my second project focused on using opportunistic stratified sampling in order to determine which maintenance and operational practices are associated with the extent of macro fouling on the waterlines of commercial vessels. This extent would be measured in level of fouling (LOF), a categorical ranking based on percent cover of the waterline covered in macro fouling.

Methodology

The primary goal of our research with waterline evaluations was to spread our sampling efforts across all vessel types: Auto (Referred to as Ro-ro through my data), Bulk, Container, General, Passenger, Other, Tankers, and Unmanned Barges. Our secondary goal was to spread the sampling across different coating types and ages.   The tertiary goal was to focus on several

different factors that could potentially attribute to higher levels of fouling- including ships with long residency periods in their recent history, older anti-fouling coatings, and more trips to tropical ports, to name a few.
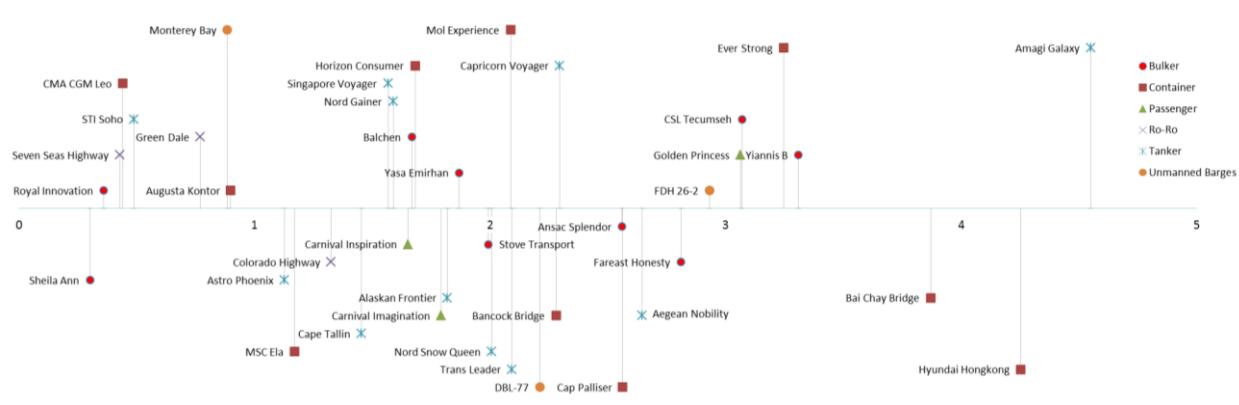

Above displays a timeline scaled from 1-5 years displaying our secondary goal of spreading the sampling across different coatings, ages, and ship types.

Each morning upon arrival in the office, I referred to the Oil and Ballast Water Management whiteboard containing all vessel arrivals and departures in port facilities throughout the Bay Area, Sacramento, and Stockton. The sampling method was often opportunistic, based on whether or not inspectors would be available to go to a specific port or vessel that day. Upon vessel selection, a hull husbandry form would be secured in one of three ways: collection from a shared drive on the computer, communication with Jackie Mackay in Long Beach California to obtain forms that had not yet entered the database, or infer that a report had not been submitted and needed to be retrieved from either the ship or the ship's agent.

I would go out each morning with inspectors to vessels where I would document the level of fouling by capturing at least five pictures each of the bow, the mid-ship, and the stern. Simultaneously I would use the iPad developed with ArcGis to input the ship's latitude and longitude, pull up HHRF data, and record the LOF on a scale of 1-5. The data could be uploaded directly from the iPad and accessed later from my desktop.

Upon arrival back to the office, I would verify the ArcGis data I had already inputted earlier and submit any missing data. I also had photoQuad on my desktop, a program allowing me to determine the accuracy of my visual LOF scores.

Original Image	photoQuad image
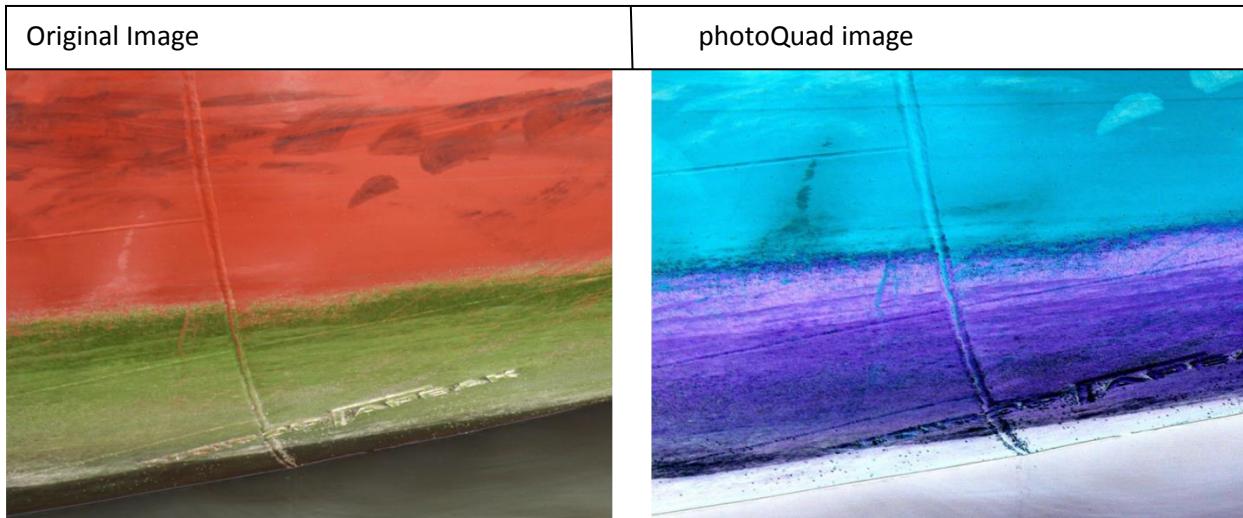
Barnacles seen with plain eye view are on the left side represented with white dots. PhotoQuad allowed me to accurately determine whether or not my visual estimation was a close approximation. The photo on the right highlights barnacles in black. It can be determined that there are more barnacles available visually through photoQuad.

Finally, the data were analyzed for association to determine if there were linear relationships between two variables. Our data would hopefully provide insight into potential risks, to indicate which vessels would be a priority under the adoption of future biofouling regulations.

Field Work

Our sampling took place in over 8 ports, 6 in the Bay Area of California and 2 in Southern California, the Ports of LA and Long Beach. Twenty-nine samples were from the Bay Area.Twelve samples came from the Ports of LA and Long Beach where we took advantage of their busy cruise ship terminals for sampling we would have otherwise missed in the Bay Area. While we originally had 46 samples, not enough hull husbandry data was available on 5 ships to include in our research.

Traveling to Northern and Southern California provided a wide range of ships for our research. We originally set a goal to survey 34 ships, which would be exceeded by the end of the internship.

Results

The following chart displays the cumulative LOF's for all 41 ships included in the research project, projecting the differences in areas of fouling, as well as extent of fouling, across our entire matrix of ships.

Coating Age x Cumulative LOF
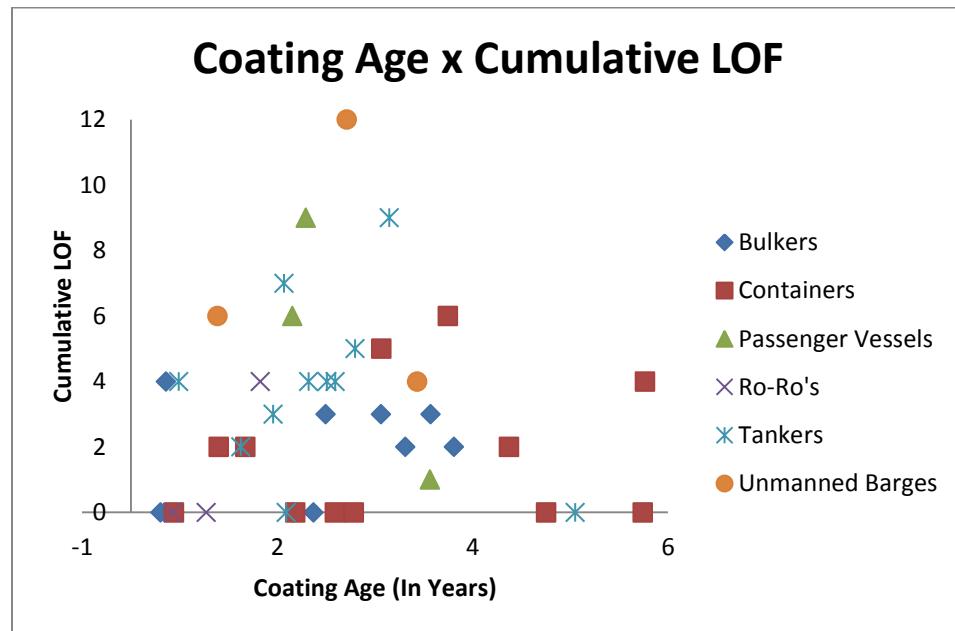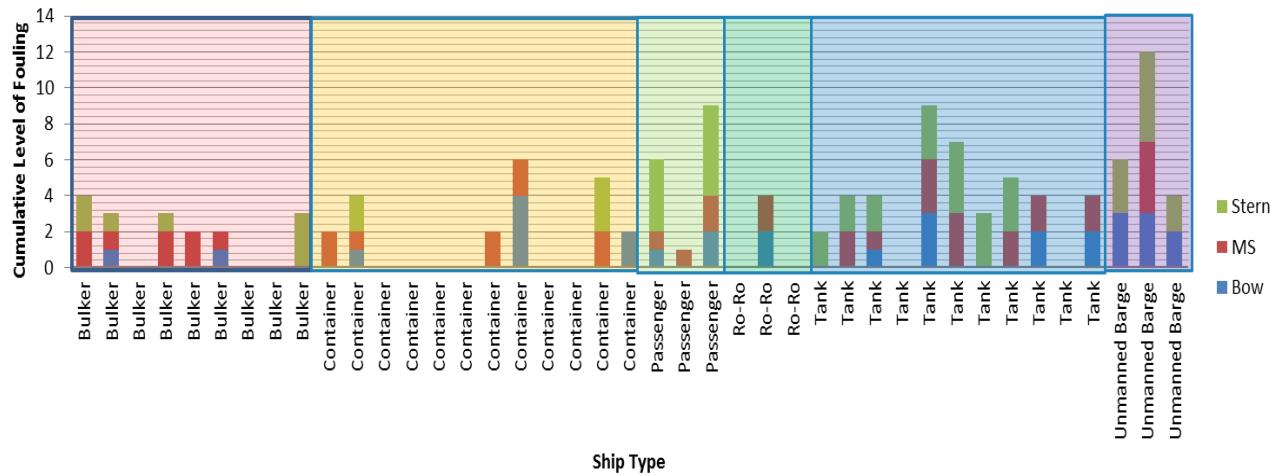
One of the trends we noticed was the relationship between coating and the cumulative level of fouling for certain ship types, displayed above. Bulkers and containers best demonstrated weak positive linear relationships, but both would benefit from a larger sampling size. If there was also a larger sampling size for tankers, these too may have potential for a positive association.

Speed x Cumulative LOF
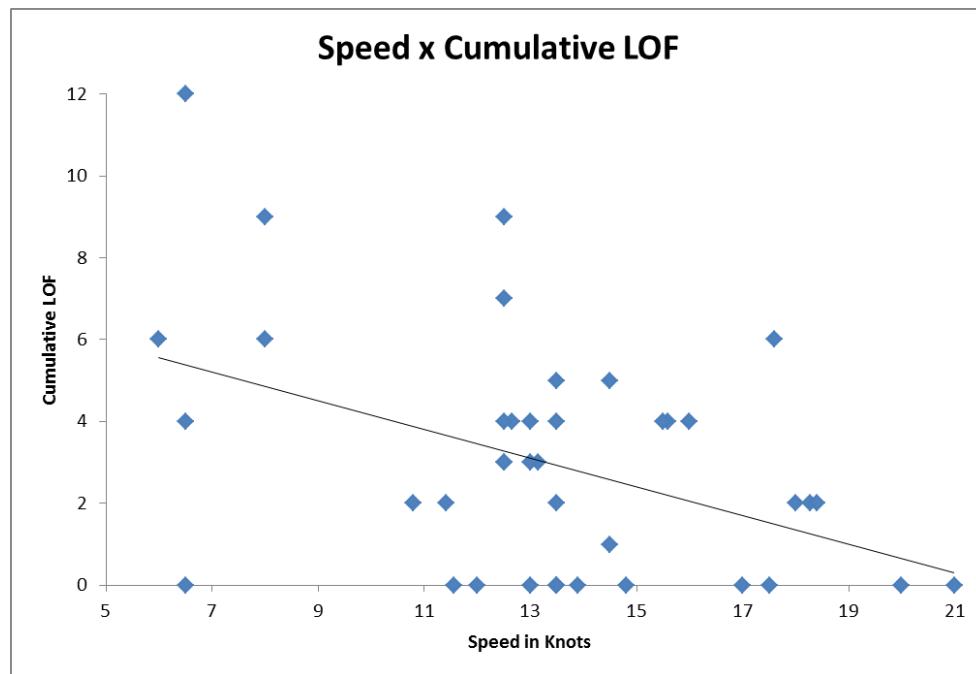
We also took notice of the relationship between speed and the cumulative level of fouling on commercial vessels. It is encouraging for our data to show that an increase in speed (in knots) has a relationship with the level of fouling for ships, in general. Again, with a larger sampling size, these results may have a more robust relationship.

 # FW Ports x Cumulative LOF
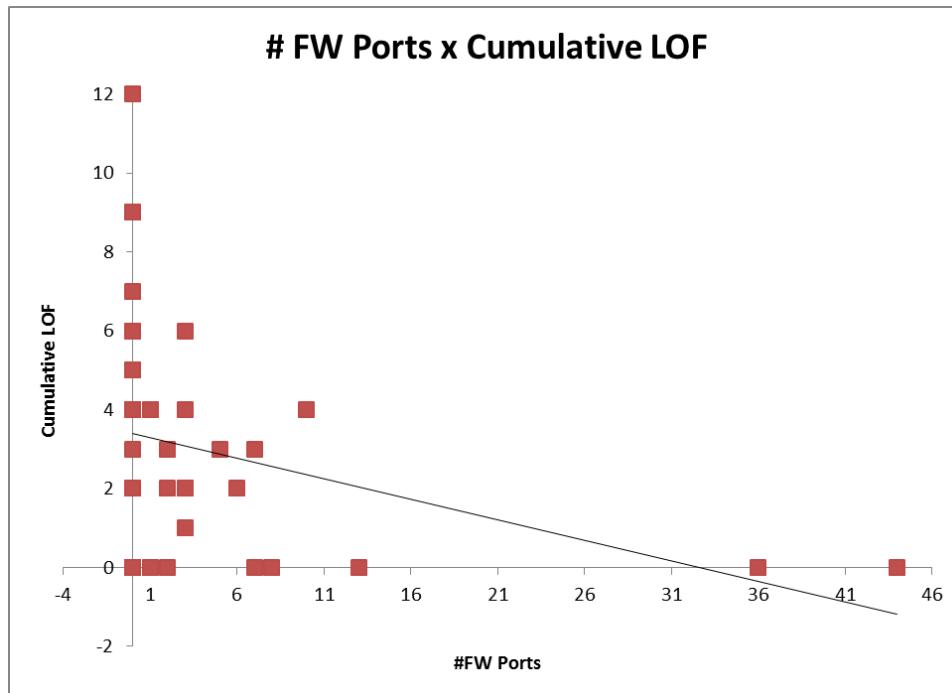
Finally, we noticed a possible association between the number of freshwater ports with the cumulative LOF. The more freshwater ports visited, the less macrofouling we recorded on

commercial vessels in California, indicative of fresh water killing most marine organisms that come in contact with it.

Through our extensive surveying of ships in California ports, we found trends that would suggest an influence on the extent of LOF scores for the waterline of ships. Speed, number of freshwater ports visited, and the age of coatings for some vessel types had the strongest relationships indicating this influence on fouling levels. While some trends were negative, and others positive, all data is important for creating predictive practices when biofouling regulations are enacted in the future. These data will be influential in creating a streamlined process in which high priority ships can be marked for inspection.

Discussion

There are numerous factors attributing to fouling, many of which occur concurrently. It would be difficult to develop a 100% accurate and precise method to predict fouling on ships. However, anything that provides a hint or potential trend can be useful for highlighting ships to inspect.

Sampling was often opportunistic, making it difficult to hit targets that I would notice in the database. However, by increasing our sample size, we were able to develop meaningful data that show potential trends for determining which maintenance and operational practices are associated with extent of fouling on ship hulls. To improve sampling, I would continue to increase the amount of sampling. The more ships we surveyed, the more accurate our data became.

The use of technology, including the iPad app and the improved camera lens, created simplicity in my research. Prior to obtaining the iPad, HHRF's had to be printed out and taken aboard each vessel. Then longitude and latitude would have to be manually inputted back at the field office. With the implementation of the iPad, I was able to carry less and pull up any information that I had already inputted. The improved camera lens also allowed me to accurately look at organisms that would have otherwise been blurred or too far away to gauge an accurate LOF score.

My project wouldn't have been possible without the help of the field office staff. All offices were more than happy to help me with the project, including advice-giving, trips out the ports, and by providing me with valuable learning opportunities.

MISP gains hints to determine predictive methods to select ships with operating practices that affect the extent of fouling on vessel waterlines, as well as a basis for improving/ developing upon the data collection methods that I used during my internship. Through this project, I have gained hands-on experience navigating and working in a port environment, working with port and ship personnel, and an understanding of port safety and operational practices that I would not otherwise have access to learn about. Through my opportunities to work with professionals in the maritime industry and the State Lands Commission, I have also broadened my understanding of ballast water, biofouling, and the marine science field in general. I was also exposed to the legislative and public policy aspect of the State Lands Commission, attributing to my passion for public policy.

The project increased my confidence in Excel, data collection, and the presentation of results in PowerPoint and research paper format. I have gained public speaking experience, as well as experience in operating technology such as the camera used for surveying. Finally, this project has given me the opportunity to express my own creativity by allowing me to demonstrate my own initiative and apply it to real-life situations in report format.

My Personal Experience Working with State Lands' Marine Invasive Species Program

It's extremely difficult to find a job that combines all of your interests. As someone who has a passion for public policy, the marine science field, and the maritime industry, I couldn't imagine a better internship opportunity available for myself. This internship was the ideal balance of time in the field office with hands-on, applied experience out in the maritime industry. I have to emphasize that this internship would have not been successful without the mentors and staff who helped me along the way. Without the welcoming nature and general kindness and willingness to help me learn, I would not have gained the knowledge and experience that I now take confidence in.

This has been my first opportunity to individually gain initiative and take control of my own research project outside of my marine science curriculum at the California Maritime Academy. It has taught me to be independent, but to know that I can rely on others with more knowledge or experience in an area for assistance if I am willing to learn with an open mind. The connections I have made and the networking I have done are priceless for any college student looking to work in these industries, and I cannot thank COAST, Nicole Dobroski, and Chris Scianni enough for this amazing opportunity.

Bibliography

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