Development and Application of a Catch Database to Direct Sustainable Fishing Effort

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EXECUTIVE SUMMARY OF THE FINAL REPORT

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EXECUTIVE SUMMARY

Introduction

The work of this internship occurred with an anonymized fleet of tuna purse seine vessels operating in the WCPFC (Western and Central Pacific Fisheries Commission) and IATTC (Inter-American Tropical Tuna Commission) RFMO (Regional Fisheries Management Organization) regions of the Pacific Ocean (see Figure 1). Their fishing efforts target the catch of tropical tuna, primarily skipjack, yellowfin, and bigeye tuna. While the fleet is part of a mature business, the organization and utilization of their historical catch data had room for improvement. At the time that the internship was proposed, catch data was stored in two ways. The first was an online portal which received daily reports from the vessels while fishing. This portal compartmentalized all catch records into individual fishing trips and required management to enter a trip and open an additional pop-up window before being able to view the details of a set. The options to summarize and analyze the long-term catch of a vessel or catch of multiple vessels at once was extremely limited and cumbersome. The second method of catch data storage was within a third-party software system. Although this system did provide the fleet with the ability to view catches spatially on a map of the fishing grounds, it locked data into a point data format, causing catches to overlap each other and hide information when the map was scaled out or when multiple sets in the same area were shown at the same time (see Figure 2). The data entered into this software is also in a format specific to that program, preventing the export into a file that could be further analyzed in a GIS (graphic information system). The only option for analysis of data entered into this software was to enter into a contract with a fourth party who would provide raster views and summary analysis information for the fleet or individual vessels. Although this information was

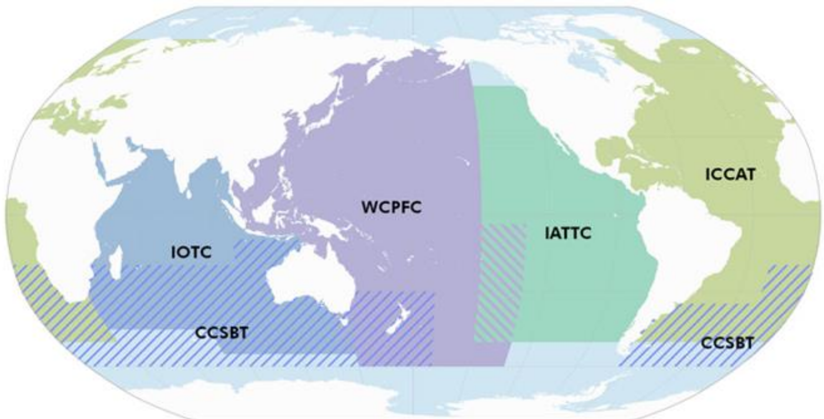

Figure 1. Global RFMO Map
A map showing the jurisdictions of all Regional Fisheries Management Organizations (Image credit: PEW 2011)

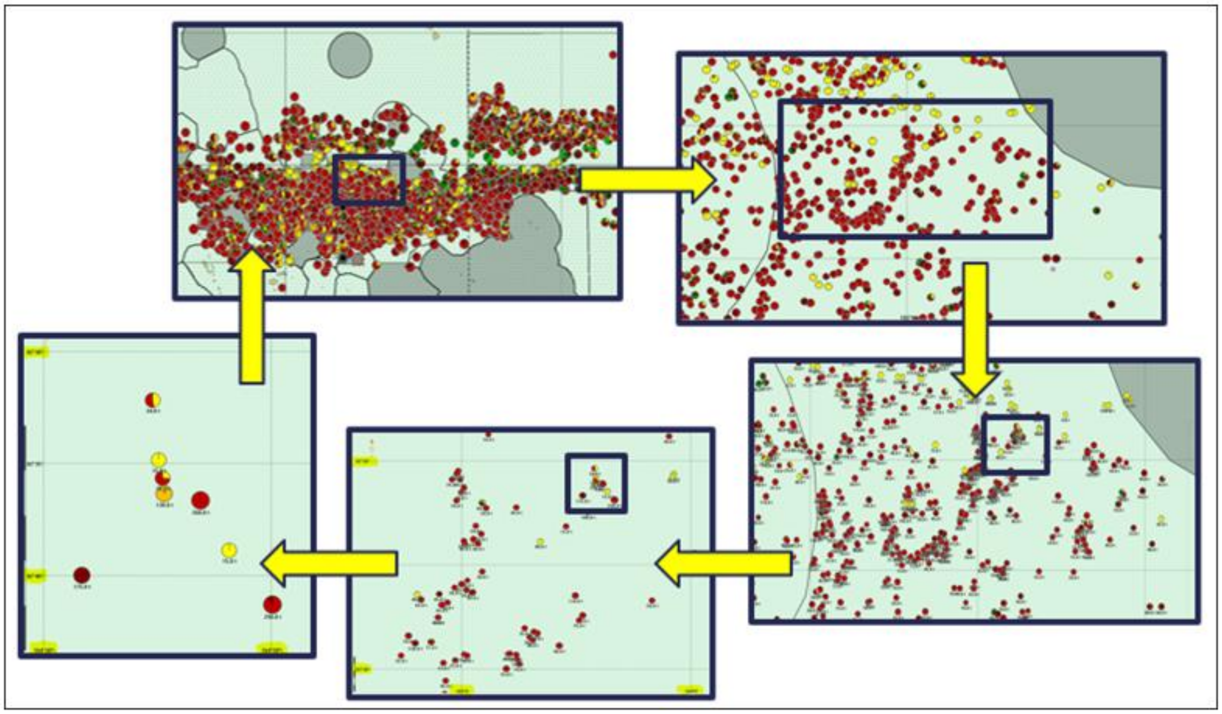

Figure 2. Catch Data Visualization in the Third-Party Software
This series of images is showing how much data is occluded while viewing a large number of sets. The images zoom to the boxed in the image before it until the viewer reaches the level of zoom that clarifies the tonnage and species of each set. This series of images demonstrates the problem created while trying to gain information from a large number of sets in this platform.

strongly desired by the fleet, the annual fee for such fourth-party analysis was nearly $60,000 and well beyond the budget of a small fishing operation.

The internship described here focused on addressing the fact that the fleet's historical catch data was incompletely utilized as a result of inefficient formatting, lack of flexibility for analysis and manipulation, and reliant on costly third parties options for spatial analysis. The end result of the internship is a workable excel database that includes all relevant variables for analysis of catch, effort, and vessel or captain performance. It is formatted for easy filtering, production of pivot tables, and entry into a graphic information system (GIS) for further spatial analysis. This database provides the fleet with the flexibility and power to fully understand their fishing effort, fleet performance, environmental impact, and impact on individual stocks or size classes of both target and non-target species.

Scientific Report

The database is structured so that variables for each set are aligned horizontally across the columns, and each set will have a single row of data. The first category of variables describes the situation around each set. They relate to the timing of the set (year, month, and date), the vessel and trip data (vessel name, captain, and trip number), location of set (EEZ zone and coordinates), and type of set (FAD vs. school, the buoy ID that was set on, which vessel that buoy is assigned to, and who planted that FAD). For the one-year subset of the database that was analyzed in the GIS during this internship, oceanographic data at the point of each set was pulled as well (plankton concentration (mg^3/m) and sea surface temperature (°C) (SST)). The second category of variables relates to the target catch resulting from each set. Each species (skipjack (SJ), yellowfin (YF), and bigeye (BE)) are subdivided into the size classes relevant for each of those species. There are additional columns added that sum the total for each species and each size class in a single set. The last category of variables included in the table describe the non-target species interactions that occur during each set. Unfortunately, captain reports don't include details around the condition of each bycatch species upon release, so management will be reliant on examination of other sources (captain logs, observer reports, and studies on post-release mortality for each species) to understand how the numbers in the excel catch database equate to impact on a bycatch species. The variables described here are summarized in Tables 1 and 2, along with the status of the database at the

Variables included in the Excel Database (Target)		
	Pre-internship	Post-internship
Year	x	x
Month	x	x
Date	x	x
Captain	x	x
Vessel	x	x
Trip Number	x	x
Territory	x	x
Coordinates		x
Plankton Concentration (mg^3 /m)		x
Surface Temperature (°C)		x
FAD vs. School	x	x
Buoy ID	x	x
Buoy Owner (vessel)	x	x
Buoy Planted By	x	x
Target Catch		
Total Metric Tons (MT)	x	x
Total Skipjack (SK)		x
Total Yellowfin (YF)		x
Total Bigeye (BE)		x
Total under 3 lbs		x
Total 3-4 lbs		x
Total 4-7.5 lbs		x
Total 7.5-20 lbs		x
Total 20+ lbs		x
Skipjack		
SJ under 3 lbs	x	x
SJ 3-4 lbs	x	x
SJ 4-7.5 lbs	x	x
SJ 7.5+ lbs	x	x
Yellowfin		
YF under 3 lbs	x	x
YF 3-4 lbs	x	x
YF 4-7.5 lbs	x	x
YF 7.5-20 lbs	x	x
YF 20+ lbs	x	x
Bigeye		
BE under 3 lbs	x	x
BE 3-4 lbs	x	x
BE 4-7.5 lbs	x	x
BE 7.5-20 lbs	x	x
BE 20+ lbs	x	x

Table 1. Target Catch Variables
Representing the status of the excel database before and after the internship. The internship focused on filling in additional data (bycatch data, oceanographic data, coordinates of the sets), adding additional summary columns to facilitate quick analysis using pivot tables and, in the GIS, (total MT for each species and for each size category), and filling in previous years of data.

start of the internship and after completion of the internship. At the beginning of the internship, there were various stages of data entry for each of the groups of variables entered above, and data had only been entered through 2016. Data entry during the internship focused on completing the target catch entry for all years available (2013-2021), entering non-target catch for several years that had only included the target catch initially (2018-2021), and adding coordinates to the sets already entered so that a larger database can be incorporated into GIS analysis (2018-2021). The years currently entered for each category of data are described in Table 3.

Variables included in the Excel Database (Non-Target)		
Non-Target Interactions		
Silky Sharks (FAL)		x
Oceanic Whitetip Sharks (OCS)		x
Whale Sharks (RHN)		x
Scalloped Hammerheads (SPL)		x
Bigeye Thresher (BTH)		x
Basking Shark (BSK)		x
Lemon Shark (NGB)		x
Blue Marlins (BUM)		x
Black Marlins (BLK)		x
Indo-Pacific Sailfish (SFA)		x
Striped Marlin (MLS)		x
Swordfish (SWO)		x
Shortbill Spearfish (SSP)		x
Manta (MAN)		x
Munk's Devil Ray (RMU)		x
Giant Manta (RMB)		x
Pelagic Stingray (PLS)		x
Sharptail Mola (MRW)		x
Wahoo (WAH)		x
Dolphinfish (DOL)		x
Rainbow Runners (RRU)		x
Sergeant Major (ABU)		x
Yellowtail (YTC)		x
Oceanic Triggerfish (CNT)		x
Black Triggerfish (MEN)		x
Tripletail (LOB)		x
Bullet Tuna (BLT)		x
Frigate Tuna (FRI)		x
Great Barracuda (GBA)		x
Amberjacks (AMX)		x
Mackerel Scad (MSD)		x
Olive Ridley Turtle (LKV)		x
Green Turtle (TUG)		x
Loggerhead Turtle (TTL)		x
Leatherback Turtle (DKK)		x
Bird (BIZ)		x

Table 2. Non-Target Catch Variables
Prior to the internship, none of the bycatch interactions were entered into the database. The species listed below represent all those reported by the vessels between 2018-2021.

	Pre-internship	Post-internship
Catches Entered		
2013		x
2014		x
2015	(partial)	x
2016	x	x
2017	x	x
2018	x	x
2019	x	x
2020	x	x
2021	x	x
Non-target Interactions Entered		
2013		
2014		
2015		
2016		
2017		
2018		x
2019		x
2020		x
2021		x
Coordinates Entered		
2013		
2014		
2015		
2016		
2017		
2018		
2019		x
2020		x
2021		x
Oceanography Entered		
2013		
2014		
2015		
2016		
2017		
2018		
2019		x
2020		
2021		

Table 3. Years of Data Entered
Upon completion of the internship, all target catch has been entered into the database. Non-target interactions have been entered for the 4 most recent years. Coordinates have been entered for the 3 most recent years. Oceanographic data was only entered for the trial year (2019) to begin working with it in the GIS. Following presentation of the GIS analysis to the company, the remaining data gaps will be filled in so that a larger portion of the excel database can be analyzed through both pivot tables and GIS.

Position data was also pulled for each of the individual trips made by the vessels during the sample year chosen for GIS analysis. This data was saved into separate CSV files to allow for visualization of the catches and trip pathway in ArcGIS.

The internship host company agreed to provide one year of historical catch and vessel position data for analysis in ArcGIS, with the understanding that the methodology should be scalable for inclusion of additional data following the internship. The data from that year was pulled into a separate file, which was saved into CSV format. Two additional columns were added to record oceanographic parameters (sea surface temperature (SST °C) and plankton concentration (mg^3 /m), both pulled from the software used onboard vessels for oceanographic and meteorological data) for each fishing set. After a few small adjustments to prepare the file for entry into ArcGIS (ex. converting the coordinates from degrees minutes seconds into decimal format and removing extra excel design formatting), the file was ready for spatial analysis. Data was uploaded to ArcGIS onto a base map that had been wrapped around the dateline and loaded with exclusive economic zones (EEZ) boundaries from marineregion.org. The sample data was uploaded in point data format (see Figure 3), and later converted into raster format based on various attributes of relevance to the fleet (Figure 4). The structure of the database allows for streamlined selection, layer

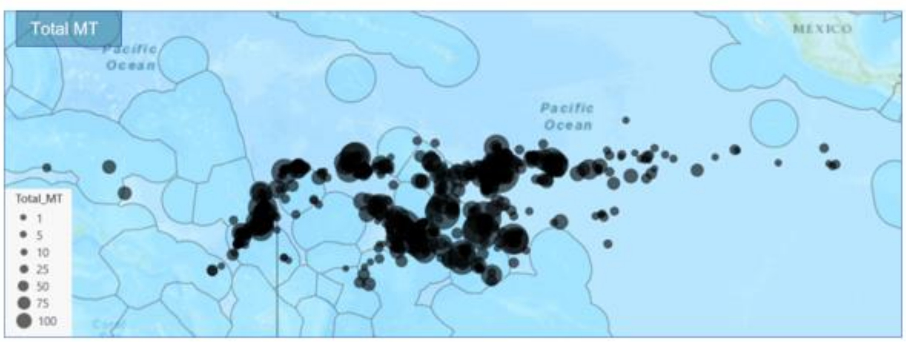

Figure 3. Catch Database from Point Data
Visualization of the 2019 catch database in a point data format based on the attribute Total MT. The symbology is set to proportional symbols based on the total MT of each catch with transparency to show areas of overlapping catch.

Figure 4. Rasterized Catch Database (Total MT)
Since the point data visualization still retains some of the problems from the Catsat view (overlapping sets and no summary analysis), the point data was rasterized into the layer below based on the Total MT attribute.

production, and analysis based on any of the attributes included in the original excel database. Using this selection method, rasterization tool, and raster calculator tool on ArcGIS it was possible to perform several analyses of interest to the fleet. For example, catch of juvenile tuna is undesirable to the company, due to the lower economic value, complication with storage (increased risk of saltwater intrusion and tissue damage), impact on the stock, and higher rate of rejects during unloading. For these reasons, a raster layer was created for the two lowest size categories of tuna (representing a combined size class of 0-4 lbs), which was then divided by a raster layer of the total metric tons (MT). The resulting layer demonstrated areas that had a disproportionately high rate of juvenile catch per total ton (Figure 5).

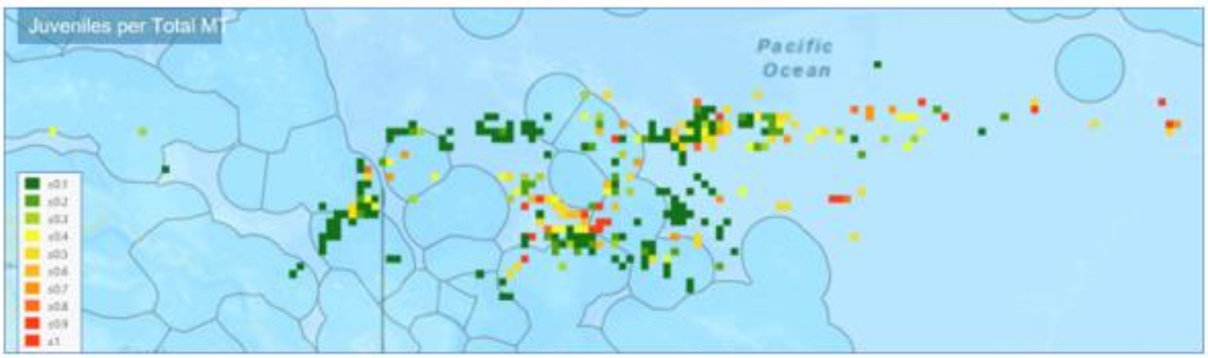

Figure 5. Juveniles per Total MT
Catching fish under 4lbs provides the fleet with a lower economic return, holds more risk for poor fish quality (bruised meat, low yield, and salt intrusion) and has a higher impact on the stock. For this reason, it is relevant to understand the areas that produce a disproportionately high rate of juvenile tuna. The raster images below represent a summation of the raster files for the attributes Total u3lbs and Total 3-4 lbs, divided by a raster file for Total MT.

Since the goal of this internship is to provide a tool for the fleet's ongoing use, it is necessary to make this procedure simple to update with additional catch data. For this reason, several models were created using the ArcGIS ModelBuilder tool. The model which correlates to the production of the "Juveniles per Total MT" raster analysis in Figure 5 is shown in Figure 6. The methods described for this analysis were also used to examine species-specific fishing metrics, catch per unit effort (CPUE) by total tonnage and by number of sets, identification of areas to target (ex. high rates of large yellowfin catch), and areas to avoid (ex. high rates of shark interactions per total MT). These analyses not only help the fleet to understand their fishing effort, but enable them to query the database in order to direct more productive and sustainable fishing effort moving forward.

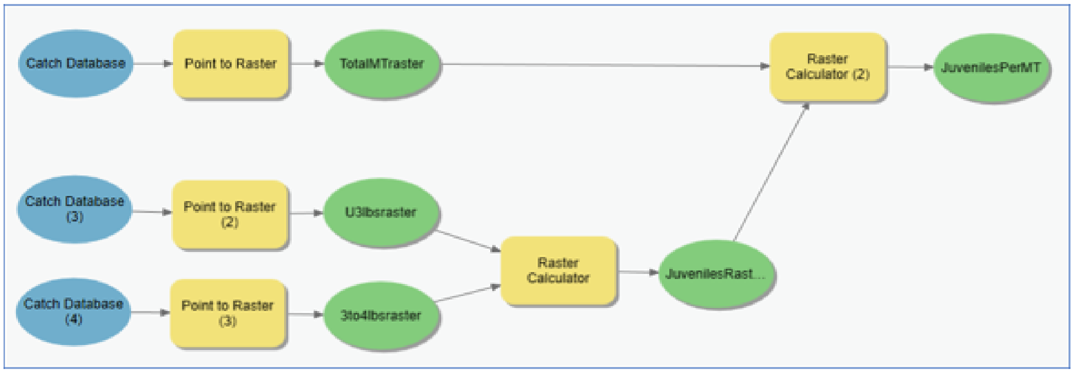

Figure 6. Model for Juvenile Tuna per Total MT of a Set
The model is designed to incorporate updates to the catch database csv (point data file) and automatically produce a raster image to highlight areas of disproportionately high rates of juvenile tuna per total MT of the set. Management considers the lowest two size categories to be economically and practically problematic (see discussion), so these two layers are added together and compared to the raster layer for the total tonnage per cell.

Finally, histograms were produced based on the number of sets made within various ranges for the SST and plankton concentration. The standard deviation ranges from the mean values of each parameter can be used to set map filters in the onboard oceanography software programs to identify fishing grounds with similar oceanographic conditions to previous sets. These images represent valuable fishing information for the fleet and are not published in this summary.

Business Report

The company through which the internship was completed contracts management and operational services to a fleet of tuna purse seine vessels, each of which represent an individual limited partnership company. Each of the vessels pay a monthly fee to the management company based on the services provided, including accounting, catch management, operational planning, fish sales, and vessel maintenance. The company's employees are organized in a functional structure based on the roles that they provide to the vessels. The main functional groups are logistics and operations, accounting, marketing, engineering, science, and human resources. There is typically one head for each department who reports directly to the CEO. Most of the decision making is centralized with the CEO, although employees are encouraged to provide input and direct decisions that are relevant to their area of expertise.

The majority of the tasks performed by individual employees typically fall into the two categories of routine task performance and adaptive task performance. The routine tasks include all of the daily and known requirements to operate a fleet (ex. provision of supplies for a fishing trip, reporting of data throughout and after a trip, providing crew payments following the unloading, etc). In addition to those routine tasks, adaptive tasks arise as well, resulting from unpredictable breakdowns at sea, unusual fishing conditions, or unpredictable port calls depending on the catch and effort of competing vessels in the region. Although they make up a smaller portion of the daily tasks, the CEO also places high value in creative task performance in regard to finding suitable options for port calls that meet the needs of that vessel while providing the best price, ideas to improve logistics, and consideration of the value and challenges of operating under US flag compared to other countries. Due to the complexity of the fishing industry, it is rare for one person to see a single large project from the beginning to end or to feel that the actions of an individual concretely produced a clear end result. Completion of tasks more often involves collaboration amongst several internal and external colleagues across long timelines. In this scenario, it can be challenging to receive clear feedback on an individual's contributions. For this reason, the company has invested considerable effort into organization of the tasks performed by each member of the team to facilitate expectations and understanding of accountability within the team. This effort was triggered by a former emphasis on the idea that every member of the team should be able to move smoothy between roles. The intent of this approach was to increase resilience around the company's collective ability, but it produced high levels of stress for employees due to the significant ambiguity over who was accountable for various tasks. It was also easy to have overlap in employee effort that produced inefficiencies. Not only did this create lapses in rewarding successes, but also made it challenging to locate and correct errors. Following this organization of accountability, the company gained an ability to manage performance based on objectives. With the expectations for each individual clear, it was easier for the employee and managers to understand and respond to their performance throughout the year. This also increased the employee job satisfaction by evening out the workload amongst individuals and providing a platform for them to review their satisfaction with pay, growth opportunities, and the day-to-day work.

The financials are tracked in several company pools to match the company structure. The accounting department provides regular updates to the balance sheet (BS), the profit and loss records (P&L), and the income statement on an individual company basis and on a consolidated basis. In addition to these monthly views, the P&L documents are also provided on a per-trip basis. The reason for this is that it's common for all of the upfront costs of a trip to occur in one month, while the revenue from unloading occurs in the next month. This can create a relatively volatile picture of the financial health of a vessel since revenue is only recorded upon fish delivery at the end of a trip, after the high costs associated with trip preparation and waiting for the vessel to fill up with tuna. Therefore, consideration of the P&L on both a monthly and per-trip basis are necessary to assess how well the vessel company is performing. Through the provision of these reports, the accounting department is able to capture that financial value of the various company's activities in a comparable and transparent format that allows managers to understand the performance, inefficiencies, and opportunities to improve the business. There is not a dedicated finance department in this relatively small company, so the financials are provided directly to the CEO. The CEO works in partnership primarily with the group controller and operations manager to evaluate the accounting information. During this evaluation, they call upon other members of the team for matters relevant to their area of expertise. This takes advantage of knowledge that each team member may have within their niche of the business and facilitates a group understanding of the financial health of the company and performance of the vessels.

The marketing for the fleet falls into two categories; one for the sale of raw tuna material and the other for the sale of finished goods to consumers. The sale of raw tuna is negotiated by a third-party broker based on the current tuna price at various ports of unloading. The price of raw tuna material is determined by a "per metric ton" cost-based pricing approach, assuming an average weight yield of 42% of usable meat from each fish, with slight variance between species. Since fixed costs of production are relatively stable, the overall value is determined by the raw material availability, which represents a variable cost. The per-ton cost of harvesting tuna experiences large fluctuations depending on season, region, fishing ground access fees, and regulatory limitations. Thin profit margins are associated with the sale of whole tuna from vessels, making it an extremely competitive industry. Maintenance of multi-generational relationships are often the key to success for fleets during these negotiations. Careful attention is also paid to the operational cost and length of trips, as small mistakes can quickly cascade into a financially disastrous trip.

The second category of marketing that was examined during this internship was the sale of finished tuna goods to consumers. A previous association with a consumer facing branded product was used as a case study to examine the marketing environment and strategy within the tuna industry. The product in question (anonymized for this report) was undergoing a relaunch effort that aimed to capture 10% of the “specialty with sustainable oil” segment of the United States shelf stable tuna market by the year 2023. This market segment is estimated to make up 3% of the total shelf stable tuna sale volume, and to be worth around $100 million annually. It is a growing market, which represents a huge point of value in the US consumer market, since canned tuna is typically viewed as a lower priced commodity product. Despite assertions of commitment to sustainability, US consumers historically have not been willing to pay the true value of sustainably caught tuna. When the price climbs too high, US consumers typically switch to the next lowest protein source. In effort to build a customer base within the US market, the marketing proposal for this branded product line was targeting environmentally minded and higher income individuals within the Pacific Northwest. The goal was to increase brand awareness through social media marketing and partnerships with influential food bloggers and restaurants, while increasing sales volume through e-commerce. While this was occurring, the company planned to enter into agreements with regional distributors, who would facilitate distribution to local brick and mortar retailers, such as PCC.

Summary and Conclusion

The work conducted throughout this internship will provide lasting benefit to the business that hosted it and to fisheries management and research overall. The internship involved the transformation of unorganized historical catch data into a universal database which includes a full range of variables identified by management to be relevant for understanding of the fleet’s effort. This database is formatted for easy analysis through filters, pivot tables and spatial software such as ArcGIS. From the business perspective, the value of this work will allow the fleet to increase revenue, decrease non-target catch, and mitigate environmental impact of fishing operations. Not only do the resulting analyses help management to understand the efficiency of their operation, but they can be shared with the captains to facilitate more selective fishing strategy. Increased understanding of the vessel’s catch and impact empowers the company to make decisions to streamline their operations. The database and ArcGIS methods presented here provide that increased understanding, which will only compound through extended utilization as additional catches are added to the records.

The value of this work extends to fisheries management and research more broadly. The methodology presented from this internship and resources required to complete the analysis are simple and could be easily employed throughout a range of fleets and fisheries. The catch data management scenario described at the beginning of the internship is quite standard for many fishing operations. Even if a fleet were only able to maintain the cheaper excel database, the format could be designed for easy provision to a third party with the ArcGIS license and skills. The information could then be provided back to the fleet with raster views of their fishing effort, target catch, non-target catch, environmental impact through sensitive species interactions, and oceanographic parameters which correlated to the catch of any of these categories. This information could also be used by fisheries managers to better understand the fleet operations and impact. Not only could this be used for general fisheries management, but it could be used to target questions about high-risk species or species with uncertain data histories (ex. oceanic whitetip sharks). One of the great disconnects that has become apparent throughout my work on the industry side of fisheries is the lack of utilization of fishermen knowledge in tackling scientific questions. Acknowledging the limitations of this source of data (ex. concern over vessel misreporting, only representative of the species within the fishing grounds, and potential temporal variability if the fishery is seasonal), the fishing industry can offer a wealth of knowledge for species that are extremely costly and challenging to gather data on through traditional scientific means. Use of the methods presented from this internship have the potential to be catered to a range of industries and species, greatly improving the scientific understanding of data-poor species with which fishermen interact. The increased scientific understanding that would result from such a partnership would improve fisheries management in a way that reduces impact on those sensitive species while promoting sustainable management of target catch. In summary, the analysis and methods presented here can be used to positively inform industry, fisheries managers, and scientists in a way that leads to more targeted and sustainable fishing operations.

Works Cited

PEW. July 6, 2011. “Recommendations to Kobe III Joint Tuna RFMO Meeting.” Online Image. Retrieved on 10/5/2021 from https://www.pewtrusts.org/en/research-and-analysis/fact-sheets/2011/07/06/recommendations-to-kobe-iii-joint-tuna-rfmo-meeting.