Aerial Monitoring of Ocean Vessels in Southern California

June 2018 – Annual Project Report

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Thanks to our Project Partners and Supporters:

LightHawk, Vantuna Research Group, Campbell Foundation,
Resource Legacy Fund and U.S. EPA

Project Overview

Objective long-term data on the type, extent and location of boating and boat-based fishing directly supports the success of marine spatial planning and resource management of coastal oceans. This project was initiated to generate an objective fishery-independent dataset to define the extent of boating activities in the state waters off the coast of mainland southern California. Now that a network of Marine Protected Areas (MPAs) has been established off this coast, these data allow in-depth descriptions and analyses of trends in fishing activities and compliance with the new regulations associated with this network. This information will be very useful in the adaptive management and enforcement of this network.

This project reflects the work of three partners; The Bay Foundation, LightHawk, and Vantuna Research Group.

Pre-MPA

September 1, 2008 was the first of 41 flights that accurately mapped the type, location and activity of vessels (from oil tankers to kayaks) operating in state waters of the mainland coast of southern California from Point Conception, Santa Barbara County to the US / Mexican Border. 5,304 vessels were observed and recorded during a two and one half year effort, (9/1/2008 through 4/1/2011). This objective, fisheries-independent dataset was incorporated into the South Coast Marine Life Protection Act Initiative by providing spatially specific information on the extent and type of fishing occurring off the coast. These data helped the stakeholders and decision makers involved in this process determine the locations for a network of MPAs while allowing areas valuable to fishing to remain accessible.

Post-MPA

January 20, 2012 marked the first flight following the establishment of the south coast MPA network. The same method applied pre-MPA continues to be used to describe trends and responses to the MPA network, namely from the fishing communities that have been restricted due to the MPA network. The information from this effort will be useful to decision makers, enforcement agencies, stakeholders, scientists and resource managers charged with enforcing and adaptively managing the newly established network in two ways. Firstly, as the location, type and activity of vessels are observed and collected, noncompliance with the new regulations is accurately depicted by this dataset. Locations with high rates of noncompliance are identified, which enables the California Department of Fish and Wildlife and others to engage in strategic and highly effective enforcement efforts. In addition, sectors of the fishing community with high rates of noncompliance can be addressed in similarly targeted and effective way as a fishery, independent of location. Secondly, adaptive management of this network by the dataset generated during post-MPA (when compared with pre-MPA data) will provide objectivity to this public process by specifically elucidating trends in the amount, location and type of fishing occurring post-MPA. We can anticipate a highly charged politicized environment for this process, and this type of empirical information is especially effective in countering false or misguided claims by individuals or industries.

Aerial Survey Methodology

These surveys collect spatially specific data regarding the distribution, type and activity of vessels operating in state waters following the implementation of MPAs in the south coast region. The Southern California Bight is divided into two transects; the southern transect begins south of LAX, ending at the Mexican Border and the northern transect begins north of LAX, ending at Point Conception. Small aircraft capable of high maneuverability and low speeds are used to fly directly over vessels while survey personnel accurately record location, vessel type, activity, and (when possible) a photograph. Depending on weather conditions, aircraft fly at an altitude of 500 to 1000 feet (average elevation for pre-MPA equaled approximately 650 feet) and travel at 80 to 120 knots. LightHawk coordinates volunteer pilots and their aircraft to complete the surveys. The collection of data from small fixed-wing aircraft allow for a transect to be completed in approximately two to two and one half hours depending on number of vessels encountered and other factors e.g., weather, airspace restrictions.

Aerial survey team comprising; pilot (front), spotter (front), GPS technician (back), Image collected courtesy of LightHawk.

The survey team consists of a pilot, spotter, GPS technician and photographer. Some of the planes are incapable of carrying a pilot plus three passengers; in this circumstance, the photographer role is adopted by the spotter. The spotter directs the pilots' flight path to intersect the vessels on the water, describes the type and activity of the vessel at time of contact and directs the GPS technician to enter a point and corresponding information into the computer. When possible, the photographer captures a photograph of the vessel(s) to aid in post flight QA/QC (Quality Assurance Quality Control). Due to the speed of the aircraft, rapid and accurate identification of vessels encountered on a transect is required. Therefore, the spotter, aided by binoculars or telephoto camera lens, must be familiar with the various boat types and activities boaters engage in, in the south coast region.

This information is recorded by the GPS technician into one of the predefined categories (Commercial Fishing, Commercial Non-fishing or Recreational) in a GPS data dictionary along with observed vessel type and activity (underway, fishing or anchored/not fishing), date, time, and any relevant notes. Ideally, vessel positions are not logged until survey planes are directly overhead for highest spatial accuracy. In areas with high vessel density or restricted airspace, where logging vessels individually is infeasible, multiple boats may be logged to a single representative point and later extracted using GIS.

Table 1. This table illustrates the relationship between the data categories. The broad Vessel Categories are typically noted first, then the finer scale Vessel Type, lastly an Activity is assigned. This information is entered along with geographic coordinates to accurately characterize the location, type and activity of vessels operating in the 990 square miles of California State Waters off the mainland coast of southern California.

Vessel Categories		Vessel Type
Commercial Fishing		CPFV
		Lobster Boat
		Trap Boat
		Urchin Boat
		Trawler
		Purse Seiner
		Light Boat
		Gillnet
		Other

Activity
Fishing
Underway
Anchored

Vessel Categories		Vessel Type (cont.)
Commercial Non-Fishing		Passenger Boat (Ferry, Cruise ship, Booze cruise)
		Tanker
		Cargo Ship (Barge, Container)
		Support Vessel (Tug, Tender)
		Res-Mil-Enf (All Science and Gov't Boats)
		Charter (Whale watching, Diving)
		Other (Dredge, parasail, etc.)
Recreational		Sport Fishing Boat
		Power Boat
		Sailboat
		Dive Boat
		Kayak
		Jet Ski
		Other (SUP, outrigger, row boat, etc.)

Data Handling and QAQC Methodology

After completion of the aerial survey, the GPS data are downloaded to Pathfinder Office, then exported into ArcGIS for analysis. Any photos taken of the vessels are linked to the corresponding data points collected and used for post-flight QAQC and training purposes. All entries with incomplete data were excluded. Additionally, all points with entry errors, such as inconsistencies between boat type and vessel type, were revised. As a result, consistent naming and classification conventions were kept between years. Once these data have been verified as accurate through QA/QC processes, the information is updated to the entire dataset from which maps and statistical analyses are derived. Additional descriptive fields are assigned to the dataset, including project year, pre or post-MPA classification, and transect direction (North or South) for later analysis.

Error Calculation

A certain degree of error is inherent in the collection of fine-scale spatial data from a moving aircraft. To quantify this error, a series of calibration points were collected during flights. Fixed objects with known coordinates, such as piers or oil platforms, were recorded. These observed locations of the calibration points were then matched with each point's actual GPS coordinates, and a distance between the two was calculated in ArcGIS. These distances between observed and actual were then averaged together to produce the mean error of observations, which was estimated to be 191.16 meters. This error was then incorporated into many components of the analysis. The study area of the California Coastal Waters was extended by observed margin of error, and all points falling outside of this boundary were excluded.

Summary Statistics

The summaries following are drawn from data collected by this effort. Data collected between 2008 and 2011 were consolidated as a pre-MPA assessment. Subsequent surveys were conducted from January 2012 to May 2018. These surveys were examined both annually and grouped as a post-MPA classification. The spatial and temporal variability of these data were then examined to inform broadly the distribution of boating effort in the Southern California Bight using ArcGIS and R software.

General Summary Statistics

Table 2. Number of flights, total vessels observed, and mean vessels per transect by project year.

Year	Number of Flights per Transect	Total Vessels Observed	Mean Vessels per Transect
2008	11	1210	110
2009	11	1106	101
2010	16	2031	127
2011	1	220	220
2012*	28	4197	150
2013	22	2742	125
2014**	9	1421	158
2015	4	399	100
2016	5	628	126
2017	8	782	98
2018	4	490	123

*Beginning in January 2012 MPAs were implemented.
**Beginning in June 2014, the survey interval for the study was modified from monthly to quarterly.

Table 3. Total number of vessels observed by transect.

Transect	Total Vessels Observed	Total Number Transects/Flights
North	4,002	59
South	11,444	60

The number of flights flown for each transect direction (north/south) varied slightly both within and between years. To compare variables or observations between years, all data was normalized for survey effort. Total observations were divided by the number of flights flown for that transect and year to determine the average observations per flight. These averaged values were subsequently compared to determine trends in the data.

The density-number of boats operating on the southern transect from Los Angeles to the US Mexican Border is significantly greater than the density on the northern transect from Los Angeles to Point Conception. We found this reduced density of vessels on the northern transect of the study area to be a significant driver of many relationships explored in the analysis. Although there were greater densities of boats observed on the southern transect, the relative distributions of each activity were fairly consistent (Figures 1 &2). Far more boats were observed underway, followed by fishing, with the least number of boats observed at anchor. Likewise, a similar trend was found when examining the types of vessels observed each year.

Recreational boats are the most common, with Commercial Fishing and Commercial Non-Fishing recorded significantly less frequently on both northern (Figure 3) and southern (Figure 4) transects. Commercial and Commercial Non-Fishing vessels tended to be recorded with far less inter-annual variation. This is likely due to the purpose of these vessels operations, and are therefore less impacted by ocean conditions, fuel prices, days of the week, or other variables that would discourage or alter recreational boat use.

Given the differences in fisheries, substrate distribution, MPA locations, ocean conditions, and sheer numbers of fisherman, fishing effort was compared separately between northern (Figure 5) and southern transects (Figure 6). Fishing effort and density of fishing vessels were found to be much greater in the south. With an average of 56.84 vessels observed actively fishing per transect each year.

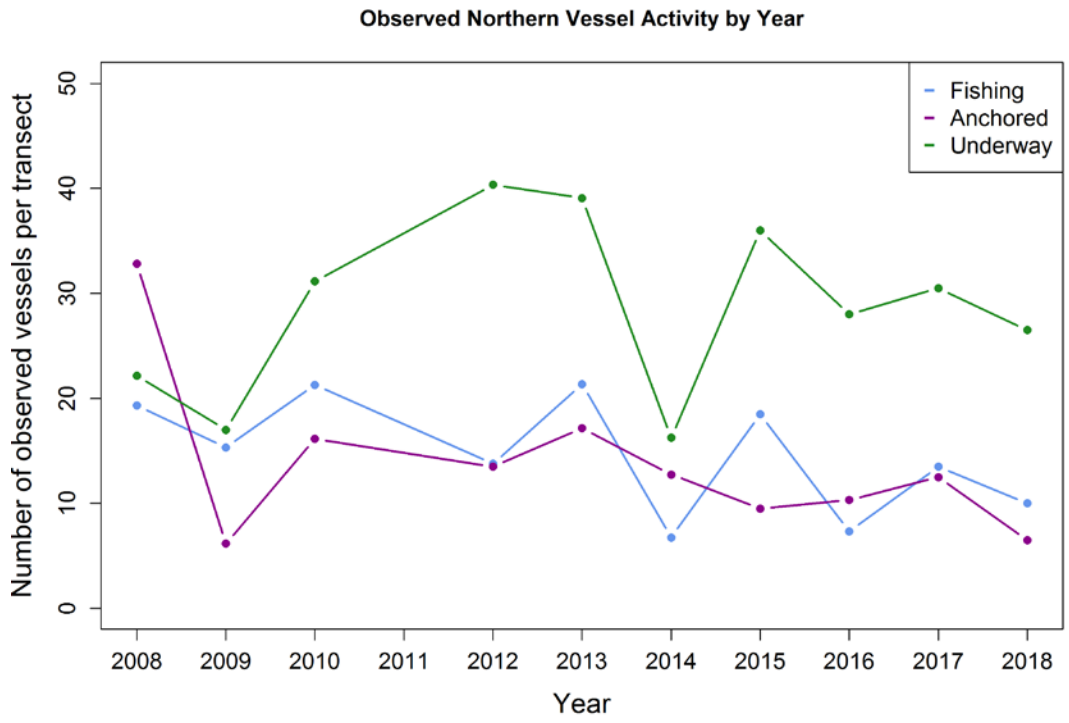


Figure 1. Examining the distribution of vessel activity by year on the northern transect (LAX to Point Conception, CA).

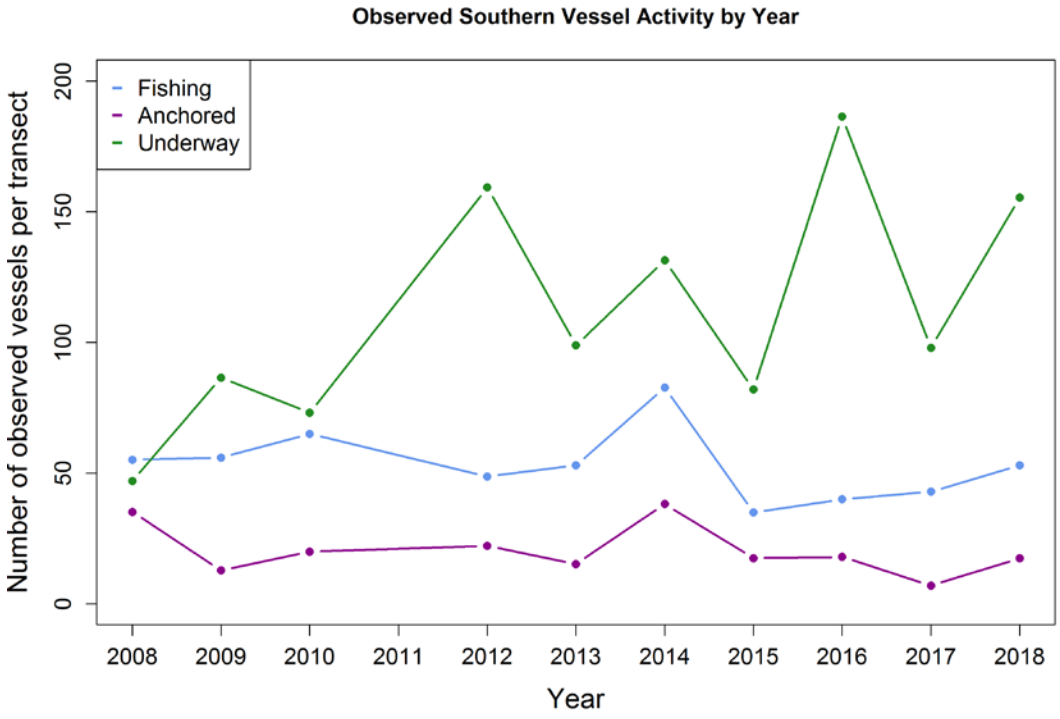


Figure 2. Examining the distribution of vessel activity by year on the southern transect (LAX to the US/Mexico border.

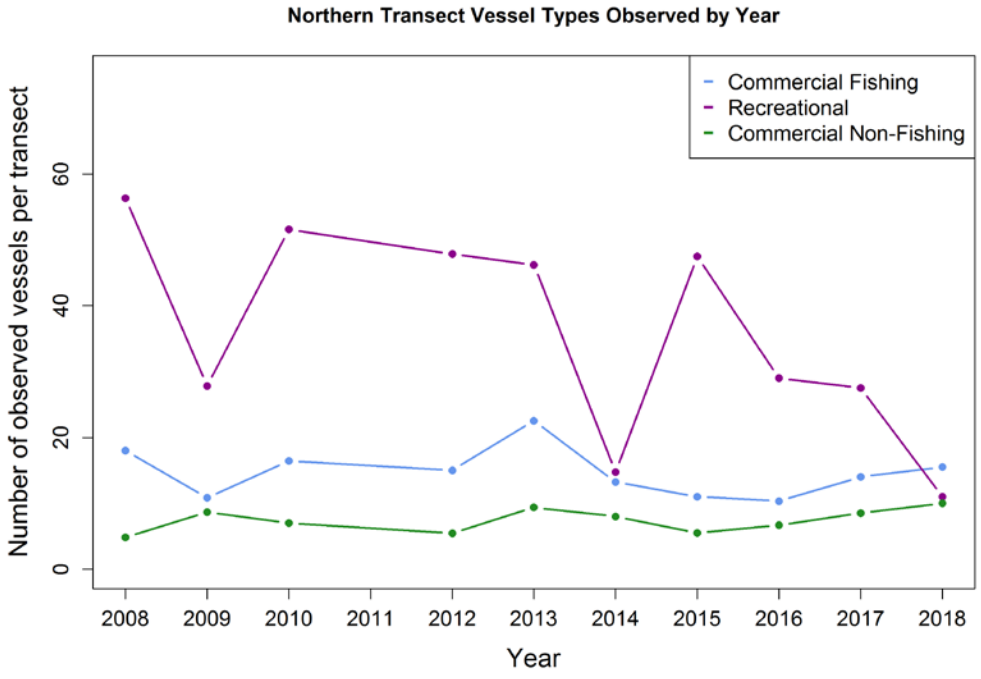
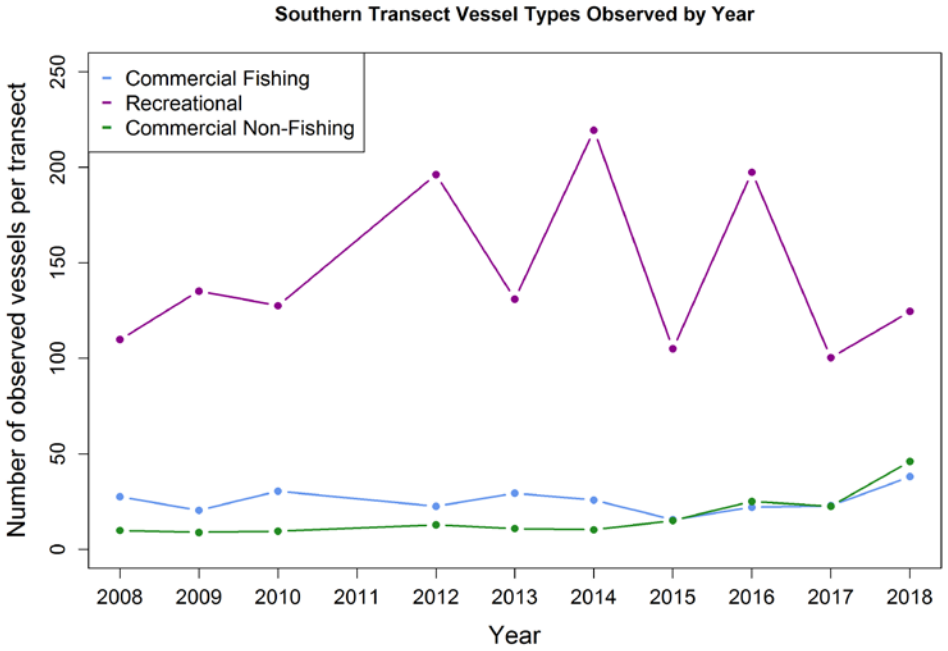


Figure 3. Vessel types observed (Commercial Fishing, Recreational, and Commercial Non-Fishing) by year for northern transects.



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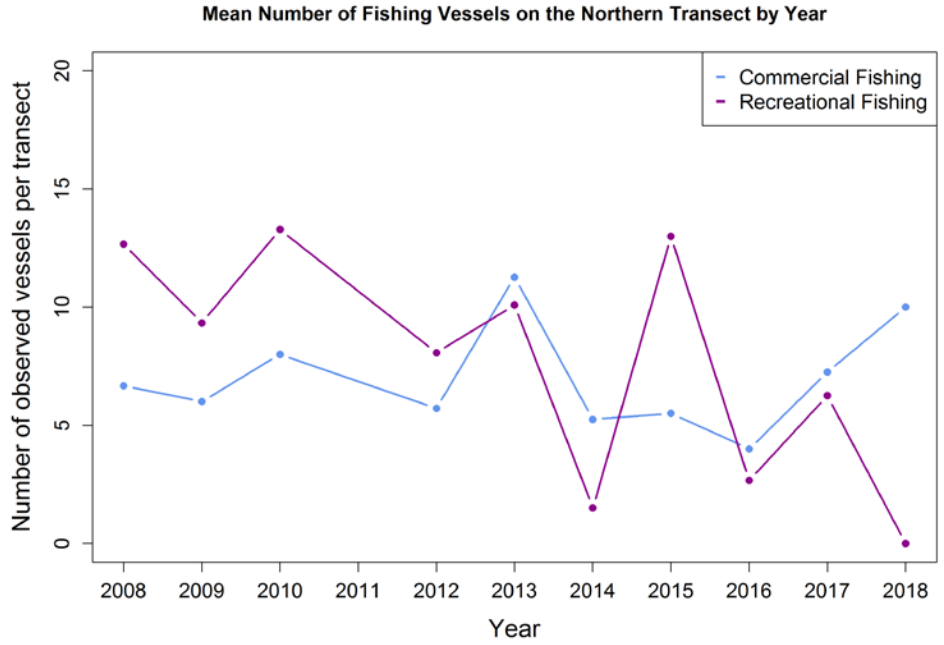

Figure 5. Mean number of commercial and recreational fishing vessels observed on the northern transect from 2008 – 2018.

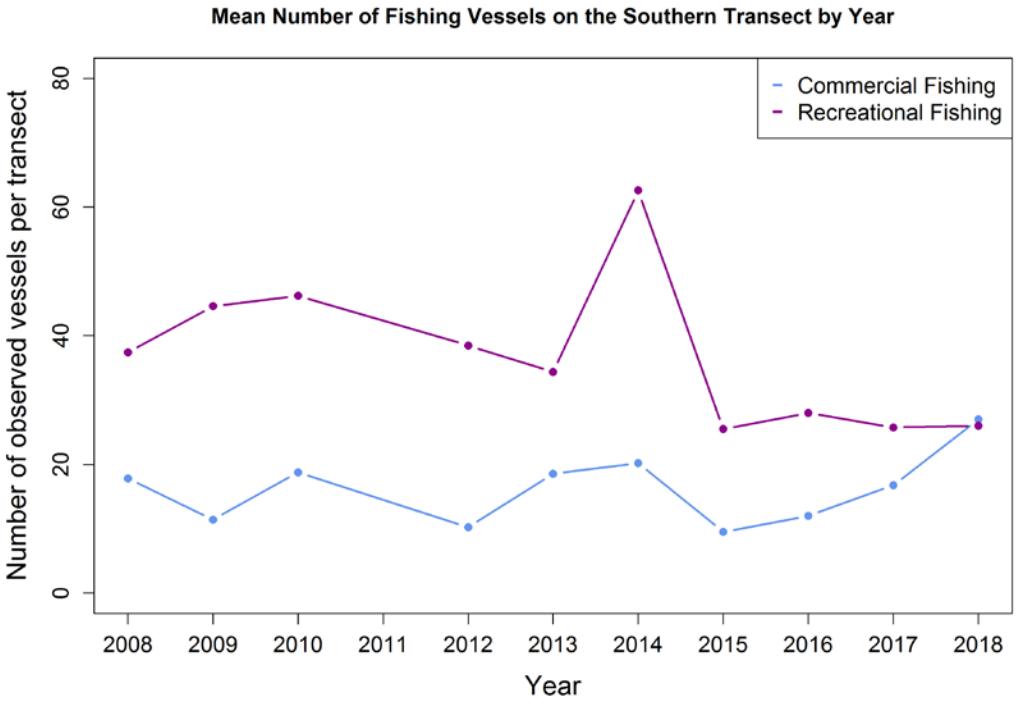

Figure 6. Mean number of commercial and recreational fishing vessels observed on the southern transect from 2008 – 2018.

Compaction

One major concern for the establishment of MPA's is the potential for the compaction of fishing vessels as they are displaced from historical fishing grounds following implementation. To quantify this compaction, the distance between each "fishing point" to its nearest neighbor was calculated for each transect. It is important to note that compaction is directly inversely related to this metric of distance between points, with lower distances signifying greater compaction.

The distance between vessels was found to vary between pre and post MPA implementation over the entire study area for all vessel types, with distances between vessels increasing after implementation of MPAs and remaining relatively constant for several years i.e. 2010-2016 (Figure 7). This trend suggests that rather than increasing compaction, the implementation of MPA's decreased compaction as vessels presumably spread apart searching for new fishing grounds as pre MPA data from 2008 and 2009 suggest greater compaction. 2017 values indicate a significant departure from the values recorded in 2010-2016 but by themselves didn't indicate a trend other than a departure from the past years. 2018 shows a more demonstrable departure from the norm of 2010-2016 and may be suggestive of a trend describing greater compaction than ever observed from this effort. Prior annual reports categorically described an increased distance between fishing vessels correctly attributed as a lack of compaction. The past two years of data, 2017-2018, demonstrate a return to pre-MPA values and the most compaction described by these data occurring in 2018 (Figure 7). The 2017 report stated the following; "The variation in the data for 2017 likely reflects the currently low sample size as the majority of surveys have yet been completed." With the additional data collected in 2018 this statement should be reconsidered as it may be indicative of a growing trend.

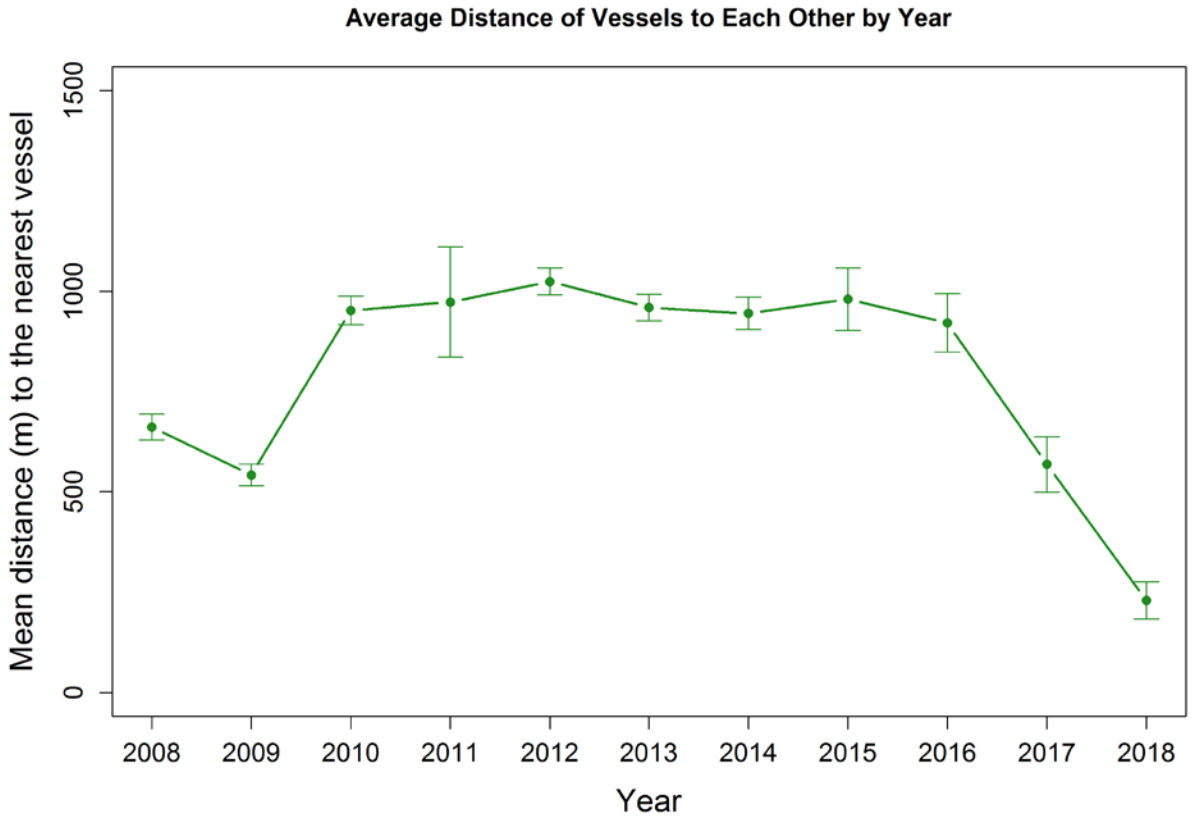

Figure 7. Average distance between fishing vessels for all transects and vessel types by project year.

Substrate

In contrast to the recent variation or departure from the norm the proportion of fishing effort based upon bottom type of substrate remains consistent over time. (Figure 8.) Fishers continue to favor hard substrate over soft substrate in 2018. 13% of the study area is composed of rocky bottom, charaterized for the analysis as hard substrate, 87% is sand and mud (soft substrate). Approximately 33% of the total fishing effort pre and post-MPA was determined to occur on this hard substrate, despite the fact that it comprises only a small portion of overall area (Figure 8). We found substrate type to correlate strongly with other factors explored in the analysis. With ten years of data collected this preference for hard bottom substrates over soft bottom should be classified as characteristic of southern California fishing in the early part of the 21st century.

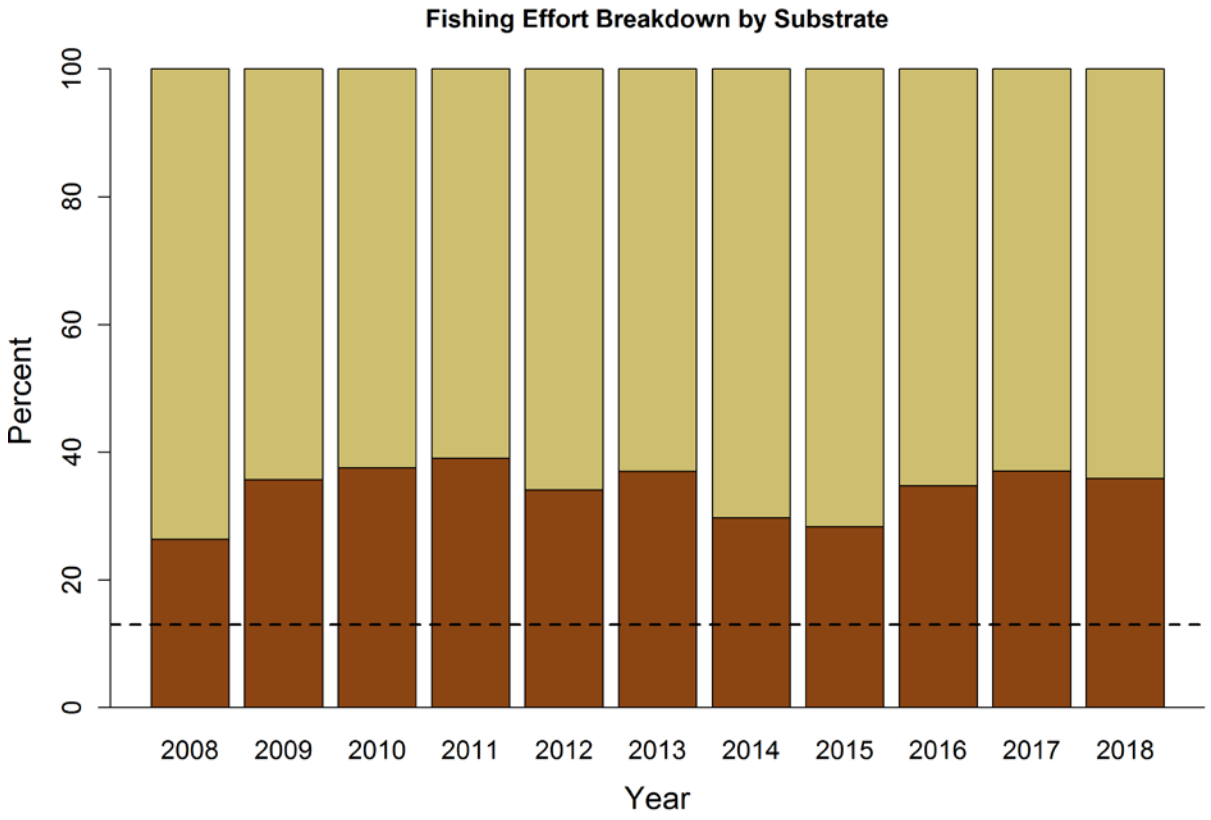

Figure 8. Percent of fishing effort by substrate from 2008-2018. Black dotted line indicates the amount of hard substrate available in southern California, brown represents the proportion of fishing observed on rocky bottom/hard substrate, tan represents proprotion of fishing observed on soft substrate.

Fishing Effort Relative to MPA's

In analyzing spatial aspects of fishing effort, changes in fishing trends around newly-implemented MPA's were explored. The distance between each actively-fishing point and the nearest MPA was calculated and averaged for all transects and vessel types (Figure 9).

In addition to the plotted values below, some other trends were identified in the data corresponding with proximity to MPAs. The data suggest that average proximity of fishing to MPA boundaries was found to be significantly greater for the northern transects than southern; clearly describing that boats are fishing closer to MPA's in the south than in the north. This is possibly due to the greater number of both ports and MPA's south of LAX, leading to much greater proximity of fisherman fishing close to port and MPA's. Finally, boats tended to fish significantly farther from MPA's when fishing soft substrate than when fishing hard substrate for northern transects, while there is no significant difference in the south. This is likely an artifact of the relative differences of MPA distribution relative to substrate in the north and south portions of the Southern California Bight.

Here again we note that the data from 2018 suggest a significant departure from the pattern of fishing related to distance from an MPA, (post MPA data from years 2012-2017). 2018 data also diverged from the norm regarding distance to nearest fishing vessel, (Figure 7. and compaction). From these two values i.e., compaction and average distance of fishing vessels to MPA by year there is a different pattern of fishing occurring along the mainland coast in southern California relative to MPAs and other vessels than observed in the past eight and six years respectively.

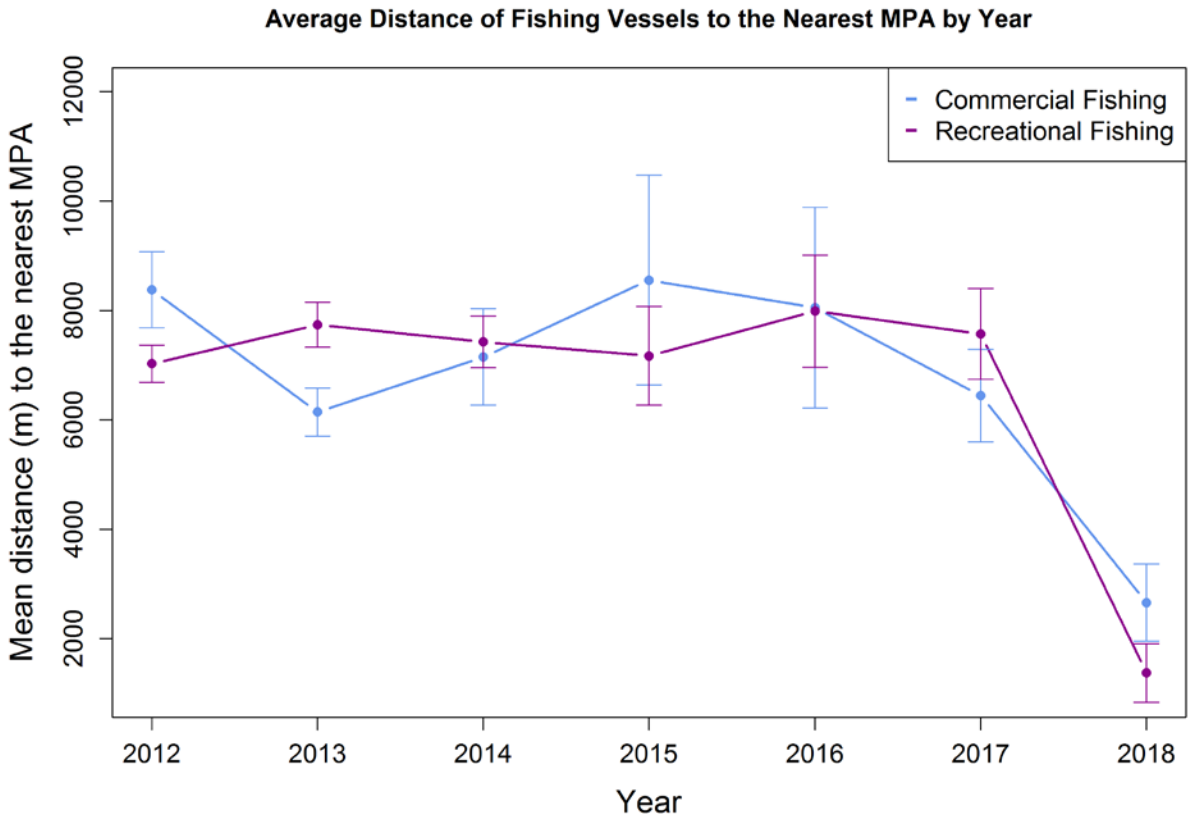

Figure 9. Average distance between fishing vessels and nearest MPA for all transects and vessel types post implementation.

MPA Compliance

One of the major objectives of the project was to investigate compliance to MPA regulations following their implementation in 2012. To examine compliance, the spatial border of each MPA was reduced by our determined margin of error. We could then be confident that all points that intersected this minimized MPA polygon would fall within MPA boundaries. Next, the classification of each MPA was referenced for take restrictions. When collecting data, only those boats with a visible fishing line in the water or fishing gear on deck in use are deemed actively fishing. Referencing these criteria, vessels were deemed compliant, non-compliant, or undetermined. All undetermined vessels were excluded, resulting in a subset of boats that are indisputably in violation of MPA regulations. Therefore, this analysis constitutes a conservative estimate. These non-compliant vessels were then compared to the total number of vessels recorded that year to calculate a percentage score of compliance.

We found a steady decline in violations of MPA regulations with time. The commercial fishing sectors that were observed displayed compliance with the new regulations with very few exceptions. A large majority (88%) of noncompliant boats were recreational vessels, with sixty recreational boats observed out of compliance, compared with eight (12%) commercial fisherman (Table 4 and 5). This is likely due both to greater awareness of commercial fisherman to regulations, and the impact of penalties, i.e., fines, jail terms, and loss of licenses for commercial poaching. In general, non-compliance seems to be limited, given the increasing low occurrences of violations when compared to fishing trends more broadly (Figure 10).

Table 4. Non-Compliant Vessels Sighted by MPA all years Post MPA implementation.

MPA Name	2012	2013	2014	2015	2016	2017	2018
Point Dume	2	0	0	0	1	1	0
Naples	2	1	0	0	0	0	0
Swami's	3	1	5	0	0	1	0
Point Vicente	2	3	2	0	0	1	0
Laguna Beach	5	2	2	1	1	2	0
Abalone Cove	0	1	1	0	1	0	0
Matlahuayl	24	3	2	0	4	2	0
Cabrillo	0	4	0	0	1	0	0
San Diego-Scripps Coastal	1	2	1	0	0	0	0
Point Conception	1	3	0	0	0	0	0
Tijuana River Mouth	1	0	4	0	0	0	0
Campus Point	4	0	0	0	0	0	0
South La Jolla	0	2	0	0	0	1	6

Table 5. Count and Percentage of Non-Compliant Vessels by Year

	2012	2013	2014	2015	2016	2017	2018
Total Non-Compliant Vessels	45	22	17	1	8	8	6
Percent Non-Compliant Vessels	0.011	0.008	0.012	0.003	0.013	0.01	0.012
North Non-Compliant Vessels	9	4	0	0	1	1	0
South Non-Compliant Vessels	36	18	17	1	7	7	6

The highest incidents of non-compliance collected by this effort are found off the coasts of San Diego and Orange County. Almost 60% of all violations, either non-compliance or willful poaching have been described in South La Jolla, Matlahuayl, and Laguna Beach.

Further examination of the maps, Figures 12-14, illustrate changes in fishing effort around MPA's which can help target enforcement and education efforts and improve compliance. Examination of Figure 14 relating to changes in fishing effort around the La Jolla MPA, shows a polygon within the MPA border reporting an increase in fishing effort with MPA implementation. This suggests a potential for a high degree of non-compliance within this region and should be a priority for enforcement agencies.

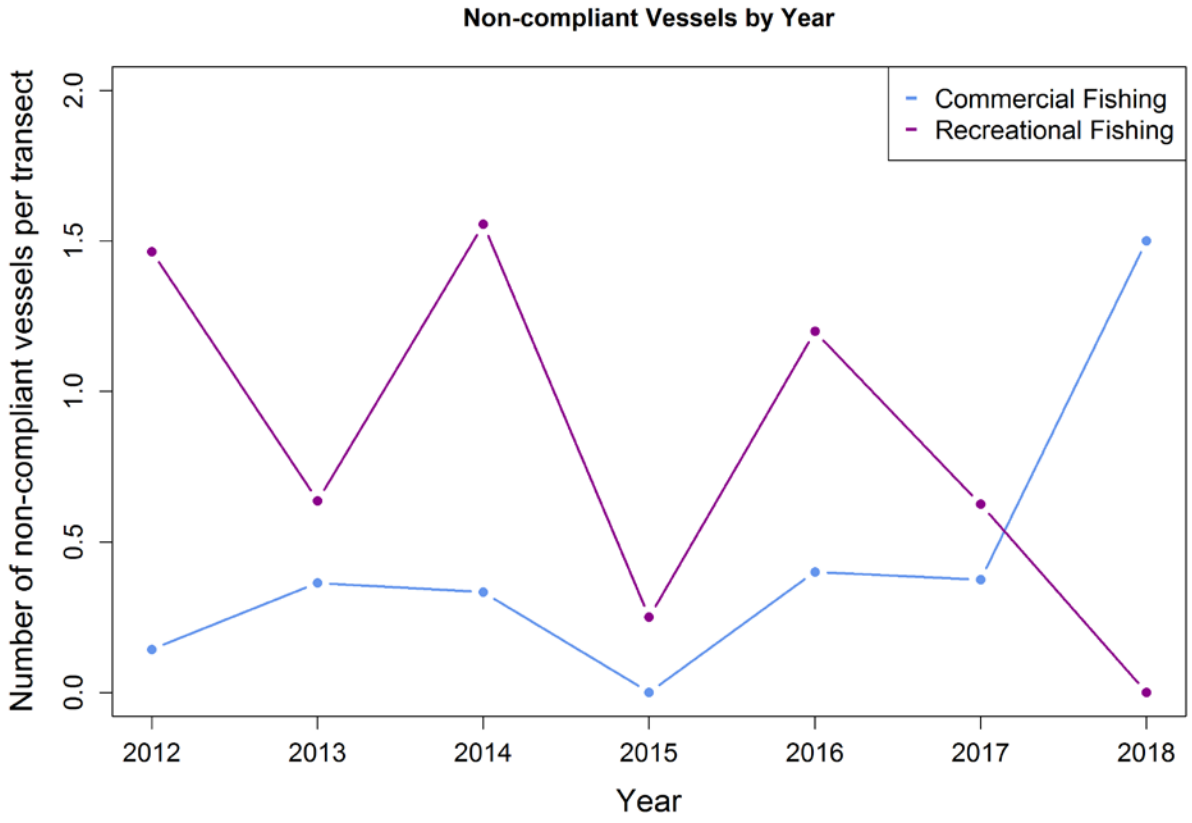

Figure 10. The average number of non-compliant vessels fishing within MPAs per aerial transect. Commercial fishermen are represented by the blue line while recreational fishers are represented by the purple line.

Non-Consumptive Uses of MPA's

There is the increased potential for non-consumptive recreational uses within these new areas. In order to explore the response of non-consumptive recreational boats to the implementation of MPA's, we examined the average distances of these vessels to MPA's with a similar methodology to the examination of boat-based fishing effort i.e., consumptive uses. Non-consumptive recreational boats were classified as all recreational powerboats, sailboats, dive boats, kayaks, jet skis, or other (outrigger, etc.) not actively fishing. The distances between these vessels were calculated and averaged by project year. We found the average distance between non-consumptive recreational vessels and the nearest MPA to decrease significantly after the MPA's were put in place (Figure 11). This significant decrease suggests that these vessels are recreating much closer if not within MPA boundaries. As with compaction and average distance fishing vessels to nearest MPA, 2018 has shown a divergent value. This holds true for recreational, i.e. non-consumptive vessel activities in or neighboring MPA's. In total our observations describe southern California boaters as more compacted and closer to the borders of MPAs then they have been since MPA implementation.

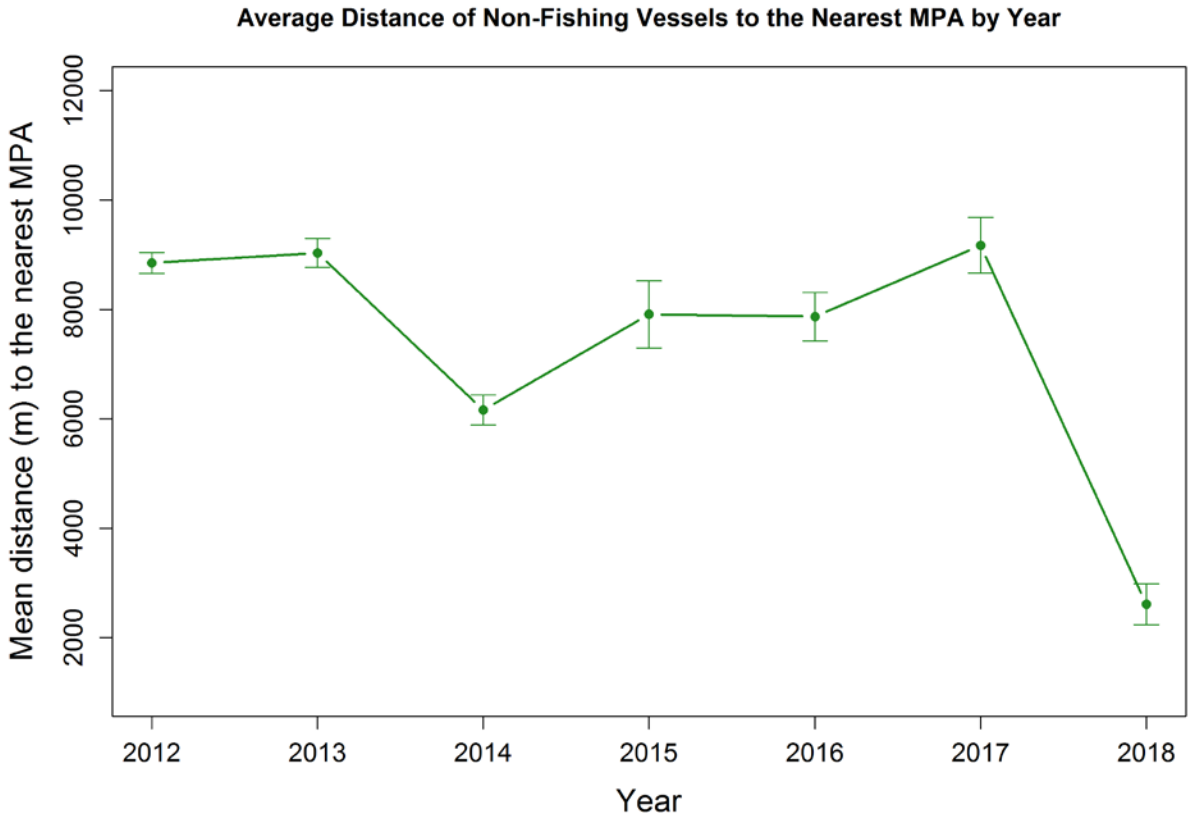

Figure 11. Average distance between non-consumptive recreational vessels and nearest MPA for all transects and vessel types.

Spatial Analysis of Fishing Effort

The point data of fishing vessels were overlaid to polygons with uniform area to provide a better visualization of large-scale trends in the spatial distribution of fishing effort before and after MPA implementation. Hexagons with 1km sides (2.6km Area) were selected because they were most easily interpreted. Points falling anywhere within a polygon were summed and then normalized by transect count. The difference between pre and post-MPA values was determined, resulting in the change in effort for each polygon before and after MPA implementation. See Figures 12-14 for maps illustrating these changes in fishing effort near Point Dume, Palos Verdes, and La Jolla. It is important to note, that given the observed error, all recorded points could fall within 191.16 m of their recorded location. Therefore, there is likely some error associated with the assigned polygon values. As shown in the figures, fishing effort has in large part moved outside of MPA boundaries since implementation in January 2012.

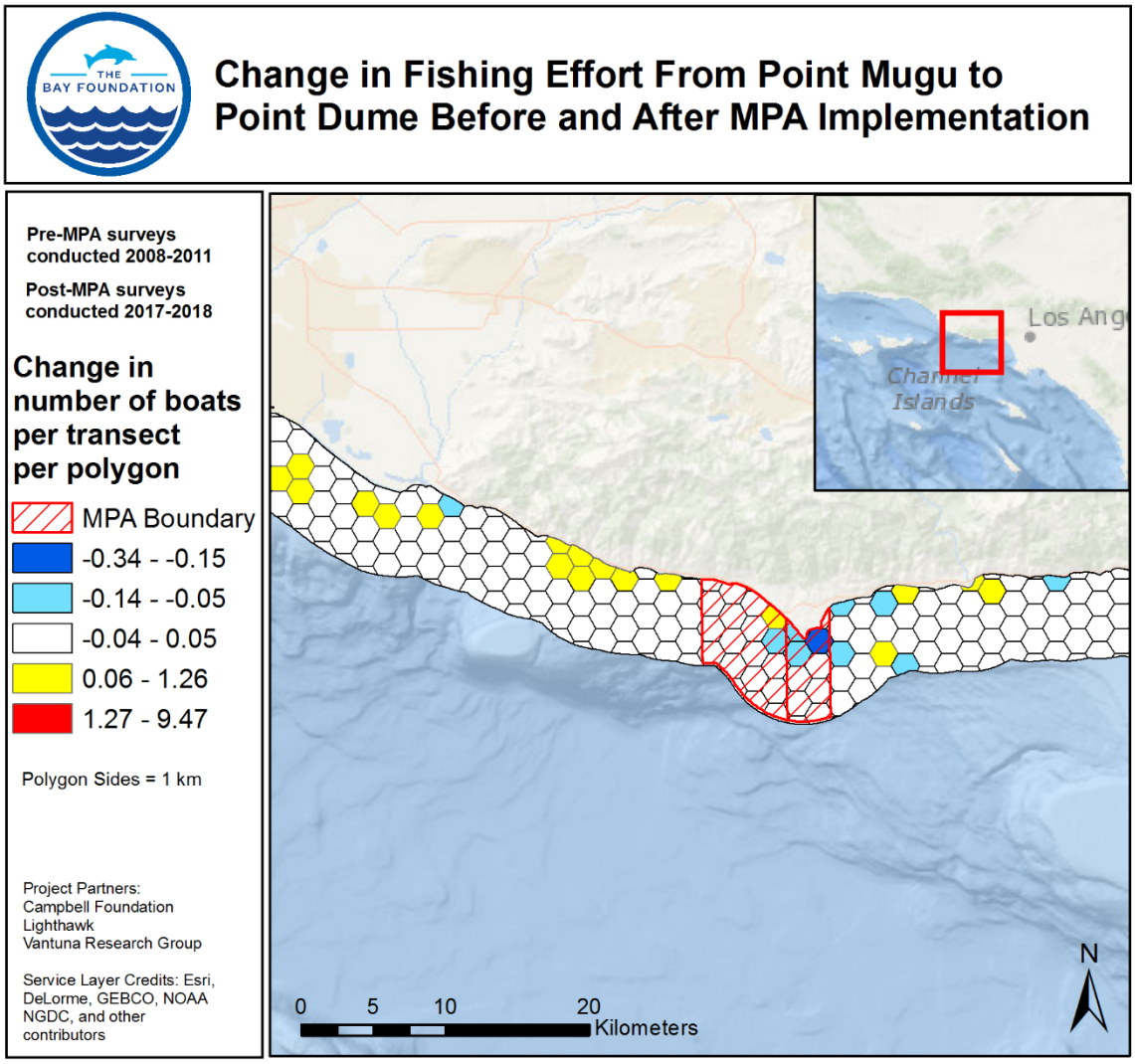

Figure 12. Change in fishing effort with MPA implementation: Point Dume, Malibu.

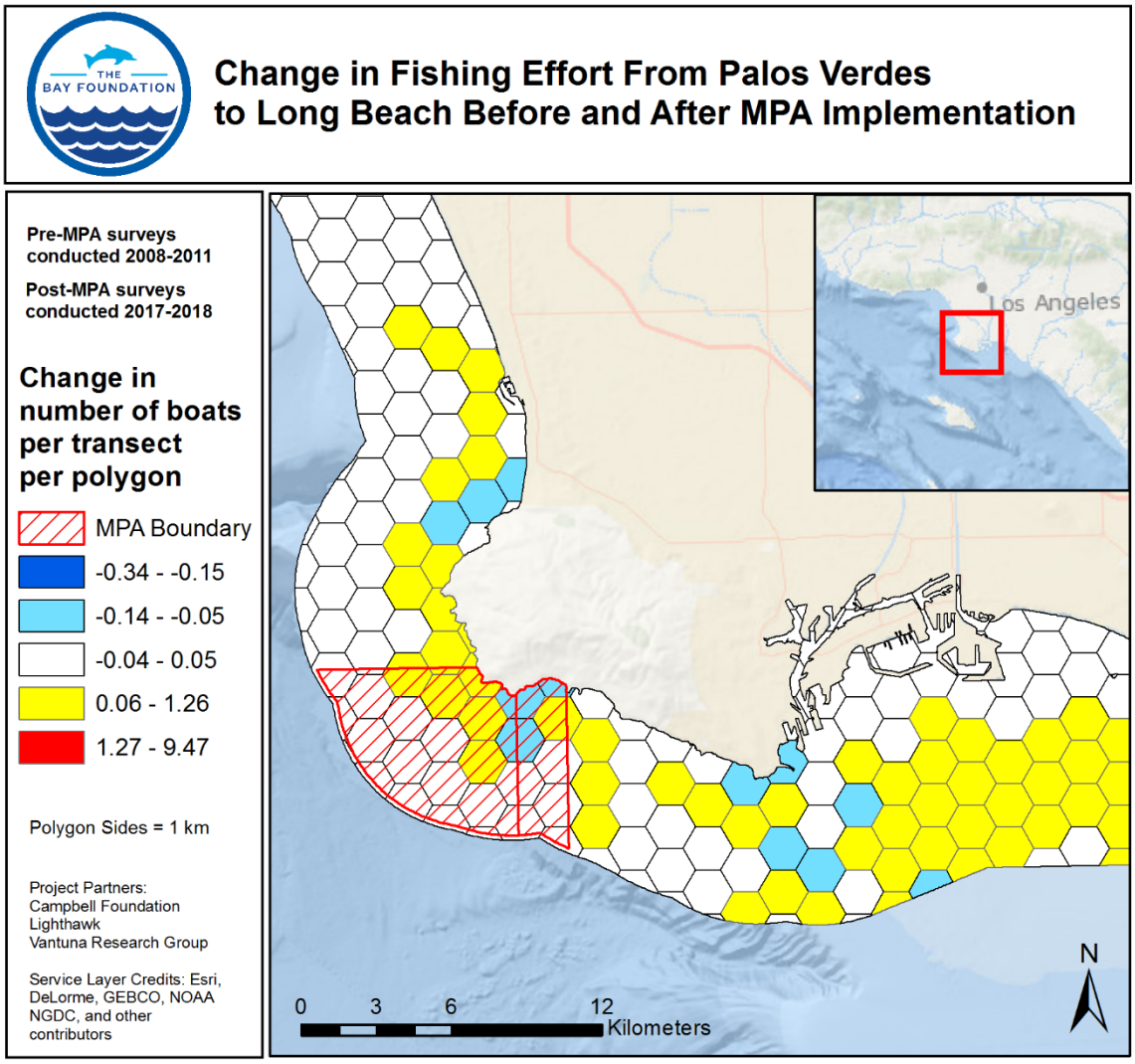

Figure 13. Change in fishing effort with MPA implementation: Palos Verdes to Long Beach

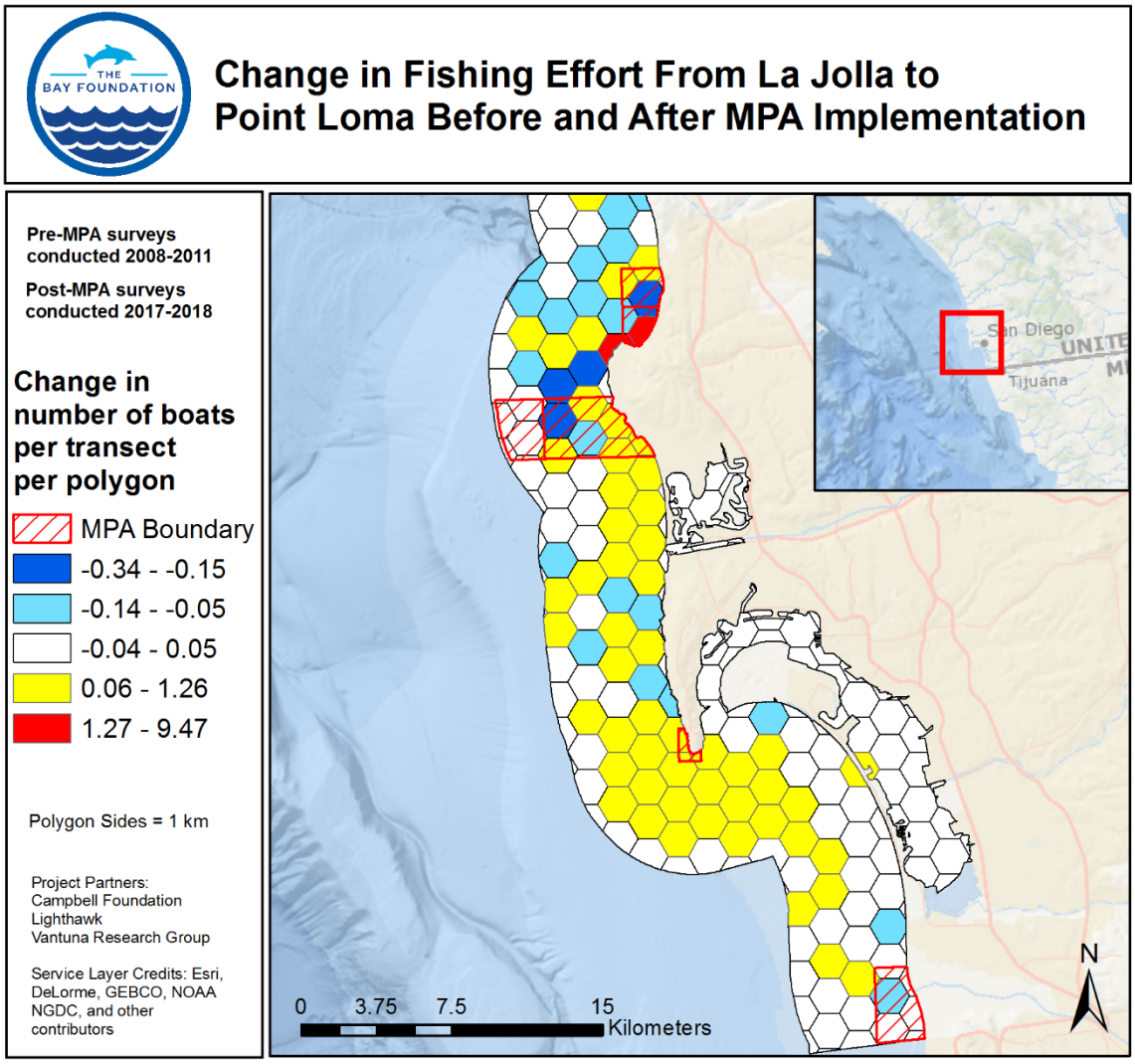

Figure 14. Change in fishing effort with MPA implementation: La Jolla to Point Loma

Summary

This program was initiated to provide a fisheries independent dataset that would correctly characterize the extent, type and distribution of fishing effort along the mainland south coast of California. Data have been collected using the same methodology before and after the establishment of a network of MPAs spanning the mainland coast from Point Conception to the US Mexican border including several of the Channel Islands. Over the past 10 years this program has identified several consistent trends that are characteristic of fishing along the mainland coast; that fishers prefer hard substrate to soft substrate when fishing, the density of vessels observed along the south transect remain significantly greater than the northern transect, the number of commercial fishing vessels observed over the years has remained relatively constant, and that rates of noncompliance with MPA regulations dropped shortly following the establishment of the MPAs and remain low. These results suggest that the MPAs have been well received by fishing interests and that the design of the MPA network has not unduly disrupted fishing in southern California. Thus, the regions socioeconomics as they relate to fishing, based upon the data collected and analyzed by this effort, appear to have been properly protected from disruption.

Interestingly 2017 and 2018 show a divergence in the pattern of fishing off southern California not observed since the establishment of the MPAs in January of 2012. The proximity to a neighboring vessel or the boundary of the nearest MPA has decreased in these years. Whether this trend continues or is only an exception to the overall trend observed over the past years will be determined by future surveys. It maybe that the expected increases in density and biomass of fishes within MPAs are forcing more animals to the perimeter of the MPAs or beyond creating spillover that maybe attracting fishers to the MPAs at this point. During MPA design, compaction of fishing effort was an often-stated concern by fishing interests. Specifically, that compaction of fishing effort would lead to negative interaction between fishing vessels vying for access to high priority targets and that the concentration of fishing effort would result in localized over-extraction of resources and lead to habitat degradation. Accordingly, The Bay Foundation and its partners in this program will continue to focus on this key dynamic which may impact both fishing and biological resources.

Outreach efforts during this report period started with the April 27, 2017 meeting of the California Department of Fish and Game presented in conjunction with the State of the California South Coast: Summary of Findings from Baseline Monitoring of Marine Protected Areas, 2011-2015. Additional presentations have included the following: several south coast MPA collaborative meetings, presentations to academic and research audiences at the University of Southern California, University of California Los Angeles and Loyola Marymount University, Annual Meeting of the Southern California Academy of Sciences, and the Southern California Chapter of the Society of Environmental Toxicology and Chemistry.