DEBRIS FREE SEAS

Assessing Lost Gear Removals in Southern California by a Nonprofit

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As authors of this Group Project report, we archive this report on the Bren School's website such that the results of our research are available for all to read. Our signatures on the document signify our joint responsibility to fulfill the archiving standards set by the Bren School of Environmental Science & Management.

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The Group Project is required of all students in the Master of Environmental Science and Management (MESM) Program. The project is a year-long activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Group Project Final Report is authored by MESM students and has been reviewed and approved by:

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Acronyms

CCS	California Current System
CDFW	California Department of Fish and Wildlife
ESA	Endangered Species Act
FAO	Food and Agriculture Organization of the United Nations
MMPA	Marine Mammal Protection Act
MPA	Marine Protected Area
NOAA	National Oceanic and Atmospheric Administration
NMFS	National Marine Fisheries Service
ODA	Ocean Defenders Alliance
OPC	Ocean Protection Council
SMCA	State Marine Conservation Area
SMR	State Marine Reserve

Abstract

This project aims to evaluate the impact of derelict fishing gear on the marine ecosystem, fishing communities, and the economy in Southern California through a case study centered on the commercial California spiny lobster fishery. Data on ghost fishing and marine wildlife entanglements were analyzed alongside data from marine debris removal expeditions. We found that derelict spiny lobster trap gear does not pose a large threat of entanglement to migrating whales. Furthermore the largest impact from derelict gear is likely ghost fishing, which can result in significant profit losses to the spiny lobster fishery. Our analysis suggests that up to 12,000 pounds of spiny lobster (equivalent to 8,000 lobsters) are potentially ghost fished each year, based on the average number of traps lost in the spiny lobster fishery in a year and our estimated ghost fishing rate of 2.19 lobsters per trap. Trap loss, and subsequent ghost fishing by derelict gear, can cause spiny lobster fishers to lose anywhere from $216,122–$931,672 USD in annual profits. Additionally, we distributed surveys to gather information from recreational and commercial fishers along the coast on how gear loss affects their livelihoods. Our survey results indicate that fishers are willing to collaborate with nonprofits like ODA to mitigate the negative impacts of derelict fishing gear on the environment and their livelihoods. Further, the collated survey responses and environmental data were used to identify "gear loss hot spots" to improve gear retrieval efficiency. Lastly, our study provided recommendations and outreach materials to ODA to support its mission of a debris-free sea in Southern California and to bolster volunteer participation and grow funding opportunities.

Keywords

Derelict, Marine Debris, California Spiny Lobster, Whale Entanglement, Traps, Gear, Nonprofits, Whales, Ghost Fishing, Commercial Fishers, Fishery Profits

Objectives

Our focus is to support the Ocean Defenders Alliance’s mission to remove marine debris, notably abandoned, lost, or discarded fishing gear, hereafter collectively called derelict gear, along the coast of Southern California and evaluate its impact

to marine wildlife, benthic habitats, and fishing communities in a case study centered on the California spiny lobster fishery.

We will improve our client's gear removal efforts by:

- Identifying what current barriers prohibit fishing communities from collaborating with nonprofits like ODA. In the process, we hope to discover partnerships that will multiply ODA's impact and identify strategies that will continue to build trust between ODA and fisheries in Southern California.
- Crafting engagement materials that will bolster ODA's outreach to the coastal community to recruit volunteers and spread awareness about the marine debris problem.
- Developing an informative data-driven webpage that visually displays ODA's clean up efforts and quantifies the benefit of their work to fishing communities. Our intention is for this webpage to drive investor engagement and donations toward ODA's mission.

Our key research questions are:

- Does derelict gear from the spiny lobster fishery pose a substantial entanglement risk to marine mammals?
- Do locations of derelict gear overlap with critical habitats for lobsters?
- What is the impact of ghost fishing on the spiny lobster fishery relative to the rate of gear dereliction?
- Are fishers in Southern California willing to work with a nonprofit focused on marine debris removal?

Significance

Marine debris is a global environmental issue whereby human-made waste is intentionally or unintentionally abandoned or disposed of in the marine habitat. According to NOAA, there is no place on earth that is immune to this problem

(NOAA, 2023). Thus far, media on marine debris has been largely focused on land-based plastic pollution due to its sheer volume and visibility. Derelict gear, however, is a significant source of marine pollution that is not so easily visible, but exerts a disproportionate impact on marine ecosystems (Gilman et al., 2022). Since fishing gear was originally designed to capture marine species, it continues to do so when derelict, and has the potential to trap, injure, entangle, and even kill marine wildlife for as long as it persists in the environment. With the rapid expansion of global fisheries, this marine debris issue has become increasingly problematic and is further compounded by the transition to more durable and synthetic fishing gear materials (Gilman et al., 2022). According to the Food and Agriculture Organization of the United Nations (FAO), the problem of derelict gear in the marine environment can be addressed through implementing prevention, mitigation, and remediation strategies (FAO, 2018).

Our client, ODA, is a nonprofit organization that engages in the remediation of marine debris along the coast of Southern California and the Hawaiian islands. ODA specializes in removing derelict gear from the bottom of the seafloor with highly specialized volunteer divers. In the Southern California region, of all the fixed gear fisheries, ODA seems to primarily recover derelict traps from the commercial California spiny lobster (*Panulirus interruptus*) fishery. The spiny lobster fishery supports the livelihoods of local fishers, is highly regulated by the government, and has been an important part of Southern California's fishing culture for more than a century (NOAA, 2022). For more than two decades, ODA has been tirelessly collecting derelict lobster traps across Southern California's waters. However, the full extent of its impact on the spiny lobster fishery and fishing communities remains underestimated. Thus, we aimed to scope and quantify the effects of its efforts in our study.

In this project, we evaluate the efficacy of ODA's gear removals on the California spiny lobster fishery and identify sustainable ways to expand its impact. We focused

on derelict lobster traps because they do not move great distances due to their weight and are therefore easier to track and quantify location-based impacts. We began by investigating the effects of derelict lobster traps to marine wildlife, benthic habitats, and fishing communities from the commercial spiny lobster fishery.

This project will collate location and frequency information on ODA's gear removal outings into a map of ODA's efforts in Southern California. This map, along with other communication materials, will be publicly displayed on ODA's webpage to increase fisher engagement and investor funding.

Background

Environmental Impacts of Derelict Gear in Southern California

Derelict fishing gear is a type of large debris in the ocean that can cause significant harm to wildlife, marine habitats, and the ocean economy. Gear can be lost and discarded, on purpose or accidentally (i.e., gear interference from territorial fishers, boat propellers cutting rope line, or movement of traps due to wave action during large storm events), and would no longer be under the control of the commercial or recreational fisher that deployed it. This includes rope lines, monofilament fishing lines, nets, pots, traps, floats, and other equipment used for fishing. Once this gear becomes derelict, it can continue to trap and kill marine life (e.g., fish, crustaceans, sea turtles, seabirds, and marine mammals) - a process known as ghost fishing. Additionally, derelict gear can damage sensitive seafloor habitats (e.g., coral reefs, seagrass beds), entangle vessel rudders and propellers, ruin other fishing gear, and compete with active gear by trapping economically important species (Parker, 2013). The harmful effects of derelict fishing gear globally are well-documented and far-reaching.

One of the most alarming consequences of derelict gear, is the impact on large migrating whales, which can be entangled in vertical lines used by the fishing industry. Along the Pacific Coast, the California Current System (CCS) is a highly

productive upwelling current that serves as an important destination for migrating cetaceans including humpback (*Megapetra novaeangliae*), gray (*Eschrichtius robustus*), and blue (*Balaenoptera musculus*) whales. Vertical lines from derelict gear can entangle these megafauna, scar their bodies, cause infection, restrict mobility, lead to fluke amputation, and can result in death (Zimmer, 2018). It is estimated that between 52% to 78% of humpback whales in Northern Southeastern Alaska ranges have been entangled in fishing gear at least once (Neilson, 2006). In fact, over the course of this year-long Master Project, there have been 25 whale entanglement incidents along the West Coast (NOAA, 2022). Entanglements in vertical lines used by the fishing industry are a leading cause of death for large migrating whales in the United States (Oldach et al., 2022).

All marine mammals are protected by the Marine Mammal Protection Act (MMPA), with some further protections extended to endangered and threatened species via the Endangered Species Act (ESA). Currently, many nonprofit, governmental, research, and non-governmental organizations are working to reduce marine mammal entanglements. NOAA recently approved new trap technology that incorporates interweaving rope to lower the breaking strength of small, weaker sections of rope. This allows the rope to break more easily if a whale is caught to reduce entanglement severity. It is estimated that switching to a weaker tensile strength could reduce mortality and suffering of entangled whales by around 72% (Knowlton et al., 2016). A more recent engineering approach from UC Santa Barbara researchers looked at reducing rope slack in the water column by using counterweights to maintain vertical rope tension (UC Santa Barbara, 2022). Although these rope modifications are promising, they only slightly reduce the dangers posed to marine wildlife by rope lines.

Meanwhile, metal traps that can weigh up to 200 pounds may also damage the ocean floor substrate, particularly during large storm events or high wave action.

Unfortunately, there is little research on the damages California spiny lobster traps may cause to the benthic environment and subjective accounts from fishers show uncertainty in the matter (Stevens, 2021; Ocean Defenders: Partnership in Progress). Nonetheless, our research focuses on the direct impacts of derelict lobster traps on the target and non-target species being fished and to quantify baseline potential impacts. As a result, our research will primarily concentrate on rocky reefs, which are the primary habitats of California spiny lobsters.

In addition, the California Department of Fish and Wildlife (CDFW) has reported that areas with greater fishing activity are more likely to experience gear dereliction (Hofmeister, 2022). As a result, regions with high fishing activity near important habitats may directly endanger the fishery's target species. By recognizing this correlation, information on benthic substrate and fishing activity can be used to identify priority areas for ODA's removal efforts.

Fishing Communities

Not only does ghost fishing directly harm many marine species, it indirectly harms people. When an individual animal perishes in ghost fishing gear, that animal is removed both as a viable food source for humans and as a future participant in reproduction for that species. This most significantly impacts subsistence fishers that rely on the ocean as a food source. Subsistence fishers, however, tend to lose substantially less gear compared to large-scale commercial fishing operations due to differences in fishing effort (Hofmeister, 2022). This creates consequential inequities for communities most dependent on these resources.

When legal and sub-legal lobsters are ghost fished, population viability is diminished for market catch and sale. This can lower the catch per unit effort and harm the economic profits of all fishers. Ghost fishing can lead to significant financial losses for fisheries, with estimated costs reaching millions of dollars (Lively & Good, 2019). Many fishers recognize the importance of preventing gear

dereliction and take it upon themselves to remove lost or abandoned gear (Ocean Defenders: Partnership in Progress). However, due to the specialized skills required for safe and effective removal, not all fishers are capable of doing so. Even those who are willing may find the intensive time and labor costs to be a notable deterrent. Unfortunately, this can create a situation where some fishers choose not to contribute to gear removal efforts, resulting in a free-rider problem where they benefit from the efforts of others without bearing the cost themselves.

Marine debris also affects ecotourism and coastal residents. Locals and tourists along the California coast participate in recreational activities in or adjacent to the ocean. Studies have shown that areas already perceived as polluted or dirty, are more likely to be undervalued and polluted more (Zeidner et al., 1988). The continued input of derelict fishing gear has led to traps, nets, and fishing lines being a common site for scuba divers, snorkelers, and beachgoers. While not immediately obvious, these sightings reduce the value people place on a given area, thereby reducing the amount people are willing to pay for ecotourism or to keep it clean. This could lead to large economic losses that are not immediately apparent to coastal communities.

Ocean Defenders Alliance

Our client, Ocean Defenders Alliance, is a nonprofit organization that removes abandoned fishing nets, traps, lines, plastic, and other man-made debris along the coast of Southern California and Hawai'i. While most other debris removal nonprofits focus on beach cleanups, ODA is unique in removing derelict fishing gear from the seafloor and the shoreline. ODA is powered by all-volunteer boat and master diver crews that will descend to depths between 20-130 feet to recover derelict gear. Since underwater gear cannot easily be spotted by the naked eye, ODA is highly dependent on location reports from the coastal community, especially fishers out on the water. Fishers can report any sightings of lost gear, or report their own gear as lost, directly to ODA for them to recover. However, fishers

can be very protective of their locations, and for good reason. In the past, federal and state governments and researchers have damaged fishers' trust by asking them to share areas where they most often fished, then establishing Marine Protected Areas (MPAs) in these locations (Ocean Defenders: Partnership in Progress). This created a mistrust for government agencies and researchers, and established a precedent among fishers to not share fishing locations with any outside organizations.

ODA has worked hard to create partnerships, collaborations, and establish itself in the space as a non-regulating body with interests close to the fishing community. Yet, it has only successfully worked with 3 fishers and its cleanup efforts are still largely limited by fisher engagement. Further collaboration in this space would allow increased cleanup efficiency by highlighting areas of high fishing effort and subsequent high gear loss. If ODA is successful in this endeavor, it could stand as a shining example of collaboration between fishing communities and nonprofit organizations working as a team to clean up our oceans.

In addition to collaboration, funding is a crucial component in expanding the scope of ODA's impact. Boat maintenance costs, along with fuel and travel costs influence ODA's ability to access all sites or even clean a densely populated site in a single trip. Since ODA conducts the majority of its gear removals by scuba diving, the threshold for good ocean conditions is increased to account for diver safety as compared to commercial fishers and typical recreational boating. This further limits the times that ODA is able to operate. ODA is also heavily reliant on volunteers as a function of how much gear it can remove in a single outing. Recruiting more volunteers could help ODA spread its impact across the state of California and beyond. ODA's only boat in California is currently docked at Channel Islands harbor in Ventura, and all gear removal outings can only happen at locations that ODA can travel to and from safely in one day.

ODA encounters lobster traps as a significant source of marine debris that has been historically difficult to remove from the environment due to the labor and financial costs labor incurs. However, ODA currently does not fully understand how its efforts contribute to reducing the quantity and magnitude of derelict traps in the ocean annually. Although ODA feels that it has removed an outstanding amount of lobster traps given the size of the traps and the amount of work required, it lacks data-driven quantifications of its impact. These valuations are critical for investor endorsements to power ODA as a nonprofit organization.

California Spiny Lobster

Life History

Image 1: Adult California Spiny Lobster

The California spiny lobster ranges from Monterey Bay, California to Magdalena Bay, Baja California, with a significant reduction in abundance north of Point Conception. Spiny lobsters reach sexual maturity at 5 years, mating from December through March with spawning largely occurring May through July (Cal Sea Grant, 2023). In healthy habitats, lobsters typically live 30-50 years and undergo 4 distinct life stages: larvae, plankton, juvenile, then adult. Spiny lobsters typically reach legal size at 7-11 years old with legal lobster carapace length measuring 3.25 inches (CDFW, 2018) (Image 1). These keystone predators prey on other carnivorous invertebrates in the rocky reef ecosystem, influencing populations and mediating competition among other prey species (“Spiny Lobster Reserves”, 2018).

Fishery Overview

The commercial CA spiny lobster fishery operates seasonally from October to March and extends from the U.S.-Mexico border up to Point Conception (CDFW, 2019). The spiny lobster fishery is an economically lucrative industry for California

fishers. The 2018-2019 season had 894,469 lbs landed and was valued at $13.83 million USD. In the 2019-2020 season, fishers landed 759,000 lbs of lobsters valued at $9.54 million USD (lower than usual due to SARS-Cov-2 impacts) (Mason et al., 2021). Given that each commercial trap can cost $100 to $300, trap loss within a spiny lobster fishing season can cause financial setbacks that could be further compounded by the loss of legal lobsters to ghost fishing (Ocean Defenders: Partnership in Progress, Ketcham Supply). Currently, the fishery is considered sustainable within a global context due to government regulations and fishers' stewardship efforts (CDFW, 2011). With the continued demand for seafood, local fisheries with strong environmental regulations offer the best sustainability options for these important food stocks.

Entanglements in the Fishery

Marine wildlife entanglements may threaten the commercial California spiny lobster fishery's operations. Cetaceans, pinnipeds, and sea turtles are most commonly entangled in gear. Any ESA listed "endangered" species that gets entangled in lobster gear can trigger federal action to delay or close a commercial fishery's season (RAMP; Drift Gillnets). At present, pinnipeds are only listed under the MMPA, and species local to Southern California are not ESA listed. Other cetaceans, such as the endangered false killer whale (*Pseudorca crassidens*), typically do not forage, breed, or migrate through the areas where lobster traps are set (NOAA Fisheries, 2022e). Similarly, leatherback sea turtles (*Dermochelys coriacea*) are also listed as endangered under the ESA, however due to their migration routes, foraging behaviors, nesting locations, and tendency to avoid nearshore, they typically do not overlap with spiny lobster fishing grounds (NOAA Fisheries, 2022f). Green sea turtles (*Chelonia mydas*) are only listed as ESA "threatened", and thus do not have the power to shut down a fishery (NOAA Fisheries, 2022g). Green sea turtles also tend to stay in bays, estuaries, and harbors to feed and consequently do not overlap with spiny lobster fishing grounds. For the spiny

lobster fishery, this lack of overlap indicates that entanglement risk would not be relevant in gauging whether pinnipeds, sea turtles, and some cetacean entanglements threaten fishery closures and substantial regulation. However, some species of whales, markedly humpback whales and gray whales, do have some overlap with spiny lobster fishing grounds. Measuring the threat of fishery shutdowns and heavy government regulations from entanglements is an important metric to gauge the future existence of the fishery.

Presently, there is no general consensus on the risk that the commercial California spiny lobster fishery poses to migrating whales. The commercial Dungeness crab fishery in Northern California has faced heavy legislation and seasonal closures recently due to issues with whale entanglements (RAMP, 2022). Similarly, the U.S. East Coast's American lobster (*Homarus americanus*) fishery has faced large backlash due to the multitude of North Atlantic right whale (*Eubalaena glacialis*) entanglements in their trap gear (Myers & Moore, 2020). The California spiny lobster fishery, Dungeness crab fishery, and American lobster fishery all use similar fishing equipment and techniques, raising concern about whether the California spiny lobster fishery poses the same risk of entanglement to migrating whales. This project is an initial evaluation as to whether the spiny lobster fishery poses a notable entanglement risk to migrating whales in Southern California.

Unknown Impacts from Derelict Gear

The California spiny lobster fishery inadvertently loses more than a thousand traps annually (Mason et al., 2021). Derelict traps continue to catch spiny lobsters, rock crab (*Cancer productus, Metacarcinus anthonyi, and Romaleon antennarium*), sheep crab (*Loxorhynchus grandis*), Kellet's whelk (*Kelletia kelletii*), and other fishery-targeted and non-targeted species. To combat these losses, CDFW requires commercial lobster fishers to have escape ports for sub-legal lobsters and small non-target species, as well as time-destruct devices on trap doors that degrade and

break after a set amount of time underwater to prevent ghost fishing (CDFW, 2019). CDFW has also made best practice recommendations to help reduce the risk of losing a trap (Earth Media Lab, 2017). While these efforts have reduced the amount of ghost fishing and traps lost within the fishery, over a thousand traps are still becoming derelict annually (Hofmeister, 2022). Anecdotal evidence also shows that traps do not always land 'door side up', meaning they continue to ghost fish these valuable keystone predators even when the timed-opening mechanism activates (Image 2). Further, during storms or large swell events, derelict traps that are correctly operating, have the potential to cause benthic impacts as they are dragged back and forth along the bottom by swells (Stevens, 2021). Additionally, the traps typically have 20+ feet of rope attached to them, which poses risk of damage to benthic habitats. However, there have been no formal or informal studies to determine the direct impacts of derelict commercial California spiny lobster traps on the benthic environment.

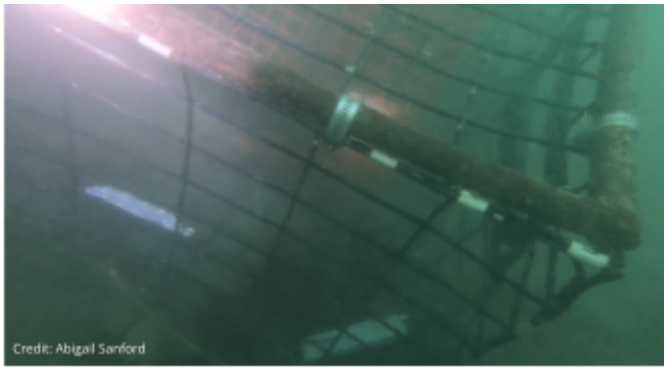


Image 2: Upside Down Lobster Trap Actively Fishing

In the 2019-2020 commercial season, 2,431 lobster traps were reported as lost, though this is known to be an underestimate (Mason et al., 2021, Hofmeister, 2022). Although thousands of traps become derelict annually, only a few hundred are removed by nonprofits, volunteer fishers, and the state each year. Logbook reporting and trap tag requirements have increased what is known about derelict traps, however there are still uncertainties surrounding ghost fishing, entanglements, habitat destruction, and the total number of traps lost and recovered. These uncertainties stem from 80-90% logbook compliance rates, short sample ranges (reporting first began in the 2017-2018 season), and a lack of studies investigating ghost fishing, entanglements, and habitat destruction from derelict

California spiny lobster traps. This project seeks to solve some uncertainty through the use of studies done in other lobster fisheries, data from logbooks, and information from our Fisher Feedback Survey to extrapolate estimated impacts and costs.

Based on the current, best available science, the vast amount of traps in the ocean pose a degradation threat to California's coastal ecosystems, including ecosystems of concern like eelgrass beds (*Zostera sp.*) (Reed and Hovel, 2006). Additionally, high trap dereliction correlates significantly with areas of high fishing effort (Mason et al., 2021). The actual amount of lobsters lost to ghost fishing within these derelict traps is unknown. However, a study in Florida Bay estimates that 3-6.8 lobsters were lost annually per derelict trap (Butler & Matthews, 2015). Another study in Norway found that 0.9-1.27 of their lobsters were ghost fished per trap (Adey et al., 2008). These numbers indicate that within the spiny lobster fishery, there could be between 2,200-16,500 ghost-fished lobsters per year. The difference in these estimates emphasizes the need for more accurate ghost fishing averages for California spiny lobster traps.

Currently, managers at CDFW do not have enough information to properly regulate derelict gear in the fishery and have stated that understanding mortality rates (both natural and human-caused) is one of the highest priorities of the Spiny Lobster Fishery Management Plan (CDFW, 2016). Our work would allow them to more accurately calculate total mortality rates within this fishery and make management decisions based on the best available science.

Methods

General Approach

We focused on ODA's gear removal outings in Southern California. Our study site encompassed coastal communities and fisheries from Point Conception to the

U.S.-Mexico border. To quantify the impact of its efforts, we analyzed ODA's logbook data from the past 20 years, categorized marine debris into 6 major categories, and summarized the total debris removed for each category. We decided to focus on derelict traps recovered from the commercial California spiny lobster fishery for the duration of this project for 2 primary reasons; the heavy weight of traps makes them easier to track since they typically stay near the location they became derelict, and the financial costs and labor required to retrieve these traps is significantly greater than other forms of marine debris ODA collects.

First, we assessed the whale entanglement potential of the spiny lobster fishery using data provided by CDFW and the National Oceanic and Atmospheric Administration (NOAA). Next, to assess instances of ghost fishing, we employed a winter quarter intern to record occurrences of ghost fishing that took place during ODA's gear removal expeditions, but were not accurately documented in the logbook initially. Then, we assessed the scale of ODA's impact by comparing our findings on ghost fishing to regional reports on trap loss by CDFW between 2020 and 2021. Additionally, we calculated the financial resources that ODA would need to scale their operations in order to recover the number of traps reported as derelict by CDFW in that same year.

Furthermore, we conducted an original survey to gain a deeper understanding of the prevalence of gear loss and the concerns of fishers in Southern California. We crafted questions for all types of fishers, but analyzed responses specific to the commercial lobster fishery. We compared survey responses to trap loss reports by CDFW and gear replacement costs in the region. We also used the survey to determine whether coastal fishers would be willing to work with nonprofits that remove marine debris such as ODA.

Finally, to increase investor engagement with ODA's work, we generated communication materials including 2 maps, flyers, stickers, a video, and webpage content (Results: Gear Loss Hotspot Predictions, Appendix A). One map displays ODA's recovery expeditions along the coast of Southern California from 2002-2022, overlaid with rocky reef spiny lobster habitat data and sensitive eelgrass bed habitat data. The second map visualizes fishing effort in the spiny lobster fishery overlaid with benthic substrate habitat in the region. Flyers were created to increase recruitment of volunteer scuba divers and deck crew as well as to spread awareness about ODA. Stickers were created to drive traffic to ODA's landing page to either report debris and/or donate to the organization. A documentary-style video was created to capture the humanity and mission that powers ODA's work with the hopes of building trust with fishers and inspiring funders to partner with ODA. The maps and information from our logbook analyses were integrated onto ODA's webpage to provide data-driven insights on ODA's benefit to the California spiny lobster fishery and fishing communities.

ODA's Logbook Analysis

Marine Debris Removal Data

We took a critical look at the breakdown of marine debris handled by our client to assess the extent of impacts from marine debris. We broke down ODA's marine debris removal data from 20 years and over 505 cleanup outings into 6 main debris categories and summarized the total debris removed for each category and debris type.

Entanglement Potential Data

To investigate the entanglement risk migrating whales face from the California spiny lobster fishery, NOAA's whale entanglement data was obtained from Fisheries Biologist, Lauren Saez (NOAA Fisheries, 2022a). This data contained the total number of entanglements for the State of California from 1982 to March of 2023.

There were a total of 444 whale entanglements reported within the dataset caused by 14 fisheries. Of those reports, 245 of them did not have enough identifying information to connect the entanglement to a specific fishery.

Whale entanglement data was used as a proxy to measure the threat of fishery shutdowns and heavy government regulations from entanglements of ESA-listed species since any ESA-listed endangered species has the power to delay or close a commercial fishery. This data was filtered and compared by trap fishery in the Southern California region that overlaps with ODA's gear removal locations.

Ghost Fishing Data

We aggregated and collated an original dataset on ghost fishing and potential bycatch instances through ODA's various trip logs, media, and blog posts since ODA's logbook did not track ghost fishing with workable consistency or resolution. We brought on a paid winter intern to review 5+ videos, 300+ photos, and 79+ blog posts and to create a tidy dataset for analysis of the ghost fishing potential of a single lobster trap recovered by ODA.

From this dataset, we summarized the total number of each species found and the total number of traps recovered. Since individuals found alive would have eventually died had the traps not been removed, we opted to count both dead and living individuals as being ghost fished. We counted every lobster as an instance of ghost fishing, as even if lobsters were sublegal size, a ghost fished lobster would never reach legal size and would be similarly lost to the environment and the fishery. We chose to use the most recent public estimate for the average weight of a legal-size lobster, which is 1.57 pounds according to CDFW from the 2019-2020 lobster season (CDFW, 2019). Traps that could not be removed, often from being buried too deep in sediment, were not included in this dataset unless ghost fishing was observed and living organisms were released.

Geospatial Visualization

Cleanup Effort

ODA's expeditions, eelgrass habitat, and rocky substrate were displayed in a map to better visualize the relationship between ODA's debris removal efforts, habitats sensitive to disturbance, and areas conducive to high spiny lobster density. Location data for visualization was acquired from ODA as latitudinal and longitudinal coordinates. All data was then converted by our paid summer intern to an equivalent format (Decimal Degrees) and outings without accurate geospatial data were removed. This was then overlaid with hard substrate and eelgrass habitat data acquired from CDFW's GIS Directory and configured in ArcGIS Version 3.1.0 (CDFW Marine Region GIS Data, 2020).

Fishing Pressure & Habitat

We were able to identify areas of high spiny lobster fishing effort with the help of external advisor, Dr. Chris Free, and his expert knowledge and experience with California spiny lobster logbooks. We stored this data in a raster format for visualization and analysis in ArcGIS. The raster layer shows the general density of fishing effort based on trap nights per grid cell of associated latitude and longitude. We took the top 20th percentile of fishing effort as the areas of highest gear loss and reclassified each cell to have a value of 1 to use the raster calculator tool for our hot spot analysis.

We then used benthic substrate data from CDFW to determine areas of hard substrate that are likely to be rocky reef habitat and potentially sensitive to disturbance from movement of derelict traps. We rasterized the hard benthic substrate data and reclassified each cell to have a value of 1 for use in the raster calculator. Rasterizing the benthic substrate data, particularly at the scale that would run within the duration of this project, came with a degree of lost granularity

in the rasterized data. Nonetheless, the resulting map will still predict, within a less specific area, where the rocky substrate exists.

We used the raster calculator tool to add the fishing pressure and hard substrate data together for a final layer that predicts areas of high gear loss with greater potential harm to rocky reef areas. Finally, we then ranked the top 3 locations of high predicted gear dereliction containing the greatest area of hard substrate.

Survey Methods

We created an original survey to collect primary data on gear loss incidences for different fishing communities that spanned the same geospatial region as the California spiny lobster fishery. Survey questions were developed during a survey design course at the Bren School and included questions about the prevalence of gear loss to the fishers, willingness to work with nonprofits to collect gear, and other concerns out on the water (Appendix B). Survey questions were reviewed and approved by the external advisory committee and the Human Subjects Committee. Additionally, all members of the team completed the required Human Subjects Training course online. Once approval was granted, the survey was created in Qualtrics for wide distribution. Logic sequence flows were programmed such that respondents would be asked a specific string of questions based on previous responses. We specifically used the language, 'gear loss' in the survey to prevent animosity with the fishing community from past blame they have faced and to reduce the negative perception of the term 'derelict gear' in this context.

The survey was distributed along harbors and marinas from San Diego County to Santa Barbara County. Survey distribution began in early October 2022 with paper copies dropped off at locations that agreed to host our survey and emailed to personal and professional networks with contacts in the fishing community. We also went on an episode of the Cast & Crank Fishing Podcast hosted by Nick Trujillo to discuss and advertise the survey directly to thousands within the fishing

community from a trustworthy source (Appendix C). To increase survey participation, this survey was incentivized with a $25 visa gift card and a donated fishing rod from the Cast and Crank Podcast. The online survey closed on March 24th, 2023 and all paper surveys were collected on March 17th, 2023.

Survey results were downloaded as a comma separated value file from Qualtrics for further analysis in R. We ran a preliminary data screen that revealed that a number of these responses were not logical and most probably the result of robotic spam. This was largely determined based on the short answer questions with typed in answers that were nonsensical

In order to preliminarily screen for responses that were taken in earnest as opposed to those that were potential spam, we filtered for responses that were completed in entirety, and where the length of the survey response time was greater than 5 minutes. We assumed that the estimated time to take our survey was ~10 minutes, but some questions did not apply for all responders, therefore some response times would be shorter.

Once duplicates and potentially falsified responses were removed, we used R Version 4.2.2 to summarize the frequency of responses from different types of fishers (i.e., commercial, recreational, or both). We then filtered the dataset for responses from only commercial spiny lobster fishers and quantified the amount and cost of gear lost monthly and annually. We filtered the survey responses for those who fished for lobster as their target species and fished commercially. Unfortunately, our data could not account for fishers who reported that they fished recreationally and commercially if they reported fishing for lobster and additional species because we were unable to differentiate if the commercial status of the fisher applied to spiny lobster or the other listed fisheries. Therefore, we had to exclude fishers who fished recreationally and commercially from our results. Our

survey also did not account for crab versus lobster traps. Thus, when determining the total and average gear losses reported by respondents, we further filtered out and removed any commercial lobster fishers who said they also fished for crab because we could not deduce which fishery their reported trap loss belonged to.

Finally, a map of zip codes of respondents who were willing to collaborate with a nonprofit that targets underwater gear removal was created in ArcGIS Version 3.1.0.

Communication Methods

We crafted communication materials in the form of a video, an interactive map, and informational flyers to increase awareness about ODA's mission and improve fisher community collaborations for the nonprofit (Appendix A). For the video project, we built a network of fishers and interview participants. These participants were then contacted via email to set up an interview time and location. In-person methods were also utilized; commercial and recreational fishers were met directly on the dock to build trust and develop strong relationships. The majority of interviews were conducted on location and in-person, while a few interviews were conducted via zoom (Appendix C).

The collective deliverables of this project will be posted online on a webpage hosted by ODA. The content will primarily consist of ODA's history, story, and an interactive map that visualizes its efforts since inception, overlaid with marine benthic environment data. The webpage will be created in partnership with ODA's current website development and social media management team to ensure that all elements of ODA's brand align and build on existing brand infrastructure while being smoothly integrated into ODA website maintenance.

Outreach materials were created to increase public awareness of ODA's efforts and expand volunteer support in the design tool Canva (Appendix A). These materials

were then distributed to ODA to be used at outreach events. They were also given to fishersat harbors between San Diego and Santa Barbara County to further increase distribution. Based on NOAA's fisher community research in Southern California, outreach materials were translated into Spanish to increase audience reach and inclusion.

Results

Marine Debris Removed

Total marine debris removed by ODA in over 388 cleanup outings over 20 years in Southern California yielded 6 main debris categories: Traps (Figure 1), Trap Remnants (Figure 2), Fishing Line (Figure 4), Nets (Figure 5), Mylar Balloons (Figure 7), and Alternate Debris (Figure 8). The total count of all debris retrieved by ODA over 20 years in Southern California can be found in Table 1. Other categories of debris included are miscellaneous debris, plastic debris, lobster traps, snail traps, hoop nets, crab pots, unknown traps, mixed nets, unknown nets, and squid nets. Units vary for each category and include pounds, individual count, and feet.

There was a slight increasing trend in the amount of Traps and Trap Remnants that ODA removed from 2002-2022 (Figure 1 & 2). There will likely be a significant increase in the amount of Traps removed in 2023 due to the catastrophic gear loss from a series of major storms during winter 2022-2023. The most Traps and Trap Remnants removed in a single year (n =100 and n = 3,000, respectively) was in 2003. The least number of Traps were removed in 2006 and 2010 (n = 1). The least number of Trap Remnants were removed in 2010 (n = 0).

Traps and Trap Remnants were further parsed into snail traps, hoop nets, crab pots, and lobster traps. Of the total trap debris removed by ODA, lobster traps were found at a much higher frequency compared to crab traps, hoop nets, and snail traps (Figure 3). Hoop nets are cylindrical traps and are not nets. Unknown traps

were often partial remnants of a whole trap and, therefore, unidentifiable. Additionally, unknown traps were recorded in pounds and were thus compared with other categories also in pounds.

The amount of fishing line ODA has recovered annually from the oceans has increased over time (Figure 4). The greatest amount of fishing line was collected in 2012 (n=8,160). Fishing line retrieved by ODA includes both trap line and fishing line. Fishing line is a monofilament fishing line that is often used by recreational fishers. Trap line is a thick rope that is used to pull traps through the water column.

The amount of fishing nets ODA has annually recovered has stayed consistent over time (Figure 5). However, the largest amount of nets (n=8,495), recorded in pounds, was removed in 2011. Net debris included gill nets, mixed nets, unknown nets, and squid nets. Squid nets are found at a higher frequency compared to gill nets, unknown nets, and mixed nets (Figure 7). However, this result misrepresents the ratio of squid nets collected at ODA outings due to the amount of unknown nets and mixed nets. Finally, ODA has seen an increasing trend in alternate debris removed over time (Figure 8). Of all alternate debris types, ODA has removed more miscellaneous debris compared to unknown traps and plastic debris (Figure 9).

Table 1. Total Debris Removed by ODA in Southern California (2002-2022)

Debris Type	Quantity
Miscellaneous Debris (pounds)	16707
Plastic Debris (pounds)	8313
Lobster Traps (count)	352
Snail Traps (count)	18
Hoop Nets (count)	24
Crab Pots (count)	84
Unknown Traps (pounds)	11155
Trap Line (feet)	46350
Tires (count)	1
Gill Nets (pounds)	1759
Squid Nets (pounds)	19165
Mixed Nets (pounds)	1060
Unknown Nets (pounds)	4520
Mylar Balloons (count)	227

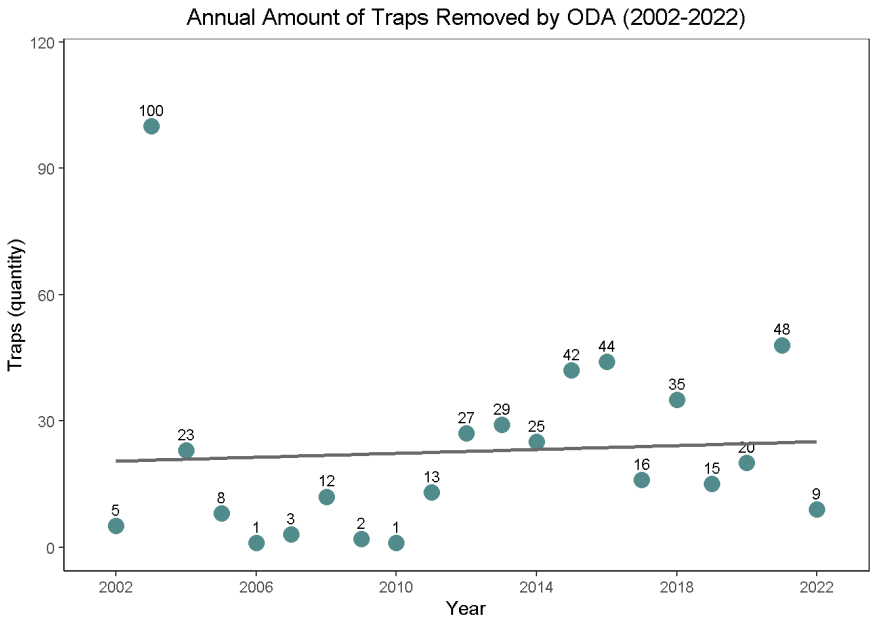


Figure 1. Annual counts of whole and mostly intact trap debris retrieved by ODA over 20 years in Southern California. Categories of trap debris included are snail traps, hoop nets, crab pots, and lobster traps. All trap quantities are in units of individual counts. A trap is considered whole if at least 5 sides of the trap are intact.

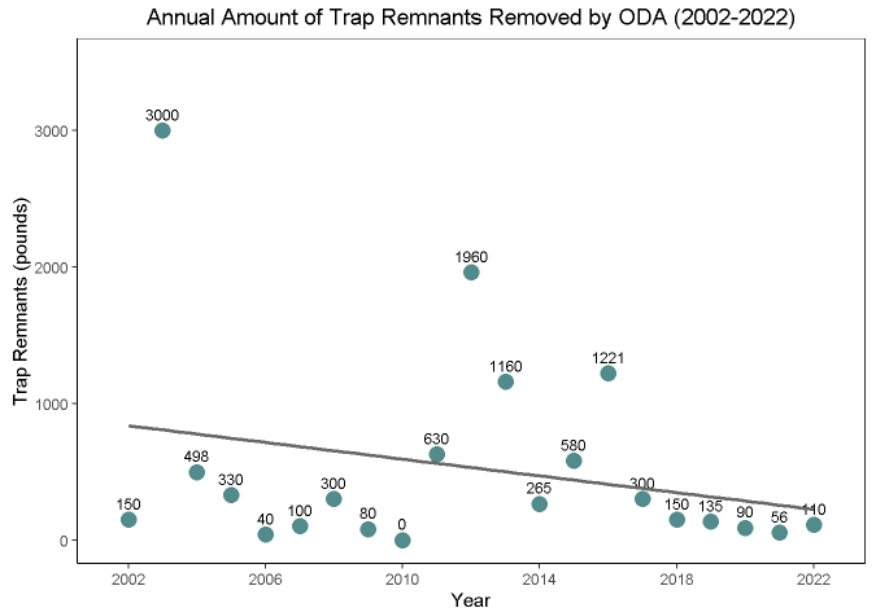


Figure 2. Annual counts of trap remnant debris retrieved by ODA over 20 years in Southern California. Trap remnants include trap debris from snail traps, hoop nets, crab pots, and lobster traps. All trap quantities are in units of pounds. A trap is considered a remnant if less than 5 sides of the trap are intact.

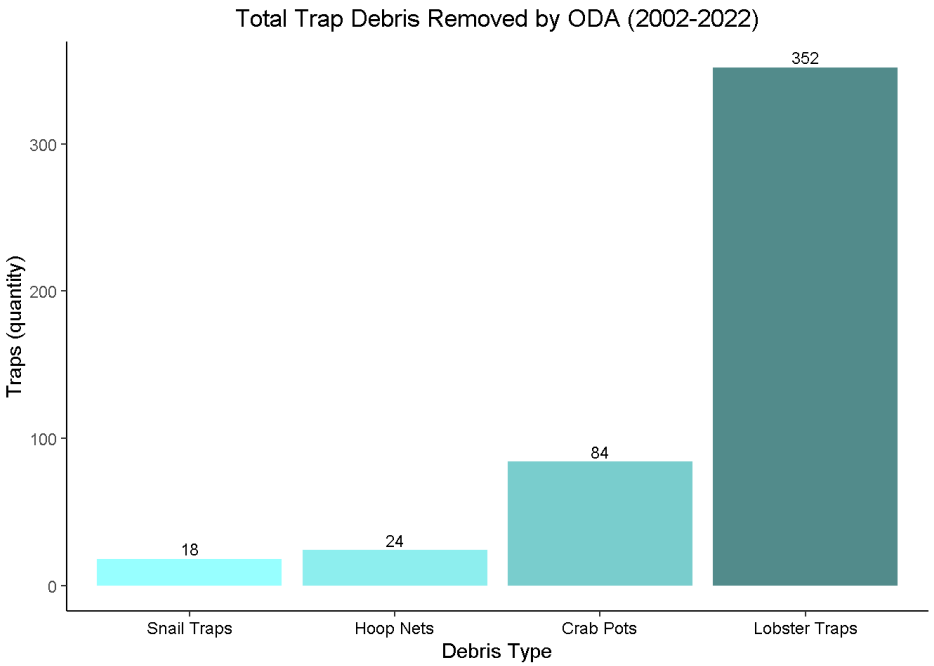


Figure 3. Total count of all trap debris retrieved by ODA over 20 years in Southern California. Categories of trap debris included are snail traps, hoop nets, crab pots, and lobster traps. All trap quantities are in units of individual counts.

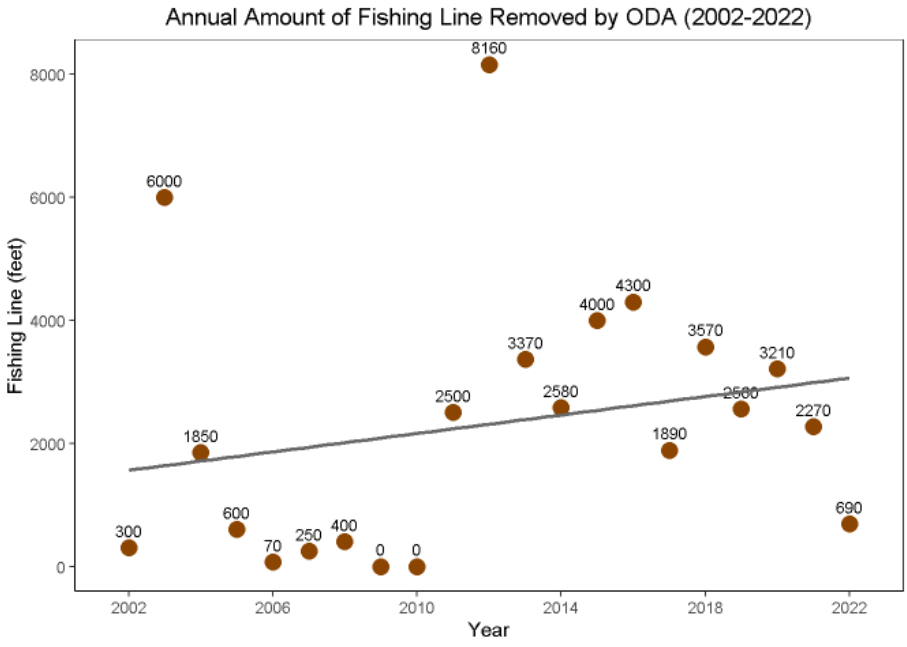


Figure 4: Annual length of fishing lines removed by ODA over 20 years in Southern California. All line quantities are in units of feet. Lines types included are trap line and fishing line combined. Fishing line refers to monofilament fiber composed of plastic nylon. Trap line refers to braided rope typically made from plastic polymers such as polypropylene.

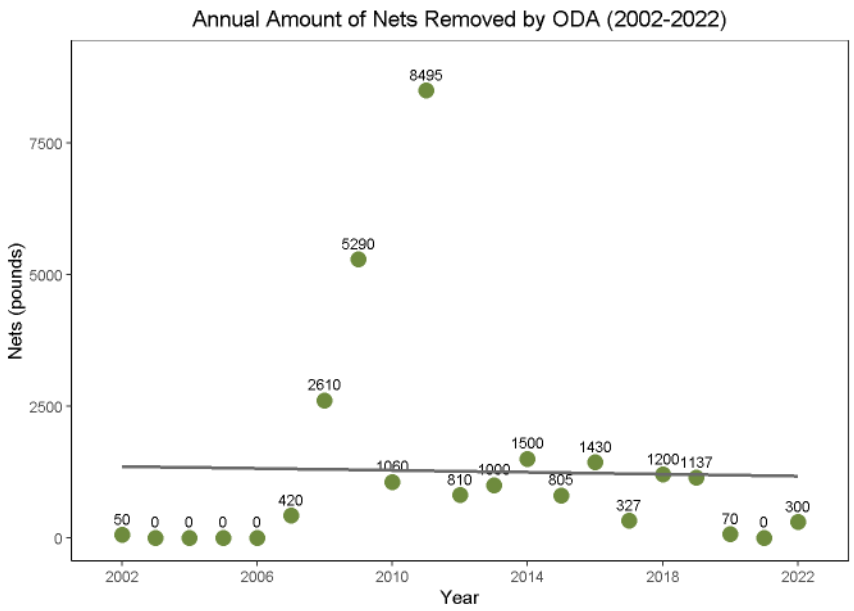


Figure 5. Annual counts of all net debris retrieved by ODA over 20 years in Southern California. Categories of net debris included are gill nets, mixed nets, unknown nets, and squid nets. All net quantities are in units of pounds. Unknown nets were partial remnants or mangled portions of a whole net and unidentifiable.

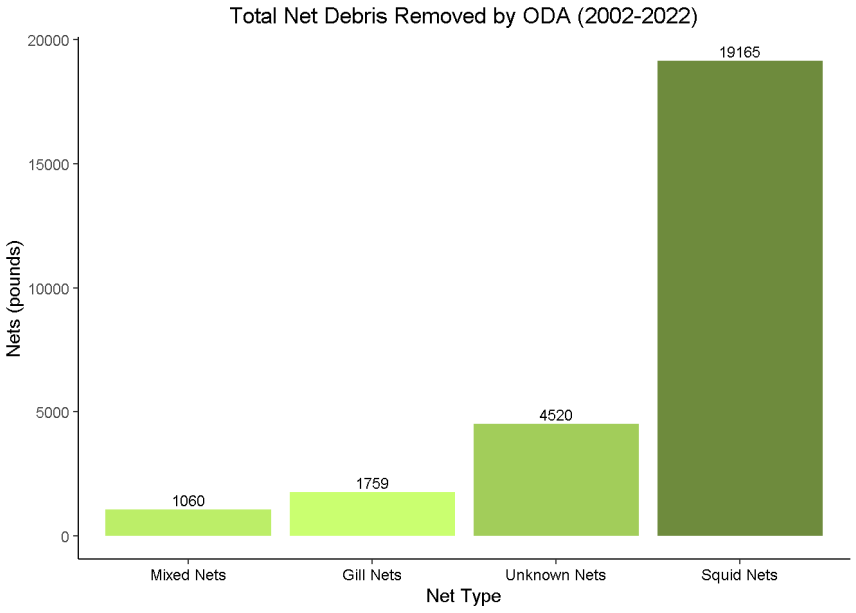


Figure 6. Total count of all net debris retrieved by ODA over 20 years in Southern California. Categories of net debris included are gill nets, mixed nets, unknown nets, and squid nets. All net quantities are in units of pounds. Unknown nets were partial remnants or mangled portions of a whole net and unidentifiable.

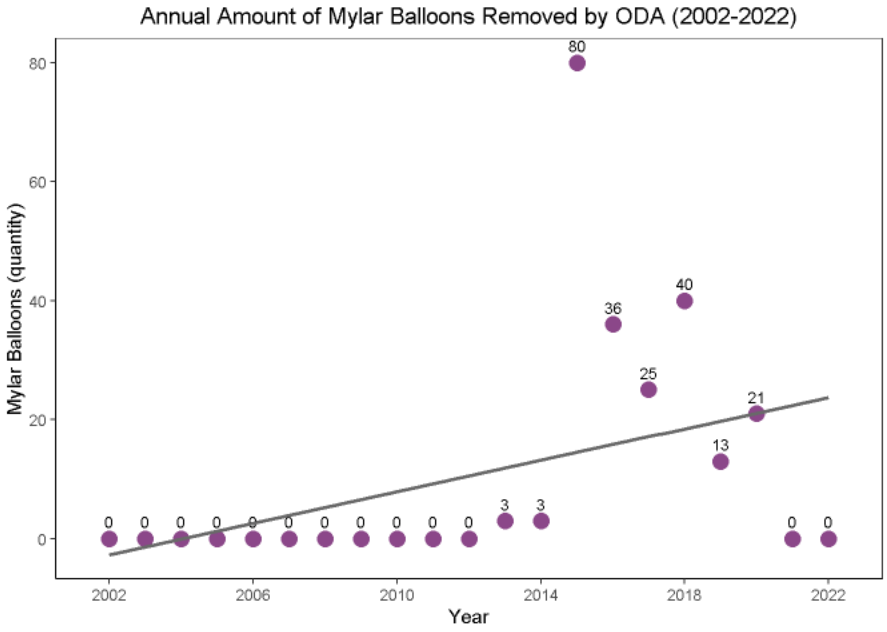


Figure 7. Annual counts of all mylar balloon debris retrieved by ODA over 20 years in Southern California. Debris quantity is in units of individual counts.

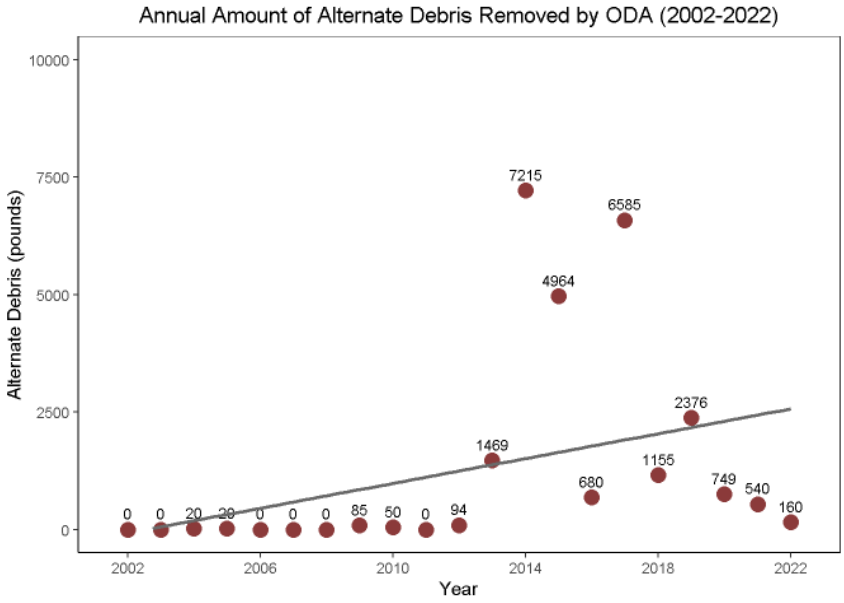


Figure 8. Annual counts of all alternate debris retrieved by ODA over 20 years in Southern California. Categories of debris included are fishing weights, plastic debris, and miscellaneous debris. All debris quantities are in units of pounds. Miscellaneous debris is all debris that does not fit into the other categories. Examples include fiberglass boats, garden hoses, and batteries.

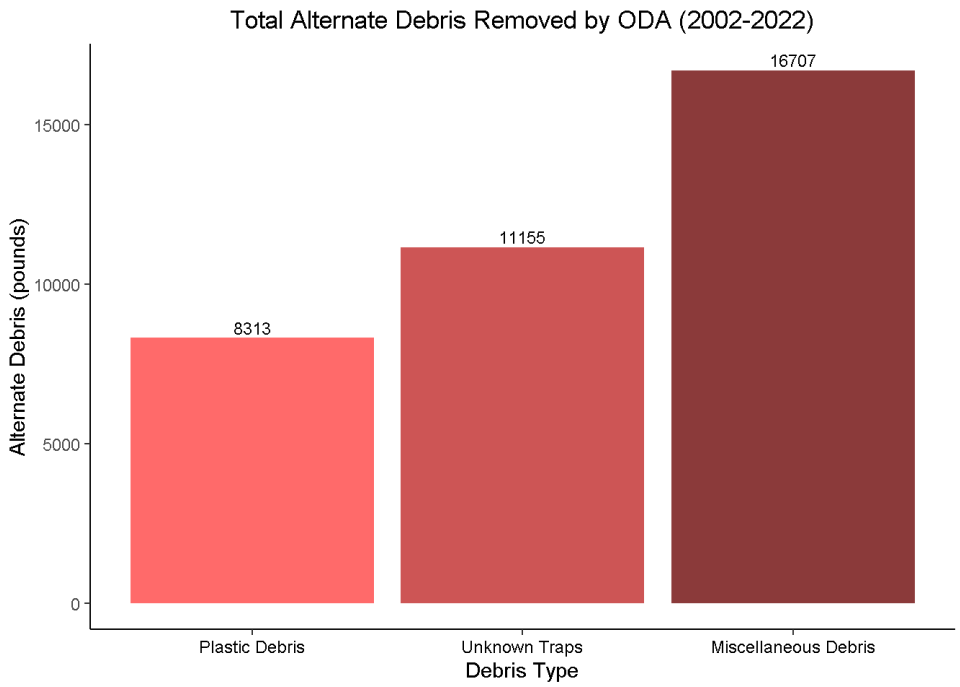


Figure 9. Total amount of alternate debris removed by ODA over 20 years in Southern California. Categories of debris included are fishing weights, plastic debris, unknown traps, and miscellaneous debris. All debris quantities are in units of pounds. Miscellaneous debris is all debris that does not fit into the other categories. Examples include fiberglass boats, garden hoses, and batteries. Unknown traps refer to trap remnants that were not part of a whole trap and are included here for proper comparison with other marine debris recorded in pounds.

Distribution of Removals

ODA has collected marine debris along the coast of Southern California, from south of Point Conception to the US-Mexico Border. Most debris outings have occurred between Redondo Beach and Dana Point because these sites were most accessible to ODA from its 3 docking sites in Laguna Beach, Channel Islands Harbor, and the Port of Los Angeles-Long Beach side (Figure 10). There are also concentrated clusters of debris removal outings that have taken place near Santa Catalina Island, Anacapa Island, and Santa Cruz Island. These clusters occur because ODA is able to access those parts of the islands in a 1-day outing from its docking sites on the mainland, but it cannot travel farther than that safely. Marine debris recovered near the islands tends to overlap more with rocky reef habitat compared to eelgrass

habitat (Figure 11). In fact, in the 20 years of ODA's marine debris collections, there have only been 2 collections that overlapped with eelgrass habitat. A significant number of debris removal outings in Santa Barbara and Ventura county waters occur in rocky reef habitat. This is because rocky reef habitat is often at a depth safe enough for ODA divers to conduct gear removal efforts and it overlaps with areas of high fishing effort from the commercial spiny lobster fishery, so it is likely to find derelict traps.

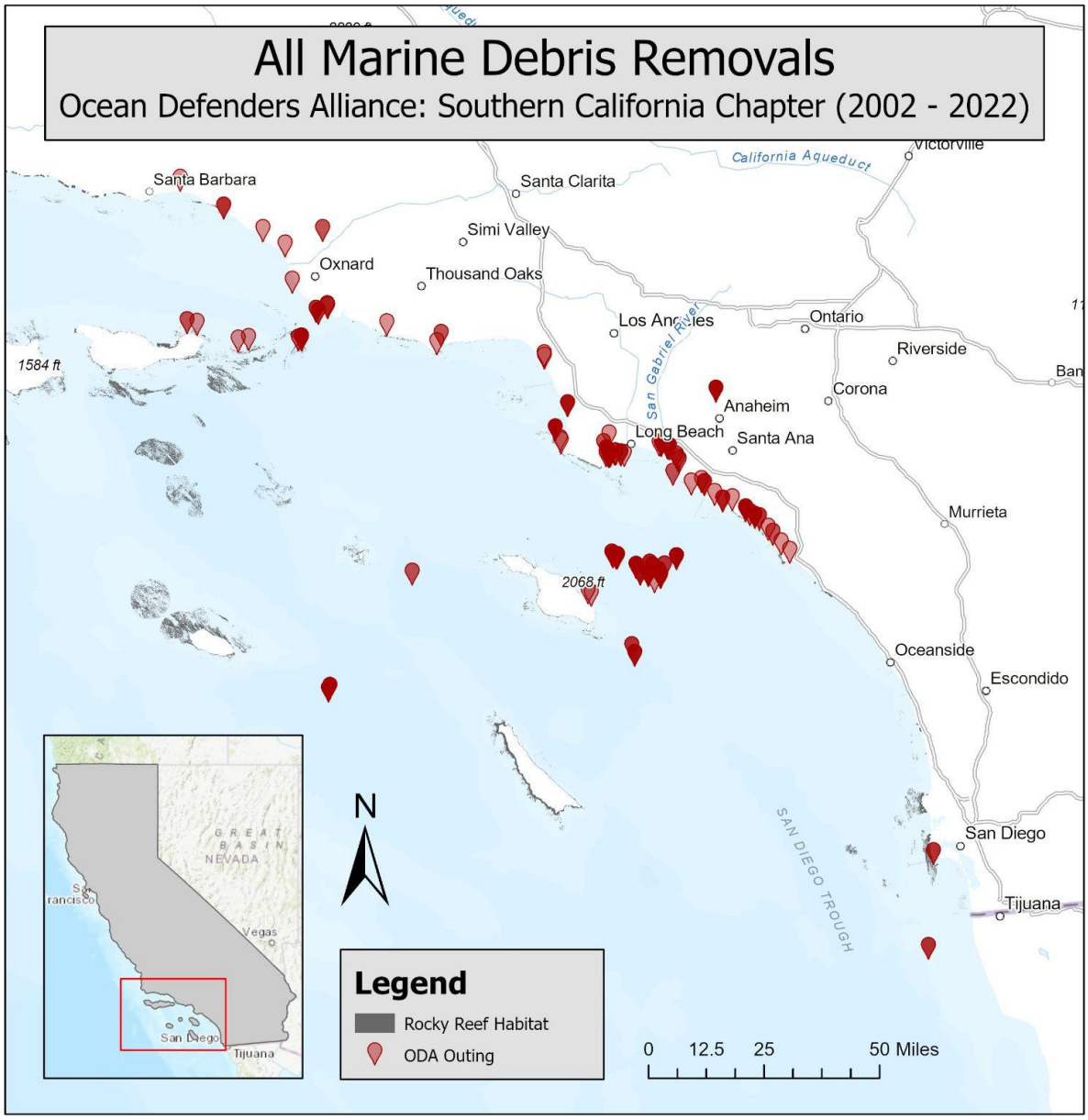


Figure 10. Locations of all of ODA's gear removal outings are displayed alongside projected rocky reef habitat locations in Southern California. Darker red ODA outings correspond to multiple cleanups occurring at the same location.

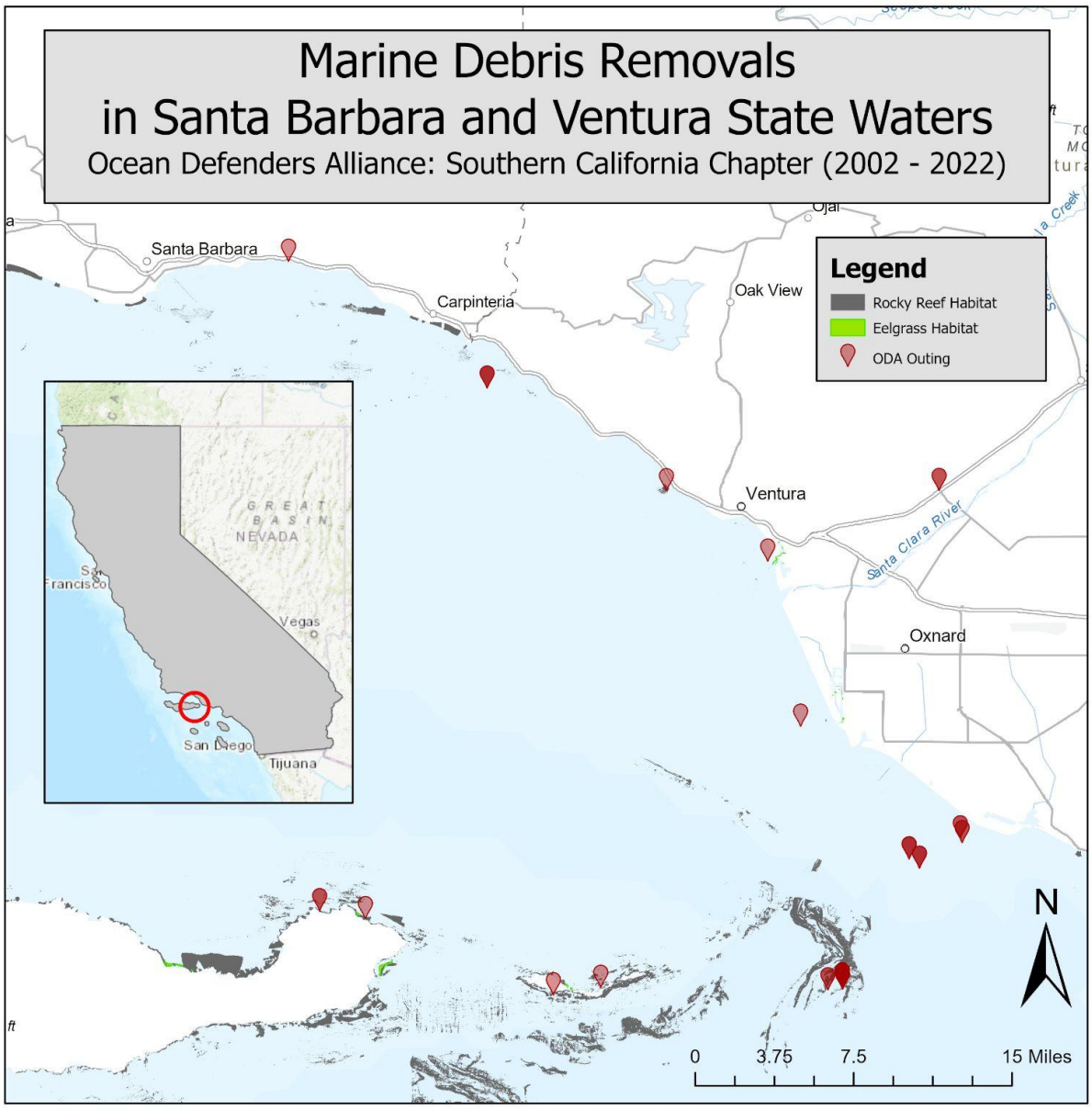
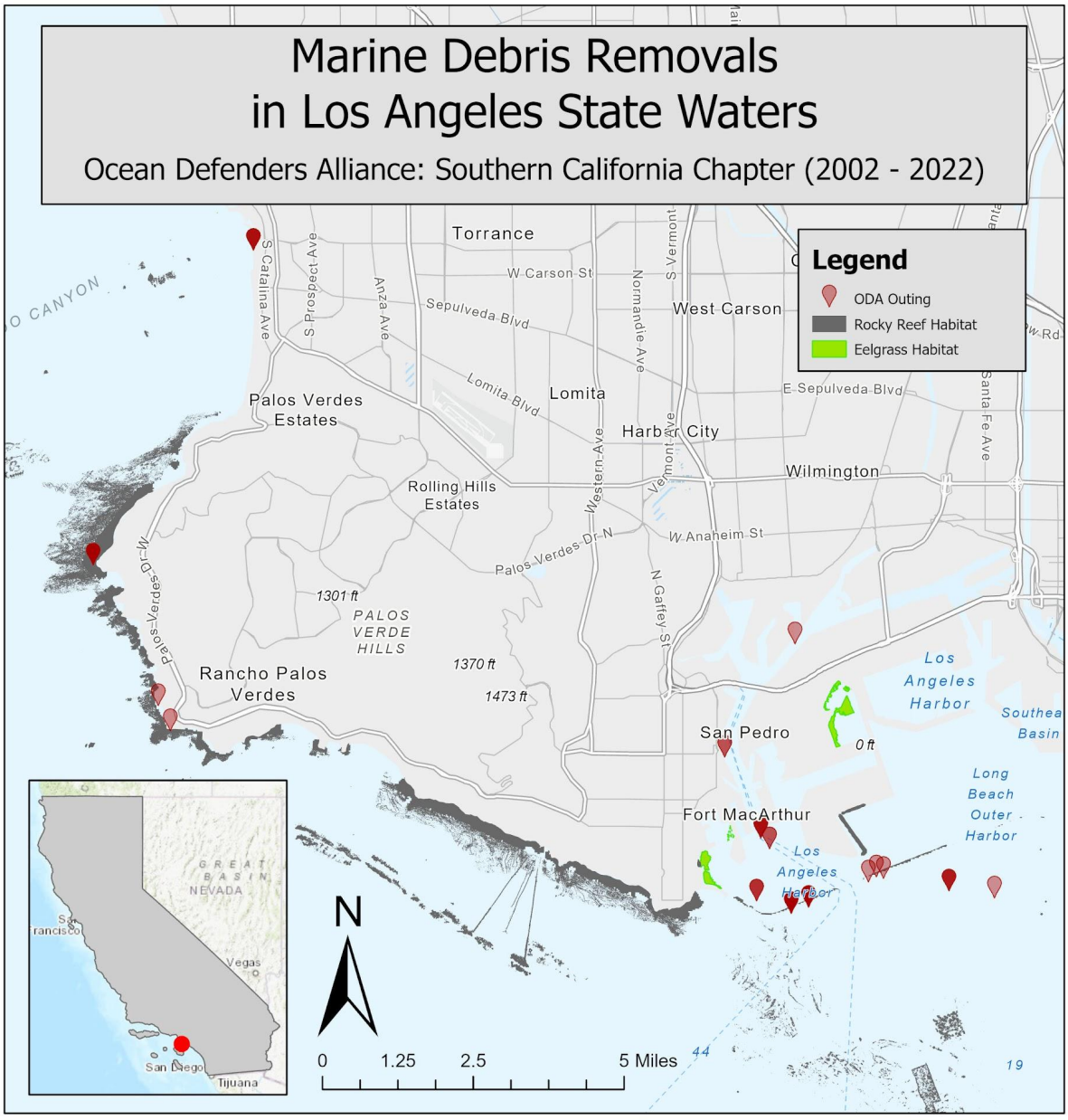


Figure 11. Locations of ODA gear removal outings in Santa Barbara and Ventura County's state waters are displayed alongside eelgrass and projected rocky reef habitat locations in Southern California. Darker red ODA outings correspond to multiple cleanups occurring at the same location.



Map made by Debris Free Seas (2023-03-22)
Sources: CA State Coastal Conservancy, OPC, CDFW, NOAA, County of LA, California State Parks, Esri, HERE, Garmin, FAO, USGS, Bureau of Land Management, EPA, NPS, 2020, Comprehensive State Waters Mapping Program, Predicted Nearshore Benthic Substrates of California with IDW interpolated White Zone; CDFW, 2019, Compilation of Eelgrass Surveys in California; © CA.gov California State Boundary, 2018

Figure 12. Locations of ODA gear removal outings in Los Angeles County's state waters are displayed alongside eelgrass and projected rocky reef habitat locations in Southern California. Darker red ODA outings correspond to multiple cleanups occurring at the same location.

Gear Loss Hotspot Predictions

The likelihood of gear loss for the California spiny lobster fishery was predicted based on fishing effort (in trap nights units). According to CDFW analysis of historical trap loss reports, there is a positive relationship between traps deployed per fishing block and traps reported lost (Mason et al., 2021). Therefore, greater fishing effort in a particular location, should correlate with predicted gear loss. We leveraged this relationship to use fishing effort to estimate the potential for derelict gear and highlight gear loss “hot spots” for ODA to target their future marine debris removal efforts (Figure 13). Without a clearer understanding of how traps move around the ocean once derelict, this is the best available resolution for approximating the locations of existing and future gear losses.

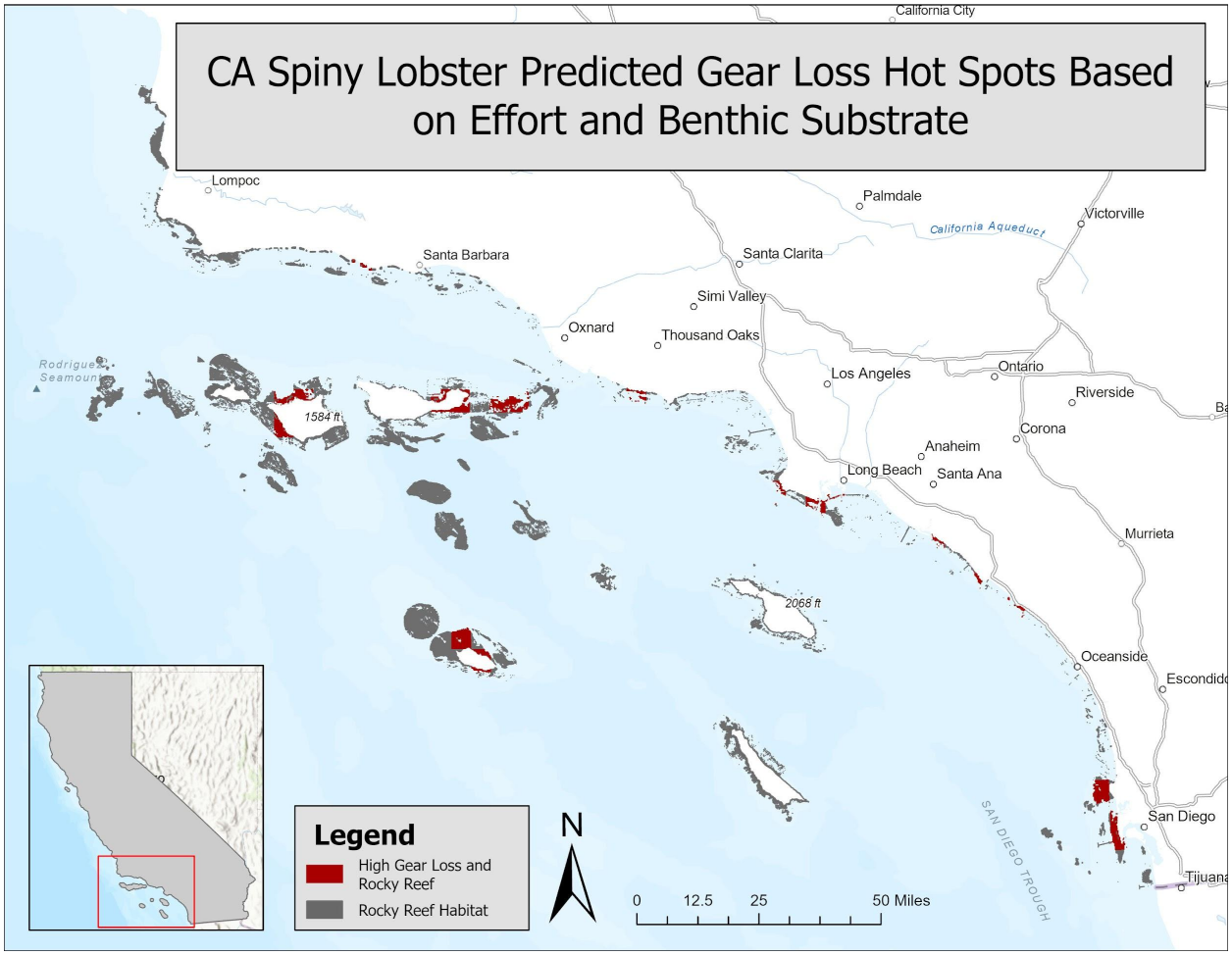


Figure 13. The map shows areas of higher predicted gear loss within areas of rocky reef habitat locations in Southern California. High predicted gear loss areas were taken from the top 20th percentile of fishing effort and then combined with areas of rocky reef habitat. There are large concentrations of high predicted gear loss areas in the waters of San Diego County, Los Angeles County, Ventura County, and Santa Barbara County.

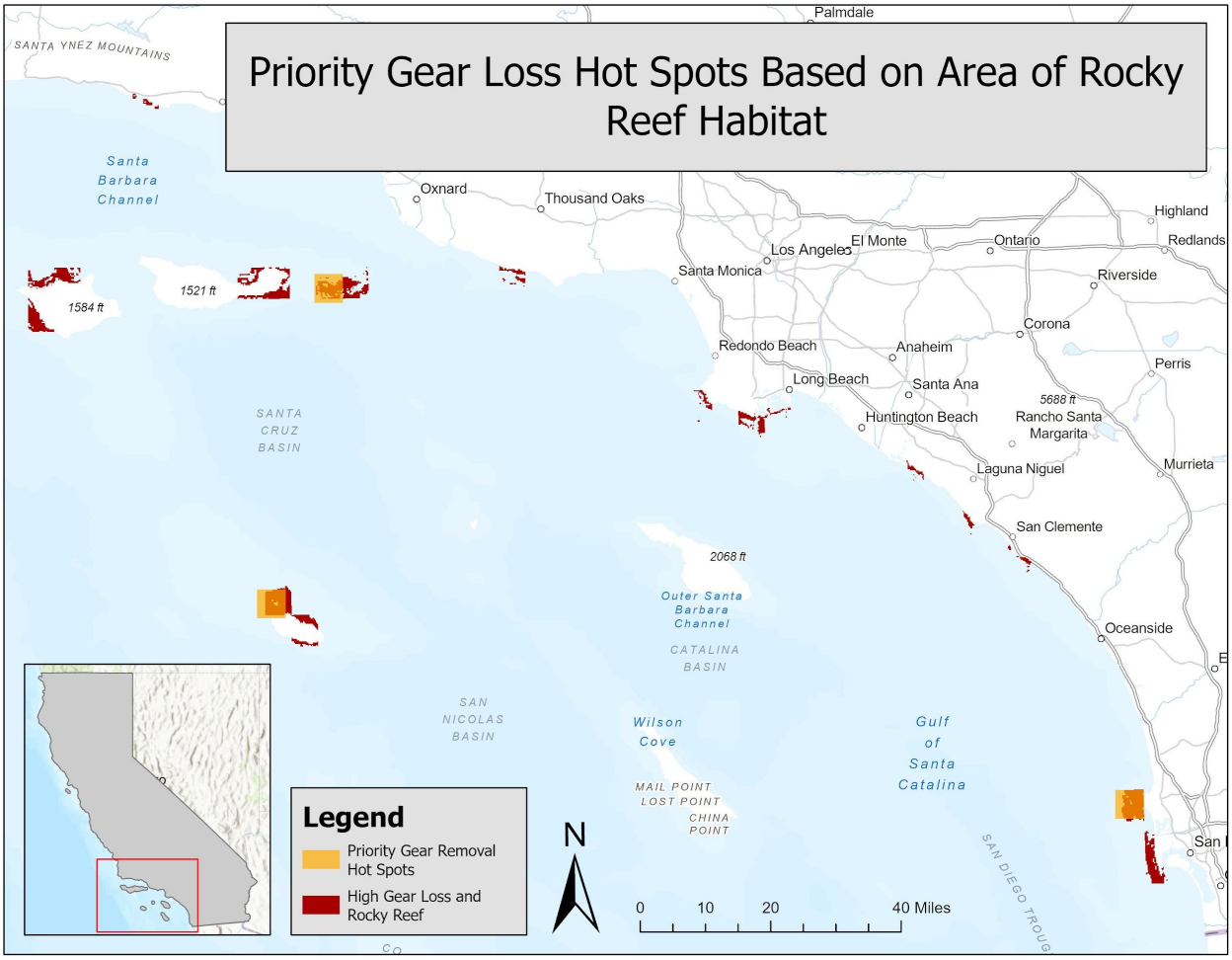


Figure 14. Priority areas for gear removal are projected over areas of high predicted gear loss in Southern Californian rocky reef habitat. The top 3 priority gear loss locations were determined by overlapping the areas of highest fishing pressure with the highest concentration of rocky reef habitat. The priority locations are located in the northern waters around San Nicolas Island, the western waters around Anacapa Island, and the western waters outside of La Jolla in San Diego County.

Entanglement Potential

From NOAA's entanglement data, we found that there have only been 5 whale entanglements attributed to the commercial California spiny lobster fishery over the last 40 years, 2 of which have been in the last 14 years (Table 2). The first 3 entanglements were gray whales, while the most recent 2 entanglements were both humpback whales. In comparison, the commercial Dungeness crab fishery has

had 105 whale entanglements over the past 40 years, which is 21 times greater than the California spiny lobster fishery. Historically, the entanglements in the commercial Dungeness crab fishery have caused seasonal delays and early closures, hence using this fishery as a comparison of entanglements in the California spiny lobster fishery (Seary et al., 2022). Further, the spiny lobster and Dungeness crab fisheries were compared due to their similarities in fishing equipment (i.e., trap fisheries) and techniques.

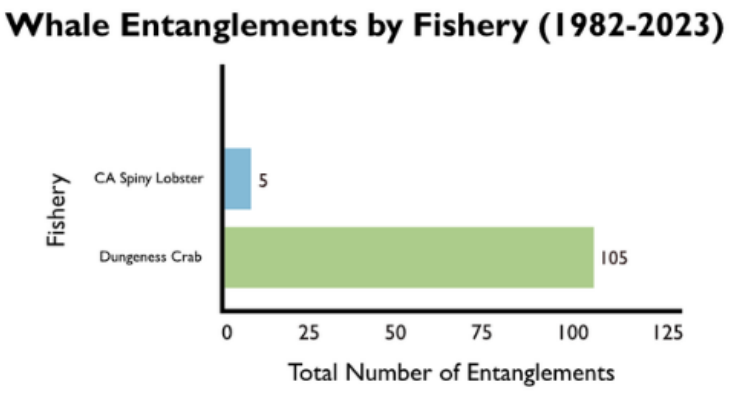


Table 2. Whale Entanglements in California Spiny Lobster Gear (1982-2023)

Year	Whale Species
1995	Gray Whale
1998	Gray Whale
2009	Gray Whale
2015	Humpback Whale
2021	Humpback Whale

Figure 15. Total number of large whale entanglements from 1982 through March 2023 for the commercial California spiny lobster and the commercial Dungeness crab fisheries. Note that the NOAA entanglement dataset has a total of 245 'unknown' and 'unidentified' entanglement types out of 444 total entanglements.

Ghost Fishing Analysis

We found that, on average, 2.19 lobsters are ghost-fished per derelict lobster trap based on our analysis of ODA's ghost fishing dataset. To determine how this translates into lost value for the spiny lobster fishery, we found the average weight per spiny lobster caught in a trap to be 1.57 pounds per lobster (Mason et al., 2021). We calculated the average market price per pound of lobster to be $18.22 (CDFW, 2023). We used estimations on trap loss for the fishery based on findings from The Fisher Feedback Survey, 5-year average trap loss reported to CDFW (CDFW, 2023), and ODA's 3-year average for trap recovery. Since reports on lost traps varied

between these three sources, the following equations outline revenue loss estimates for the fishery per method of trap loss report.

Equation 1. Lost Revenue Calculation From Ghost Fishing (LRG)

LRG =

$$Scale\ Constant \times \frac{Traps\ Lost}{Respondent} \times \frac{Traps\ Cost}{Respondent} \times \frac{Est.\ Lobsters\ Ghost\ Fished}{Trap} \times \frac{1.57\ lbs}{Lobster} \times \frac{Market\ Price}{lbs}$$

Equation 2. Lost Revenue Calculation From Trap Loss (LRT)

LRT = $Scale\ Constant \times \frac{Traps\ Lost}{Respondent} \times \frac{Traps\ Cost}{Respondent}$

Equation 3. Total Lost Revenue (LRT)

TLR = $LRG + LRT$

Survey Data Analysis

Calculation 1a:

LRG

$$= Respondents \times \frac{Traps\ Lost}{Respondent} \times \frac{Trap\ Cost}{Respondent} \times \frac{Est.\ Lobsters\ Ghost\ Fished}{Trap} \times \frac{1.57\ lbs}{Lobster} \times \frac{Market\ Price}{lbs}$$

LRG

$$= 4.35 \times 31\ Respondents \times \frac{6.25\ Traps\ Lost}{1\ Respondent} \times \frac{2.19\ Lobsters}{1\ Trap} \times \frac{1.57\ lbs}{1\ Lobster} \times \frac{\$18.22\ USD}{1\ lbs}$$

LRG = $47,559.92 USD

Calculation 2a:

LRT = $4.35 \times 31\ Respondents \times \frac{6.25\ Traps\ Lost}{1\ Respondent} \times \frac{\$200\ USD}{Respondent}$

LRT = $168,562.50 USD

Calculation 3a:

TLR = 47,559.92 + 168,562.5

TLR = $216,122.42 USD

CDFW Data Analysis

Calculation 1b:

$$\text{LRG} = \frac{3{,}631.4\ Traps\ Lost}{135\ Active\ Fishers} \times \frac{\$200\ USD}{Fisher} \times \frac{2.19\ Lobsters\ Ghost\ Fished}{1\ Trap} \times \frac{1.57\ lbs}{1\ Lobster} \times \frac{\$18.22\ USD}{1\ lbs}$$

LRG = $205,392.11 USD

Calculation 2b:

$$\text{LRT} = \frac{3{,}631.4\ Traps\ Lost}{1\ Active\ Fishers} \times \frac{\$200\ USD}{Fisher}$$

LRT = $726,280.00 USD

Calculation 3b:

TLR = 205,392.11 + 726,280

TLR = $931,672.11 USD

ODA Data Analysis

Calculation 1c:

$$\text{LRG} = 23.67\ traps \times \frac{2.19\ Lobsters}{1\ Trap} \times \frac{1.57\ lbs}{1\ Lobster} \times \frac{\$18.22\ USD}{1\ lbs}$$

LRG = $1,338.78 USD

Calculation 2c:

$$\text{LRT} = \frac{23.67\ Traps\ Lost}{1\ Active\ Fishers} \times \frac{\$200\ USD}{Fisher}$$

LRT = $4,734 USD

Calculation 3c:

TLR = 1,338.78 + 4,734

TLR = $6,072.78 USD

Given our estimate of 2.19 lobsters on average ghost fished per trap, this results in 7,952 lobsters ghost fished per year which equates to 12,486 pounds of lobster lost to the fishery and the environment annually based on the number of traps lost in one year. These calculations do not include traps lost in prior years that can still ghost fish.

Fisher Responses

The Fisher Feedback Survey received a total of 925 responses. Of those, only 202 responses were screened as human responses per our methods. While recreational fishers were the majority of survey respondents (40%, n=82), we had 62 survey responses (31%) from commercial fishers, and 58 responses (29%) from fishers who identified as both commercial and recreational fishers (Table 3).

Table 3: Fishing community distribution of all respondents

Fishing Community	Responses	Percentage
Both	58	29%
Commercial	62	31%
Recreational	82	40%

Out of 202 respondents, 44% (n=88) said they participated in the California spiny lobster fishery (Table 4). Of all lobster fishers, the majority of respondents were recreational (40%, n=35), followed closely by commercial (35%, n=31), and respondents from both (25%, n=22).

Table 4. Fishing community distribution of California spiny lobster fishers

Fishing Community	Responses	Percentage
Both	22	25%
Commercial	31	35%
Recreational	35	40%

To determine the number of traps lost per commercial lobster fisher, we filtered out all respondents that said they participated in both the lobster fishery and the crab fishery. This is because our survey grouped questions about traps/pots when traps are used by commercial lobster fishers and pots are used by commercial crab fishers (Appendix B). Thus, we filtered out 10 respondents who said they participated in both the lobster and the crab fishery, leaving us with 21 respondents who identified as commercial lobster fishers who did not participate in a crab fishery. These 21 commercial lobster fishers lost, on average, 1.38 traps per month and 2.38 traps per lobster season (Table 5). Of the 21 commercial lobster fishers, 8 surveys were conducted in person by a fish broker in San Diego. Since we can confirm the occupation and commercial status of these fishers, we have highlighted their data alongside the dataset as a whole in order to better understand our survey results.

Both the online and in-person survey respondents report similar levels of trap loss. The online responses reported slightly higher monthly losses, while the in-person survey responses reported slightly higher seasonal losses. Both of these averages are significantly lower than CDFW's estimates of trap loss, in which approximately 26.35 traps per fisher are lost based on an average from the last 5 years. It is possible that the fishers we surveyed exhibit exceptionally low gear loss. At least 1 commercial lobster fisher reported also being an urchin diver and listed little to no gear loss. It is also possible that the majority of gear loss could be attributed to a small subset of fishers that were not surveyed, and there is not an average amount

lost equally by all commercial fishers. Further research into gear dereliction causes and distribution would help to illuminate this discrepancy.

Table 5. Total and average California spiny lobster trap losses reported per month and year

Survey Access	Trap Losses	Per Month	Per Year
Online	Average	1.38	2.38
In-person	Average	1	3.75
Online	Total	29	50
In-person	Total	8	30

Respondents also reported how much they spend per month and per season to replace lost or damaged gear (Table 6 & 7). The majority of both online and in-person respondents reported spending either less than $500 or about $1,000 to replace gear each month. For yearly gear replacements however, the online and in-person responses differed. Almost 50% of online respondents claimed that they spend less than $500 a year on gear replacements, while the other 50% was split between $1,000 and over $2,000. The majority of in-person respondents, on the other hand, reported spending over $2,000 on gear replacements. One in–person respondent even volunteered that they spend between $15,000 and $20,000 on gear replacement each year. It is worth noting that because our survey answer selections only went up to “Over $2,000” spent, there is no way to know whether or not more fishers would have reported spending a similarly high amount.

Table 6: Reported average cost spent to replace gear (broken or lost) per month

Average Cost to Replace Gear Per Month	Online	In-person
Over $2,000	1	1
~$1,000	7	4
Less than $500	8	3
$0	3	0

Table 7: Reported average cost spent to replace gear (broken or lost) per year

Average Cost to Replace Gear Per Year	Online	In-person
Over $2,000	4	5
~$1,000	5	0
Less than $500	9	2
$0	1	0

The reports of income from landings is another area where the online and in-person responses differed (Figure 8). Online survey responses had 1 person prefer not to report their income, while the in-person surveys had 2. Additionally, the online survey had 5 responses left blank, while the in-person survey had 3 blank responses in addition to the “prefer not to say”, leading to a much more incomplete picture of landings income from this subset of our data. Furthermore, almost all of the fishers who responded, both online and in-person, reported fishing commercially for multiple species (e.g. urchin and finfish) meaning that the landings income cannot be directly attributed to lobster.

Table 8. Reported income from landings by commercial lobster fisher

Income from landings	Online	In-person
$150,000-$199,999	1	1
$100,000-$149,999	1	0
$75,000-$99,999	2	0
$50,000-$74,999	8	1
$35,000-$49,999	9	0
$20,000-$34,999	3	0
Less than $20,001	1	0
Prefer Not to Say	1	2

Collaborative Opportunities for ODA

Based on our Fisher Feedback Survey results, we were able to visualize the zip codes in Southern California where commercial spiny lobster fishers said they would be willing to work with a nonprofit that targets underwater cleanups to remove marine debris. These areas include Santa Barbara, Ventura, Oxnard, Los Angeles, Ontario, Long Beach, Huntington Beach, and San Diego.

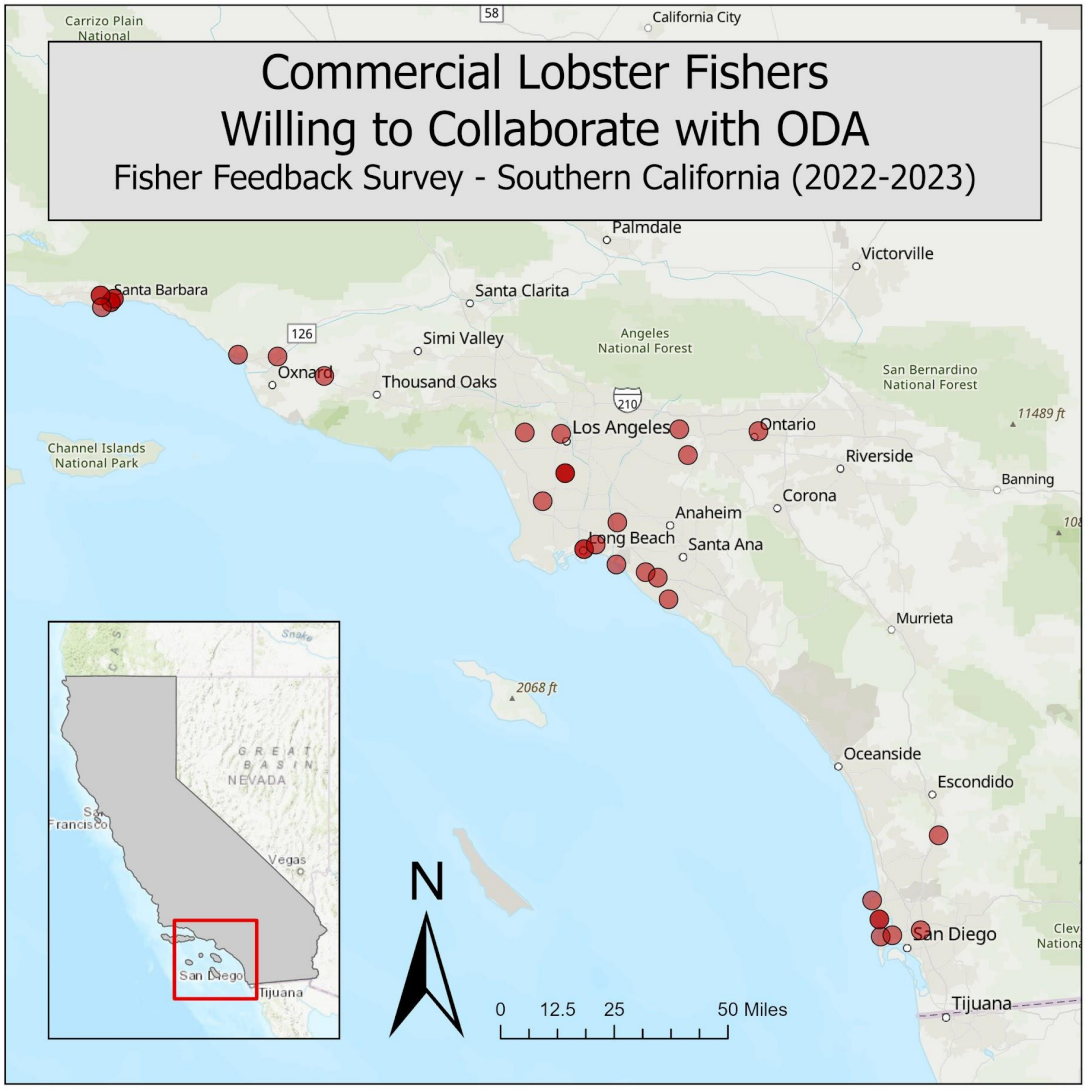


Figure 18. Map of commercial spiny lobster fishers willing to work with ODA in Southern California by zip code. These areas include Santa Barbara County, Ventura County, Los Angeles County, Orange County, and San Diego County. Locations with more fishers willing to work with ODA can be seen with darker red.

Discussion

ODA's Impact

Gradually, ODA has been able to increase the annual amount of derelict gear it removes from the ocean in several debris type categories including Nets, Tires, Mylar Balloons, and Alternate Debris (Figures 4 - 6). This is largely due to an increase in ODA's capacity to remove debris. Over time, ODA has acquired more donors and volunteers, enabling them to purchase a larger boat, expand to Hawai'i, and remove more gear during each outing.

On the other hand, trap gear removal has not increased the same, and seen a decrease by weight, annually coinciding with other debris type removals increasing. This decline is likely due to decreasing marginal returns with trap removal efforts and the establishment of MPAs. When ODA first began its work there was an overabundance of derelict traps underwater since no organizations had conducted underwater cleanups yet. This meant it was relatively easy for ODA to find where traps were along the seafloor. As ODA continued to remove more of them, it became more challenging to locate where other traps existed. Thus, it cost more time and resources to find traps than it did when ODA first began removing traps. Additionally, ODA is no longer the only organization conducting underwater cleanups, some government agencies and nonprofits are also focusing on gear removal, so there is even less ocean debris to find where these other programs and organizations operate.

Furthermore, ODA first began removing various gear underwater in Long Beach and Laguna Beach. Ten years after ODA was operating in these areas, Laguna Beach established 2 MPAs for all of their waters that prohibits recreational and commercial take of marine resources in either MPA. This includes no fishing of California spiny lobster. This meant a reduction in the amount of newly derelict

lobster traps in Laguna's waters. Therefore, ODA had to move to another location in order to target more commercial spiny lobster traps.

Overall, ODA's impact is most apparent when looking at the ecological and economic benefits its work has contributed to fisheries, regulating bodies, and the general public.

Gear Loss Prediction Analysis

Within the hot spot prediction maps, overlap exists between the red 'top gear loss' areas and where ODA has conducted outings which indicates that ODA has been operating in some areas significant to spiny lobster fishery effort and lobster habitat. Thus, if ODA continues to remove derelict gear in these significant areas, its gear removal efforts are more valuable for the environment and the spiny lobster fishery than if it removed derelict gear from other areas.

Additionally, the fact that there is overlap between our predictive hotspot maps and ODA's outings highlights that these hotspot areas are where ODA can access and are likely to find high instances of gear loss. ODA can utilize this map to conduct more gear removal efforts in these areas and reduce the amount of resources needed to find derelict gear. It can also bring this map to funders and collaborators to demonstrate that ODA has already been targeting areas of high significance and will continue these efforts in the future.

Whale Entanglement Risks in the California Spiny Lobster Fishery

Given the high rates of commercial spiny lobster traps removed by ODA, we were initially concerned with the potential for whale entanglements of both derelict and active lobster traps. We especially wanted to assess the spiny lobster fishery for entanglement risk of large whales to determine if the heavy regulations and seasonal closures currently in the Dungeness crab fishery would happen to the spiny lobster fishery in the future (McGuire, 2018; RAMP). Our investigation found

that entanglement potential from the California spiny lobster fishery does not pose a large threat of entanglement to migrating whales. However, this finding comes with a few limitations:

- Entanglements over the years are likely to be underreported as only active entanglements that are spotted on the water's surface are reported to NOAA.
- There are 245 entanglements from NOAA's dataset that are classified as 'unknown fishery' as reporters could not reliably identify which fishery the gear had entangled that whale. Therefore, it is possible that some entanglements within that category were from the California spiny lobster fishery.
- The fisheries began centuries before NOAA began collecting reports about whale entanglements, so there could be more entanglements prior to 1982 that were not included in this analysis.

We theorize that fishery characteristics and whale behavior account for the low entanglement potential observed in the commercial spiny lobster fishery. According to CDFW's enhanced status reports (CDFW, 2019; CDFW, 2020), traps for California spiny lobsters are on average set in shallower depths (less than 200 feet) and are closer to shore than Dungeness crab traps (420- 600 feet) (California Sea Grant; CDFW). Moreover, the spiny lobster fishery covers a much smaller range of coastline and fewer whale migration corridors compared to the Dungeness crab fishery. This means there are likely fewer incidences of whales coming into contact with spiny lobster trap gear compared to Dungeness crab trap gear.

Furthermore, the spiny lobster fishing grounds do not overlap as significantly with the feeding grounds of humpback, blue, or fin whales compared to Dungeness crab fishing grounds (NOAA Fisheries 2022a, 2022b, 2022c). While gray whales sometimes forage within the depth profile of spiny lobster fishing grounds, they rarely feed during their annual migration, and when they do, it takes place on the

muddy bottom nearshore where their amphipod prey lives (Jones & Swartz, 2012; 2022d). Thus, they avoid the slack rope line in the middle to upper portions of the water column that typically cause entanglements.

Whale anatomy may also explain the low entanglement potential. Gray whales have shorter pectoral flippers which could reduce their risk of entanglement compared to the longer pectoral flippers of humpback whales (NOAA Fisheries 2022a, NOAA Fisheries 2022d). Additionally, all 5 past whale entanglements caused by the spiny lobster fishery occurred between October and March, which spans the spiny lobster fishing season. This suggests that the gear responsible was most likely active, and not derelict since there is far more active gear in the water during that time of year.

While it's important to note that the entanglement potential within the California spiny lobster fishery is non-zero, our investigation suggests that derelict traps in Southern California pose the greatest negative impact through ghost fishing and the degradation potential of sensitive habitats like eelgrass.

Effects of Ghost Fishing

Once we determined that entanglements were not the primary risk to marine wildlife from derelict or active lobster traps, we turned our attention to ghost fishing. We explored how the loss of economically valuable species from ghost fishing directly impacted the commercial California spiny lobster fishery. From the aggregated ghost fishing data pulled together from ODA trip logs and blog posts, we estimated that approximately 2.19 lobsters are ghost fished per lost trap, and that up to 30 lobsters can get stuck in a single trap.

Our estimates find that ODA is helping the California spiny lobster fishery to avoid $6,073 USD of losses by recovering traps that would otherwise contribute to ghost fishing. Based on survey results, the fishery could be losing up to $216,122 USD in

revenue by trap dereliction and having those traps ghost fish target species. CDFW estimates even greater revenue loss, up to $931,672 USD each year, based on average records of trap loss. In order for ODA to entirely account for trap losses reported by CDFW, as well as the resulting revenue loss due to ghost fishing, ODA needs to scale its California operations by over 100 times its current operating levels. To do so effectively, ODA will need to partner with fishers, investors, research universities, and other nonprofits to acquire more vessels, expand its volunteer base, and build partnerships that multiply its impact.

Targeted Outreach

In the process of distributing our Fisher Feedback Survey, we discovered that fishing communities in California are vibrant, protective, and are an often misunderstood group that can be apprehensive when interacting with researchers from the UC system and government bodies. This is due to past experiences where the fishing community has been exploited by working with government agencies and academic researchers. Thus, we changed our name from “Deadliest Bycatch” to “Debris Free Seas'' during the course of our project to have a more neutral introduction when engaging with the fishing community. Still, we endured serious hostility from some fishers on an online forum, despite taking special care to word our survey questions/answers carefully given feedback received from external advisors.

At the same time, during video interviews with commercial and recreational fishers, we had powerful, positive engagement with fishers and learned how misconceptions play into this dynamic. This finding is valuable because we can advise ODA to make in-person connections when possible, and engage in an upfront and honest manner that shows how ODA’s work benefits the fishers while treating them with respect. To assist in this effort, we crafted targeted outreach materials, such as a Boat Crew Volunteer Flyer, ODA Informational 1-Pager, Report Debris Stickers, and a Fishing Community Engagement 1-pager (Appendix A1, A4,

A5, A7). These were produced to share online and in-person, were distributed for our client, and will continue to be utilized for future events to elevate its supporters and community network.

Based on our Fisher Feedback Survey results, we were able to highlight specific regions in Southern California for ODA to focus engagement with the fishing community in the future. However the limitations in our survey also highlighted some of the inherent inequities within the fishing community. Despite translating our surveys into Spanish, we received no Spanish responses even though our targeted survey locations had high Spanish speaking populations that fished. Additionally, our efforts to build trust were limited by funding, time, and the fact that no project members spoke fluent Spanish or Vietnamese (the third most common language spoken by fishers in Southern California). Thus, our most successful efforts of building trust in-person were limited to fishers that spoke English and felt comfortable with speaking to us, which excluded many perspectives that were relevant to our research. Further, many communities, like indigenous tribes, have been purposely excluded from these fisheries. Given the time and labor constraints of our project, we were unable to study how the exclusion of these communities may have affected our results. In the future, to resolve some of these inequities, we recommend conducting targeted distributions of surveys or in person interviews that are conducted by those with the time, skill, and labor necessary to include as many relevant perspectives as possible. Further we suggest that ODA works to build trust by meeting or speaking directly with fishers and hiring translators if opportunities arise to collaborate with non-English speaking fishers.

Recommendations

These recommendations are for ODA and other organizations (i.e., agencies, fishery management, local government, nonprofits) to consider in its future work.

Alternative Gear Types

To help prevent and reduce ghost fishing and habitat degradation from derelict traps, research on the most successful and affordable current alternative gear types would benefit the fishing community and natural resource managers. Though most alternative gear types focus on whale entanglement issues, efforts should be made to seek prototypes that aim to decrease the likelihood of gear dereliction.

Balloon Bans

Mylar balloons were listed as a top 3 pollutant type observed on the water during every fisher interview we conducted and also has its own debris type within ODA's logbooks. This highlights the need for regulations to help reduce mylar balloon debris. Organizations working in the space of marine debris prevention should contact local city councils with balloon ban ordinances in place or expected to occur soon (i.e., Laguna Beach and Goleta) to partner in spreading awareness around these efforts and to encourage adjacent cities to do the same for larger impact.

Deposit-Refund Programs v. Reward Programs

To assist in reducing the number of derelict traps per season, research around the most applicable program for the commercial California spiny lobster fishery should be administered. One type of fishing gear resource management operation could be based on a deposit-refund system that would require the fisher to pay a deposit upon purchase of their fishing permit based on the amount of gear they have and reclaim the deposit upon return of all gear tags at season's end. Another option could be creating a program based on the reward system framework implemented by the South Korean Fishermen's Association, where fishers collect debris during fishing operations and return this to the Association to receive a financial reward (Liu, Kao, & Chen, 2015). This reward money could be sourced from part of the commercial California spiny lobster fishery application, permits, tags, and/or other fees.

Impacts from Derelict Traps to Critical Benthic Habitat

There is a lack of data and understanding regarding the impacts of derelict spiny lobster trap movement on the ocean floor and overlap of habitat degradation that could occur among kelp forests, soft bottom substrates, and rocky intertidal zones, and reefs. More in-depth research to better understand benthic impacts, if any, would benefit the fishing community and natural resource management agencies.

Marine Wildlife Entanglements

While we identified that there is no substantial risk of cetacean entanglements in the commercial California spiny lobster fishery, there could be significant entanglement risks for other protected species such as turtles and pinnipeds. Assessing these entanglement risks with commercial spiny lobster gear through future research would benefit management needs of fishery and natural resources, and other invested community collaborators

Conclusion

Since 1999, ODA has conducted over 505 marine debris expeditions since 1999, which involved the removal of 352+ derelict commercial California spiny lobster traps. Although ODA has successfully removed visible derelict gear from the surface of the water, the continued rates of gear dereliction in the commercial spiny lobster fishery have presented challenges for ODA in identifying and removing more subtle derelict gear. Our task was to improve ODA's access to these nuanced derelict gear locations, quantify its impact, and spread awareness about its mission to fishers and fishing communities in Southern California.

While ODA's removals target derelict commercial fishing traps, our findings suggest that ODA's work benefits both commercial and recreational fishers by reducing the amount of ghost fishing of the fishery's target species. Our results also reveal ample

opportunity for collaboration between ODA, nonprofits with similar missions, and the fishing community at large.

Quantifying potential impacts from derelict fishing gear is fundamental to effectively communicate the importance of gear removal, both to the regulating bodies and to the fishery itself. Data-driven estimates were particularly important for ODA to more effectively target its efforts and share the benefits of marine debris removal with marine communities and local fisheries. These metrics allow ODA to quantify its influence and show the ecological and economic benefits of its work to funders and future collaborators. Furthermore, estimating pounds of lobster caught per lost trap and the resultant economic cost of this ghost fishing was fundamental to understanding the extent of this issue. Lastly, we found that the commercial California spiny lobster fishery does not pose a considerable entanglement risk to migrating whales compared to other trap fisheries. While fishing lines and nets pose a significant marine life entanglement risk, these can both be skimmed from the surface of the ocean. Traps, however, can exist on the seafloor for decades and can continue to ghost fish target and non-target species, resulting in consequential revenue loss to the commercial spiny lobster fishery.

This project is part of a larger goal to give ODA feedback on data recording methods that will enhance its ability to communicate with audiences, such as keeping better record of bycatch and ghost fishing instances that could make a comprehensible case of ODA's impact to funders.

This work is just beginning to understand the ultimate fate of derelict gear and marine debris, and its larger impacts on fishing communities and the environment off the California coast. This analysis will increase knowledge of derelict gear and debris hot spot zones with high potential for aggregation, in effect allowing for more efficient cleanup and mitigation efforts. Especially as it pertains to estimating ghost fishing and gear removal hot spots as they had not been performed for the California spiny lobster fishery.

In effect, we have created a framework for derelict trap management that can be applied to other fisheries with similarly high frequencies of gear dereliction. This strategy can be used to assess the environmental impacts of gear displacement, as well as marine debris at large, especially as it pertains to types most commonly seen by ODA (i.e., mylar balloons, trap line, gill nets, commercial traps).

ODA removes all types of marine debris, not just commercial fishing traps, however here we have laid out a framework for evaluating derelict spiny lobster traps that could be applied to other trap-based fisheries in the larger mission of cultivating a debris free sea.

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Appendices

Appendix A - Outreach & Recommended Materials

Figure A1. Boat Volunteer Flyer. This flyer worked to expand volunteer recruitment for ODA's cleanup outings, engaging rescue certified scuba divers and folks that enjoy being on the water to assist with marine debris removal as a deckhand. Due to budget limitations we were unable to get this flyer translated into Spanish.

Figure A2. Fisher Feedback Survey Flyer. This flier worked to expand survey participation. It is advertised directly to fishers, explaining financial compensation to participating and the problem at hand. The flyer on the left is in English and was translated into a Spanish flyer on the right.

Figure A3. New Volunteer Protocol (*pending).* This laminated document will discuss how to efficiently provide safety protocol and train new dive and deckhand volunteer crew members before departing on the boat for a debris removal outing.

Figure A4. ODA 1-Pager. This document first outlines ODA's role in the ocean, the scope of its work, and its mission. It then describes the issue at hand, highlighting the economic and ecological effects of lost gear and marine debris in the environment. Lastly, it calls the public to action, requesting they contact ODA when they see debris in the marine environment. This flyer acts as educational material and informs the public on their role in solving this problem.

Figure A5. Report Debris Stickers. These stickers were created to increase outreach and action in the public by allowing individuals to scan a QR code and easily report derelict gear and debris. The intention was to reduce barriers to reporting by increasing mobile accessibility with specially made stickers that can be placed on dive tanks, fishing tackle boxes, and reusable water bottles.

Figure A6. Debris Removal Outings (*pending).* This document will provide suggestions to keep data consistent and in a tidy format to help improve the quality of ODA's long-term data collection for its debris removal outings for future analytics , reporting, and funding opportunities.

Figure A7. Fishing Community Engagement 1-Pager (*pending).* This document will provide information on the Best Fishing Practices per other state and federal agencies (i.e., CDFW, OPC, NOAA) to share with interested members of the fishing community. Additionally, this document will share a plan of action on how ODA can follow up with fishers per zip code region that answered 'yes' to being interested in working with a nonprofit to remove marine debris from our Fisher Feedback Survey responses.

Appendix B - Fisher Feedback Survey

Question B1. Consent Form

For those participating in the Fisher Feedback Survey

Purpose:
You are being asked to participate in a Fisher Feedback Survey by thesis project Debris Free Seas at the University of California, Santa Barbara. Participation is voluntary. The purpose of this survey is to better understand choices about fishing gear type and any concerns among the Southern California fishing communities.

Procedures:
If you choose to participate in our survey, you may complete it either online or as a hardcopy survey, whichever format you prefer. The survey should take about 10-15 minutes to complete. By participating in this survey, you automatically qualify to be entered into our Visa Gift Card drawing. Please see below for further drawing details. Contact information will be kept confidential and will not be shared or affiliated with any survey answers.

Confidentiality:
The results of this survey may be shared during Master's Project Faculty Reviews and during Master's Project Final Presentations that are open to the public. However, individual's privacy will be maintained as no contact information or personal identifying information from survey participants will be collected or disclosed.

Costs/payments:
By taking this online survey, you are automatically qualified to be entered into a drawing to win a $25 Visa Gift Card. For online surveys: Please include your contact details when prompted in a separate form at the end of the survey (name, email, phone number), so you can be reached if you win. Contact information will not be shared or affiliated with any survey answers. For hardcopy surveys: Please email your contact information (name, email, phone number) to cristinarobinson@ucsb.edu to be entered into the drawing. Contact information will not be shared or affiliated with any survey answers.

Contact Information: If you have questions about the research, you can call Cristina Robinson at 714-651-1551 or email cristinarobinson@ucsb.edu or contact Dean Steve Gaines at (805) 680-1814 or email at gaines@ucsb.edu.

I have read this form and consent to take this survey:

- ○ Yes

○ No

Question B2. Which fishing community(s) do you identify with?

☐ Commercial

☐ Recreational

☐ Both

Question B3. What is the length of your boat or vessel in feet? If this does not apply to you, please write N/A.

_____

Question B4. What fishery(s) are you involved in (e.g. crab, finfish, lobster, squid, urchin, etc.)?

☐ Crab

☐ Finfish

☐ Lobster

☐ Squid

☐ Urchin

☐ Other _____

Question B5. What permit type(s) do you possess (e.g., tier of Dungeness crab permit, operator or crew member for spiny lobster, fishing license & ocean enhancement stamp, etc.)?

_____

Question B6. Do you look at weather forecasts and then deploy gear accordingly?

○ Always

○ Most of the time

○ Sometimes

○ Never

Question B7. What type of gear do you use (e.g. traps, pots, hoop nets, gillnets, hook and line, purse seine, trawls, hands, spear gun, fly rod)?

☐ Fish Aggregating Devices

☐ Gillnets

☐ Green Sticks

☐ Hook and Line

- [ ] Midwater Trawls
- [ ] Pelagic Longlines
- [ ] Pound nets
- [ ] Purse seines
- [ ] Skimmer trawls
- [ ] Traps/pots
- [ ] Hoop nets
- [ ] Spear gun
- [ ] Hands
- [ ] Fly rod

Question B8. Fish Aggregating Devices: How many sets of gear do you lose per month, if any?

0	1	2	3	4	6	7	8	9	10	10 +

Question B9. Fish Aggregating Devices: How many sets of gear do you lose per year, if any?

0	1	2	3	4	6	7	8	9	10	10 +

Question B10. Gill Nets: How many sets of gear do you lose per month, if any?

0 1 2 3 4 6 7 8 9 10 10 +

Question B11. Gill Nets: How many sets of gear do you lose per year, if any?

0 1 2 3 4 6 7 8 9 10 10 +

Question B12. Green Sticks: How many sets of gear do you lose per month, if any?

0 1 2 3 4 6 7 8 9 10 10 +

Question B13. Green Sticks: How many sets of gear do you lose per year, if any?

0 1 2 3 4 6 7 8 9 10 10 +

Question B14. Hook and Line: How many sets of gear do you lose per month, if any?

0 1 2 3 4 6 7 8 9 10 10 +

Question B15. Hook and Line: How many sets of gear do you lose per year, if any?

0 1 2 3 4 6 7 8 9 10 10 +

Question B16. Midwater Trawls: How many sets of gear do you lose per month, if any?

0 1 2 3 4 6 7 8 9 10 10 +

Question B17. Midwater Trawls: How many sets of gear do you lose per year, if any?

0 1 2 3 4 6 7 8 9 10 10 +

Question B18. Pelagic Longlines: How many sets of gear do you lose per month, if any?

0 1 2 3 4 6 7 8 9 10 10 +

Question B19. Pelagic Longlines: How many sets of gear do you lose per year, if any?

0 1 2 3 4 6 7 8 9 10 10 +

Question B20. Pound Nets: How many sets of gear do you lose per month, if any?

0 1 2 3 4 6 7 8 9 10 10 +

Question B21. Pound Nets: How many sets of gear do you lose per year, if any?

0 1 2 3 4 6 7 8 9 10 10 +

Question B22. Purse Seines: How many sets of gear do you lose per month, if any?

0 1 2 3 4 6 7 8 9 10 10 +

Question B23. Purse Seines: How many sets of gear do you lose per year, if any?

0 1 2 3 4 6 7 8 9 10 10 +

Question B24. Skimmer Trawls: How many sets of gear do you lose per month, if any?

0 1 2 3 4 6 7 8 9 10 10 +

Question B25. Skimmer Trawls: How many sets of gear do you lose per year, if any?

0 1 2 3 4 6 7 8 9 10 10 +

Question B26. Traps/pots: How many sets of gear do you lose per month, if any?

0 1 2 3 4 6 7 8 9 10 10 +

Question B27. Traps/pots: How many sets of gear do you lose per year, if any?

0 1 2 3 4 6 7 8 9 10 10 +

Question B28. Hoop Nets: How many sets of gear do you lose per month, if any?

0 1 2 3 4 6 7 8 9 10 10 +

Question B29. Hoop Nets: How many sets of gear do you lose per year, if any?

0 1 2 3 4 6 7 8 9 10 10 +

Question B30. Spear gun: How many sets of gear do you lose per month, if any?

0	1	2	3	4	6	7	8	9	10	10 +

Question B31. Spear gun: How many sets of gear do you lose per year, if any?

0	1	2	3	4	6	7	8	9	10	10 +

Question B32. Fly rod: How many sets of gear do you lose per month, if any?

0	1	2	3	4	6	7	8	9	10	10 +

Question B33. Fly rod: How many sets of gear do you lose per year, if any?

0	1	2	3	4	6	7	8	9	10	10 +

Question B34. How much do you spend to replace gear per month?

- ○ Over $2,000
- ○ ~$1,000
- ○ Less than $500
- ○ $0
- ○ Other (Please fill in) _____

Question B35. How much do you spend to replace gear per year?

- ○ Over $2,000
- ○ ~$1,000
- ○ Less than $500
- ○ $0
- ○ Other (Please fill in) _____

Question B36. If using an alternative gear type would allow you to fish for a longer duration in the season, would you use it?

- ○ Yes
- ○ No

Question B37. Instead of using an alternative fishing gear, would you consider shorter soak times? (i.e. the amount of time active fishing gear is left in the water)

- ○ Yes
- ○ No

Question B38. Would you switch gear types if using alternative fishing gear meant you could continue fishing during a fishery closure?

- ○ Yes
- ○ No

Question B39. What (if any) concerns do you have with access to fishing?

_____

Question B40. What (if any) concerns do you have about marine debris (e.g. plastic pollution, chemical pollution, urban runoff, etc.)?

_____

Question B41. What (if any) concerns do you have about lost gear?

_____

Question B42. What (if any) concerns do you have with fishery closures?

_____

Question B43. Would you work with a nonprofit organization that removes marine debris and/or helps recover your lost gear, if there was an easy way to share location information of lost fishing gear?

- ○ Yes
- ○ No

Question B44. Are you hesitant to share information regarding lost fishing gear due to the risk of sharing illegal information?

- ○ Yes
- ○ No

Question B45. How long have you been fishing recreationally/commercially for?

- ○ 0-3 Years
- ○ 3-6 Years
- ○ 7-10 Years
- ○ 10-15 Years
- ○ 15-25 Years
- ○ 25-35 Years
- ○ 35-45 Years
- ○ 45+ Years

Question B46. What gender do you identify with?

- [ ] Male
- [ ] Female
- [ ] Non-binary / third gender
- [ ] Prefer not to say

Question B47. What is your age?

- ○ 18-21 Years Old
- ○ 22-25 Years Old
- ○ 26-29 Years Old
- ○ 30-34 Years Old
- ○ 35-40 Years Old
- ○ 41-45 Years Old
- ○ 46-50 Years Old
- ○ 51-55 Years Old
- ○ 56-60 Years Old
- ○ 61-65 Years Old

- ○ 66+ Years Old
- ○ Prefer Not to Say

Question B48. What is your personal annual income?

- ○ Less than $20,000
- ○ $20,000-$34,999
- ○ $35,000-$49,999
- ○ $50,000-$74,999
- ○ $75,000-$99,999
- ○ $100,000-$149,999
- ○ $150,000-$199,999
- ○ Over $200,000
- ○ Prefer Not to Say

Question B49. What proportion of your income is from fishery landings?

- ○ None
- ○ Less than $20,000

- ○ $20,000-$34,999
- ○ $35,000-$49,999
- ○ $50,000-$74,999
- ○ $75,000-$99,999
- ○ $100,000-$149,999
- ○ $150,000-$199,999
- ○ Over $200,000
- ○ Prefer Not to Say

Question B50. How would you best describe yourself?

- ☐ White
- ☐ Black or African American
- ☐ American Indian or Alaska Native (Please Specify Tribe)

  _____
- ☐ Asian Indian
- ☐ Native Hawaiian or Pacific Islander

- [ ] Japanese
- [ ] Chinese
- [ ] Korean
- [ ] Guamanian or Chamorro
- [ ] Filipino
- [ ] Vietnamese
- [ ] Samoan
- [ ] Other Asian (Please Specify)

  _____

- [ ] Other Pacific Islander (Please Specify)

  _____

(Continues)

- [ ] Other Race (Please Specify)

  _____

- [ ] Prefer Not to Say

Question B51. Are you of Hispanic, Latino, or Spanish origin?

- [ ] No, not of Hispanic, Latino, or Spanish origin
- [ ] Yes, Mexican, Mexican American, Chicano
- [ ] Yes, Puerto Rican
- [ ] Yes, Cuban
- [ ] Yes, other Hispanic, Latino, or Spanish origin
- [ ] Prefer not to say

Question B52. Where do you reside? (please provide zip code)

_____

Question B53. Did you grow up fishing?

- ○ Yes
- ○ No

Question B54. Where do you fish?

- [ ] Northern CA Saltwater
- [ ] Central CA Saltwater

- [ ] Southern CA Saltwater
- [ ] Northern CA Freshwater
- [ ] Central CA Freshwater
- [ ] Southern CA Freshwater
- [ ] Outside of CA

Question B55. Do you fish for subsistence (subsistence refers to fishing that is done to primarily feed the family and relatives of the fisher)?

- ○ Yes
- ○ No

Appendix C - Cast & Crank Podcast

We went on a well known fishing podcast to increase responses on our Fisher Feedback Survey. The Cast & Crank Podcast has 14,000 followers on Instagram, 3,890 followers on YouTube, 1,100 followers on Facebook, and 888 ratings on Apple Podcasts (November 2022). Additionally, the survey was shared within the Bren community via Slack and on personal Instagram and Facebook accounts.

 @castandcrankpodcast  @castandcrankpodcast3022  Cast and Crank Podcast

 @Cast and crank So cal fishing podcast  Cast and Crank Podcast

Appendix D - Ocean Defenders Video

Watch “Ocean Defenders: Partnership in Progress” on Vimeo

Passcode: debrisfreeseas

Interviewees:

- **Kurt Lieber** – President and Founder, Ocean Defenders Alliance
- **Ava Schulenberg** – Program Specialist, Commercial Fishermen of Santa Barbara
- **Mike Lane** – Recreational Lobster Fisher
- **Seth Meyer** – Recreational Lobster Fisher
- **Miles Wallace** – Commercial Lobster Fisher

Appendix E - Marine Debris Removal Data for Southern California & Hawai’i

Table 1. Total Debris Removed by ODA (2002-2022).

Debris Type	Quantity
Miscellaneous Debris (pounds)	70259
Plastic Debris (pounds)	23496
Lobster Traps (count)	347
Snail Traps (count)	18
Hoop Nets (count)	24
Crab Pots (count)	86
Unknown Traps (count)	11219
Trap Line (feet)	48640
Fishing Line (feet)	96590
Fishing Weights (pounds)	6435
Tires (count)	466
Gill Nets (pounds)	1769
Squid Nets (pounds)	19165
Mixed Nets (pounds)	6930
Unknown Nets (pounds)	10187
Mylar Balloons (count)	227

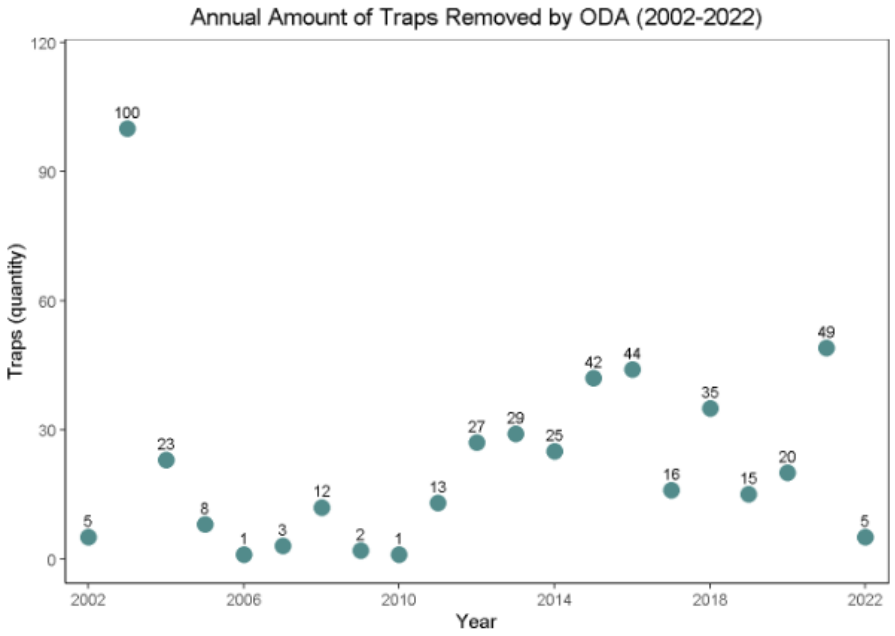

Figure 1. Annual counts of whole and mostly intact trap debris retrieved by ODA over 20 years in California and Hawai'i. Categories of trap debris included are snail traps, hoop nets, crab pots, and lobster traps. All trap quantities are in units of individual counts. A trap is considered whole if at least 5 sides of the trap are intact.

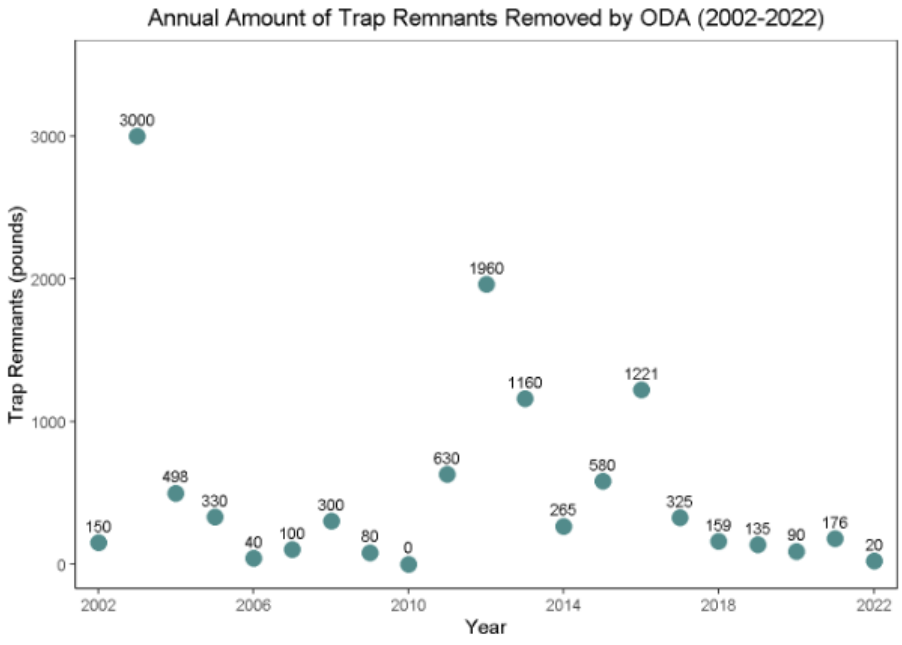

Figure 2. Annual counts of trap remnant debris retrieved by ODA over 20 years in California and Hawai'i. Trap remnants include trap debris from snail traps, hoop nets, crab pots, and lobster traps.

All trap quantities are in units of pounds. A trap is considered a remnant if less than 5 sides of the trap are intact.

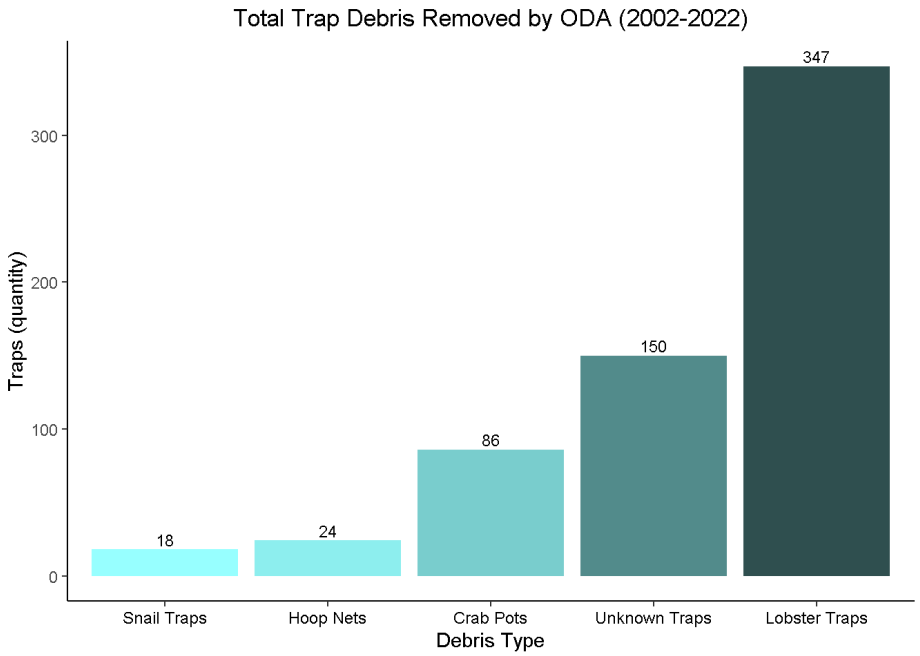

Figure 3. Total count of all trap debris retrieved by ODA over 20 years in California and Hawai'i. Categories of trap debris included are snail traps, hoop nets, crab pots, lobster traps, and unknown traps. All trap quantities are in units of individual counts.

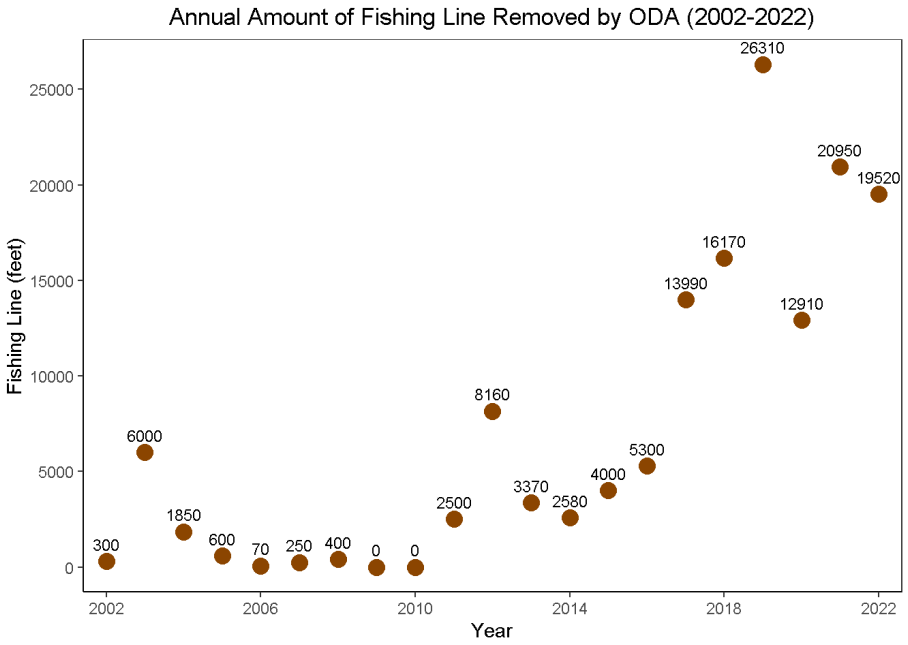

Figure 4: Annual length of all lines retrieved by ODA over 20 years in California and Hawai'i. Categories of lines include trap line and fishing line. All line quantities are in units of feet. Fishing line refers to monofilament fishing line composed of a single long fiber of plastic nylon. Trap line refers to braided rope typically made from plastic polymers such as polypropylene.

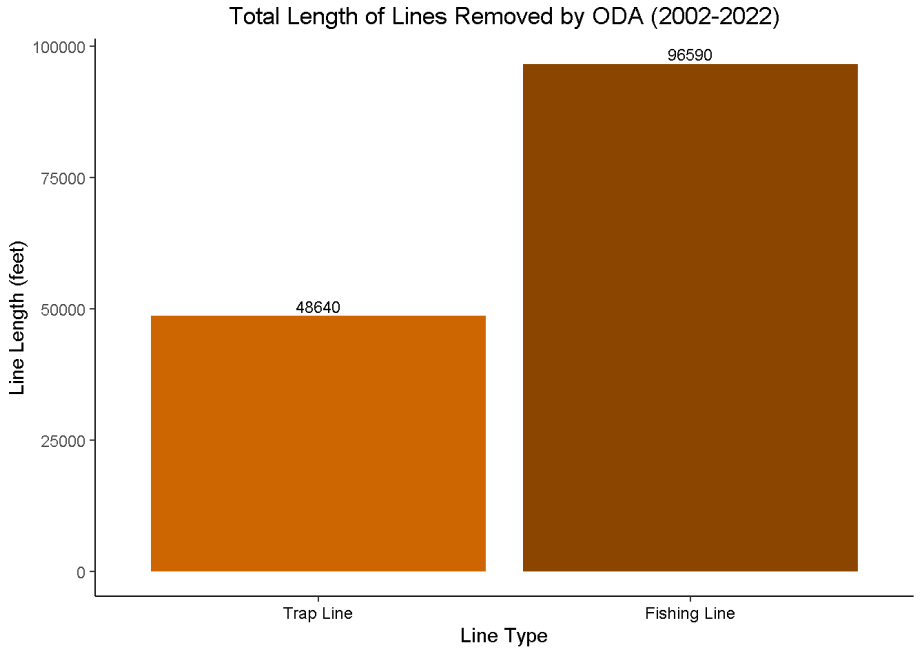

Figure 5. Total length of all lines retrieved by ODA over 20 years in California and Hawai'i. Categories of lines included are trap line and fishing line. All line quantities are in units of feet.

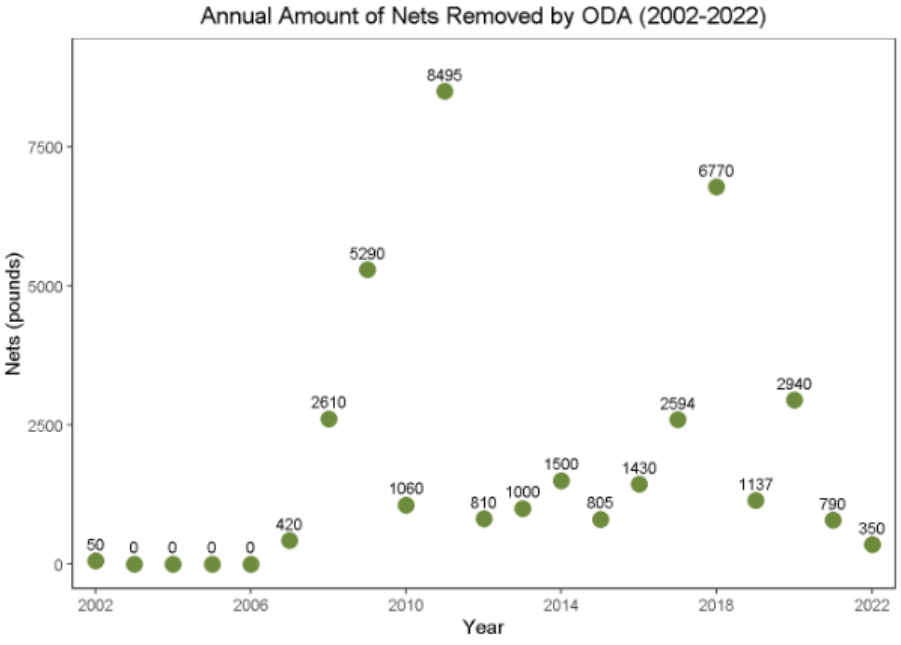

Figure 6. Annual counts of all net debris retrieved by ODA over 20 years in California and Hawai'i. Categories of net debris included are gill nets, mixed nets, unknown nets, and squid nets. All net quantities are in units of pounds. Unknown nets were partial remnants or mangled portions of a whole net and unidentifiable.

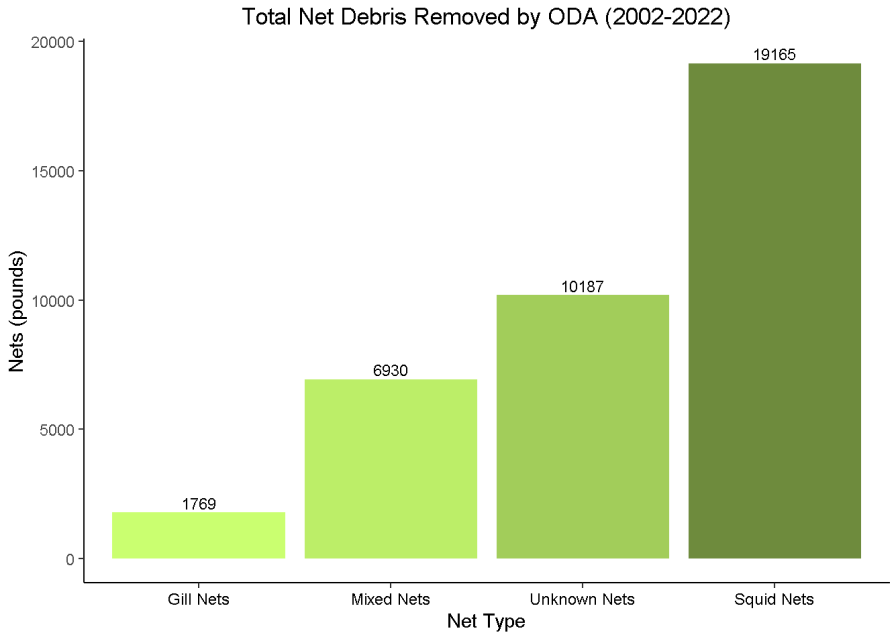

Figure 7. Total count of all net debris retrieved by ODA over 20 years in California and Hawai'i. Categories of net debris included are gill nets, mixed nets, unknown nets, and squid nets. All net quantities are in units of pounds. Unknown nets were partial remnants or mangled portions of a whole net and unidentifiable.

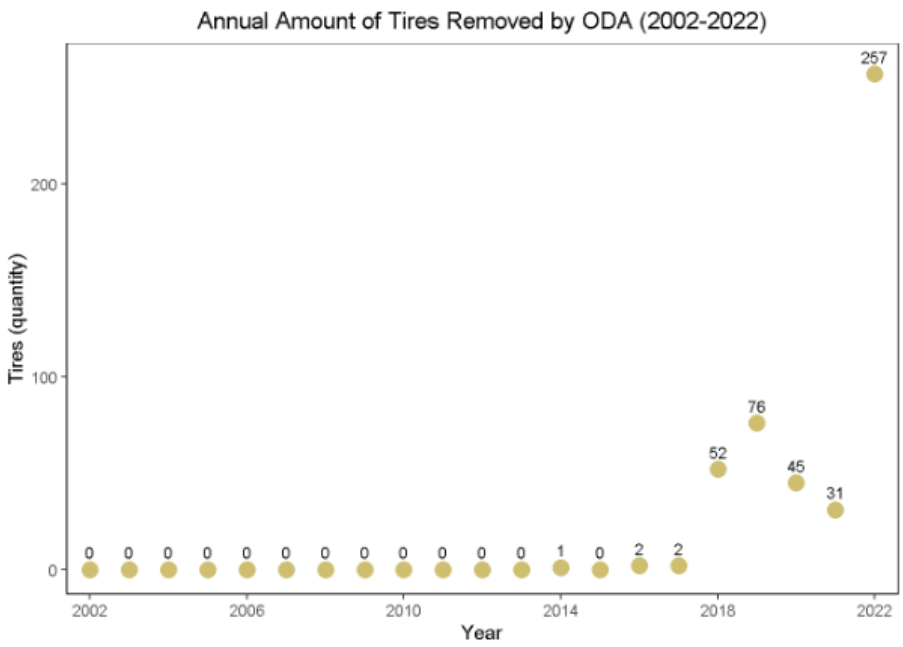

Figure 8. Annual counts of tire debris retrieved by ODA over 20 years in California and Hawai'i. Debris quantity is in units of individual counts.

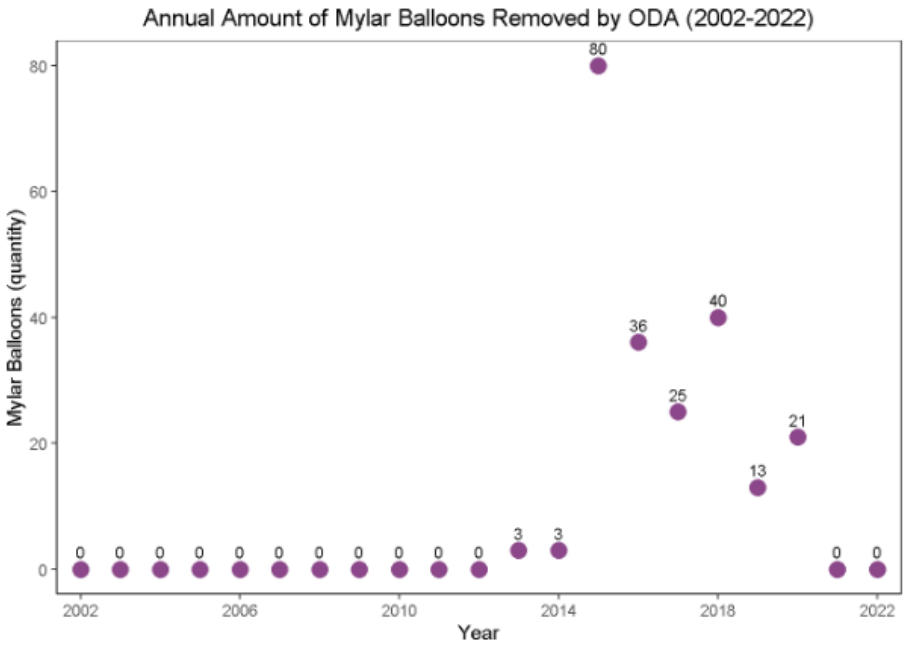

Figure 9. Annual counts of all mylar balloon debris retrieved by ODA over 20 years in California and Hawai'i. Debris quantity is in units of individual counts.

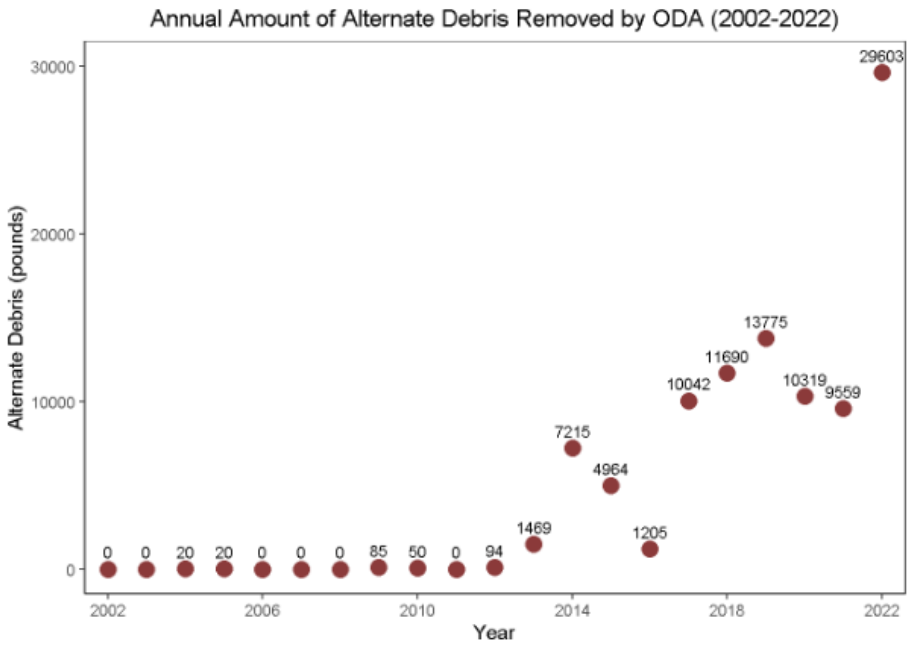

Figure 10. Annual counts of all alternate debris retrieved by ODA over 20 years in California and Hawai'i. Categories of debris included are fishing weights, plastic debris, and miscellaneous debris. All debris quantities are in units of pounds. Miscellaneous debris is all debris that does not fit into the other categories. Examples include fiberglass boats, garden hoses, and batteries.

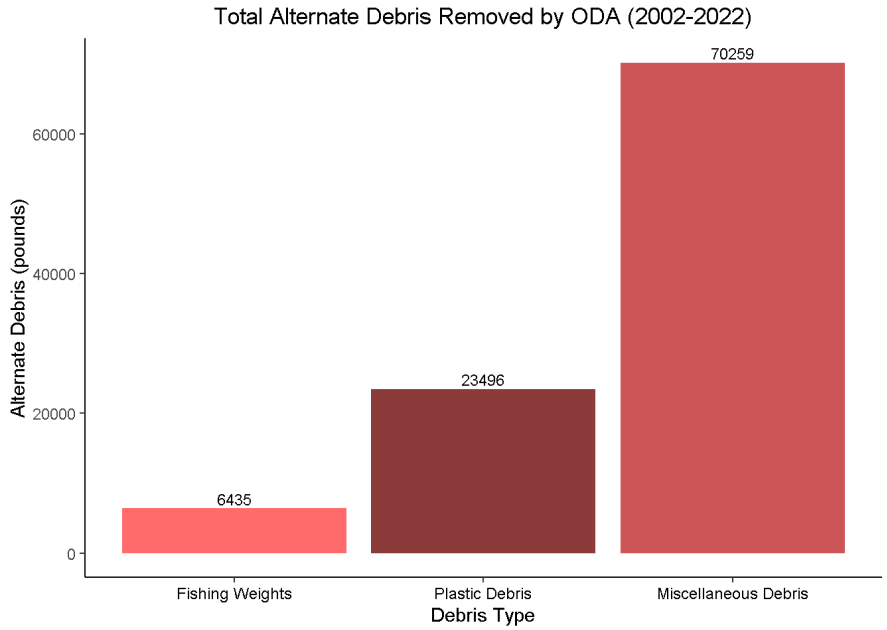

Figure 11. Total count of all alternate debris retrieved by ODA over 20 years in California and Hawai'i. Categories of debris included are fishing weights, plastic debris, and miscellaneous debris.

All debris quantities are in units of pounds. Miscellaneous debris is all debris that does not fit into the other categories. Examples include fiberglass boats, garden hoses, and batteries.

Appendix F - Future Collaborations & Partnerships for ODA

- Coastal organizations – We believe ODA would benefit from working with the following organizations based on their similar cleanup endeavors, working with the fishing community, and ways they may collaborate in effective marine debris removal cleanups:
    - CA Coastkeeper Alliance
    - Los Angeles Waterkeeper
    - Orange County Coastkeeper
    - Orange County Marine Protected Area Council
    - Santa Barbara Channelkeeper
    - San Diego Coastkeeper
    - SeaDoc Society
- Conservation agencies – We believe ODA would benefit from working with the following organizations based on ODA removing trap gear and these agency's efforts to prevent and reduce the number of marine wildlife entanglements in active and derelict gear:
    - California Department of Fish and Wildlife's Whale Safe Fisheries
    - Ocean Protection Council's California Dungeness Crab Fishing Gear Working Group
- Marine mammal organizations – We believe ODA would benefit from working with the following organizations based on ODA's fishing gear collection information and these organizations addressing marine mammal entanglements through its research efforts:
    - Channel Islands Marine and Wildlife Institution
    - Marine Mammal Care Center
    - Pacific Marine Mammal Center

    - The Marine Mammal Center
- Whale watching groups – We believe ODA would benefit from working with the following organizations based on the time these groups have on and around the water to observe derelict gear and report this to ODA via their boat captains, naturalists, and deckhands:
    - Santa Barbara County
        - Celebration Cruises
        - Condor Express
        - Santa Barbara Channel Whale Heritage Site
        - Santa Barbara Sailing Center
    - Ventura County
        - Channel Islands Dolphin Adventures
        - Channel Islands Whale Watching
        - Island Packers Cruises
    - Los Angeles County
        - American Cetacean Society LA Chapter (ACS-LA)
        - Harbor Breeze
        - LA Waterfront Sportfishing & Cruises
        - SoCal Whale Watching
        - Spirit Cruises
    - Orange County
        - American Cetacean Society OC Chapter (ACS-OC)
        - Captain Dave's Dana Point Dolphin & Whale Watching Safari
        - Dana Point Harbor
        - Dana Wharf Sportfishing & Whale Watching
        - Davey's Locker
        - Newport Landing Whale Watching
    - San Diego County
        - San Diego Whale Watch

        - Adventure Whale Watching
        - Offshore Blue Adventures Whale & Dolphin Tours
- Yacht clubs – We believe ODA would benefit from working with these types of organizations based on the time these groups have on and around the water to observe derelict gear and report this to ODA.
- Additional scuba clubs – We believe ODA would benefit from working with these types of organizations based on the time these groups have in and around the water to observe derelict gear and report this to ODA. This type of partnership has already proven successful for ODA, as we experimentally connected ODA and the UC Santa Barbara Scuba Club in February 2023. Since then, there have been 2 successful collaborative shore-based cleanups removing 18+ spiny lobster traps.