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NOAA FISHERIES

PACIFIC ISLANDS FISHERIES SCIENCE CENTER

Report to the Western Pacific Regional Fishery Management Council

December 2021

Spinner Dolphin (Stenella longirostris) Photo credit: Marie C. Hill

The Pacific Islands Fisheries Science Center (PIFSC or Center) administers and conducts scientific research and monitoring programs that produce science to support the conservation and management of fisheries and living marine resources. This is achieved by conducting research on fisheries and ocean ecosystems and the communities that depend on them throughout the Pacific Islands region, and by dedicating efforts to the recovery and conservation of protected species. The Center is organized into five major divisions: the Operations, Management, and Information Division (OMI); Science Operations Division (SOD); Fisheries Research and Monitoring Division (FRMD); Protected Species Division (PSD); and Ecosystem Sciences Division (ESD).

PIFSC continues to improve its science and operations through collaboration and integration across divisions, and increased communication, cooperation, and coordination with partners and stakeholders. In 2018, the Center developed a 5-year framework for annual prioritization of research and monitoring activities in order to fully utilize the capabilities of PIFSC and its partners (e.g., NOAA Fisheries Pacific Islands Regional Office (PIRO); Western Pacific Regional Fishery Management Council (WPRFMC)). In 2019, the Center released an updated 5-year science plan. All activity updates and reports herein are organized in accordance with the research themes (per the PIFSC Science Plan 2019–2023) outlined below:

1) Promote Sustainable Fisheries
2) Conserve Protected Species
3) Research to Support Ecosystem-based Fisheries Management (EBFM) and Living Marine Resource Management
4) Organizational Excellence

This report concludes with a listing of publications produced during this reporting cycle.

1. Promote Sustainable Fisheries

Hierarchical Cluster Analyses in Support of the Development of Territorial Fishery Management Plans and Reevaluation of Bottomfish Management Unit Species Complexes

National Standard 1 (NS-1) recommends grouping stocks into complexes of similar geographic distribution, life history characteristics, and vulnerabilities to fishing pressure. When possible, the complexes should have indicator stocks that are representative of those in the complex. Measurable and objective status determination criteria (SDC) can be established for the indicator stocks and used to help manage the stock complex. Within a multispecies fishery where complexes are required for management, the NS guidelines imply a process where individuals subject to similar fishing pressure are identified first. These geographically similar assemblages can be further aggregated based on life history characteristics and vulnerability to define a complex and, in turn, indicator species can be identified. Fisheries in the U.S. Pacific territories are multi-gear and multispecies by nature and the information extrapolated from limited intercept surveys is not always sufficient for individuals to be identified to species. These fisheries are candidates for establishing more suitable species complexes in fishery management plans (FMPs) or fishery ecosystem plans (FEPs) than those developed in previous plans. The Magnuson-Stevens Act and NS guidelines recommend decisions regarding species complexes and indicator species be revisited to ensure that they are achieving the conservation and management goals. This analysis was conducted to reach this goal and to provide a transparent and repeatable process.

We present the results of hierarchical clustering of creel interviews for boat-based operations in American Samoa (Figure 1) and boat-based interviews in Guam (Figure 2). The dendrograms are intended to delineate species aggregations that are experiencing similar fishing pressure to facilitate, when used in conjunction with life history information, the determination of species complexes for FMPs and FEPs.

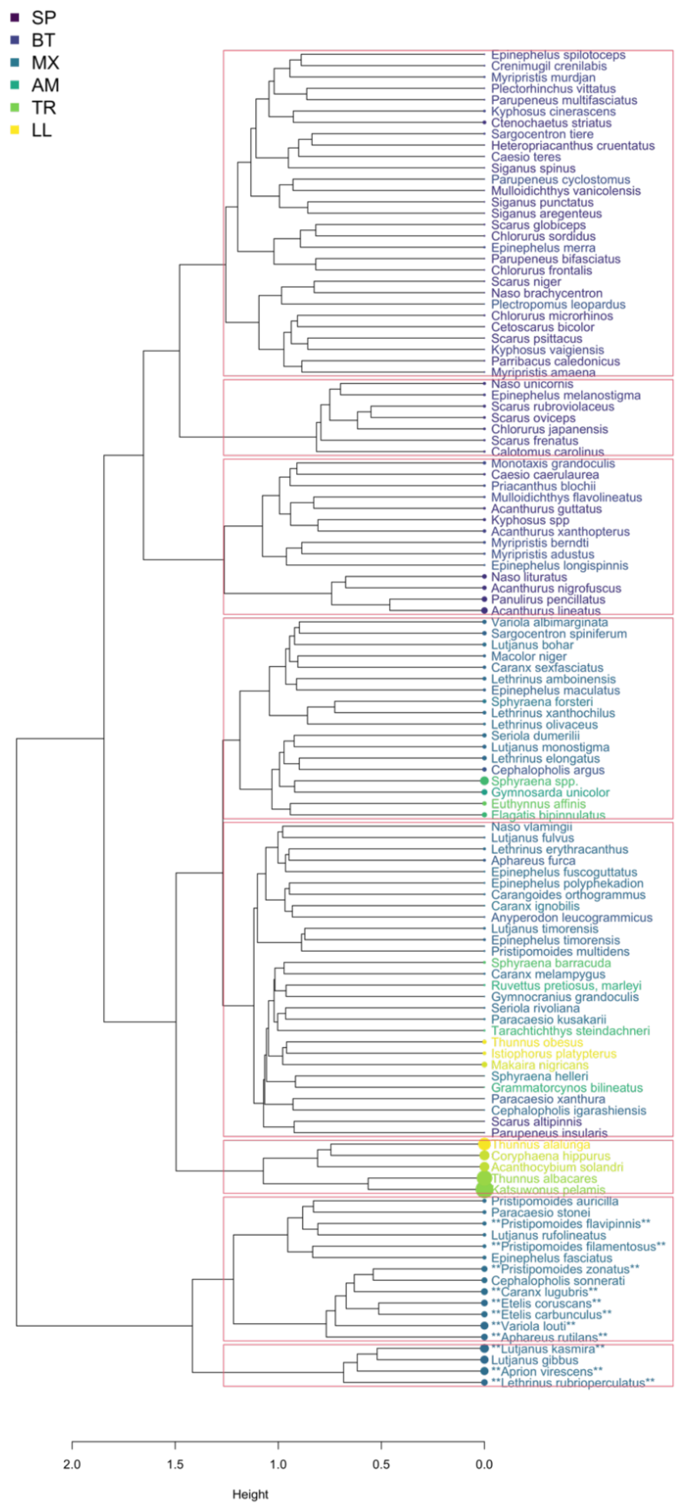


*Figure 1. Dendrogram of the American Samoa boat-based creel interviews. Color indicates the average method of capture: spear fishing (SP), bottom fishing (BT), mixed gears (MX), Atule Mixed (AM), Troll (TR), and Longline (LL). The size of the leaf dot indicates the number of interviews with a presence. ** indicates the species was previously in a bottomfish complex.*

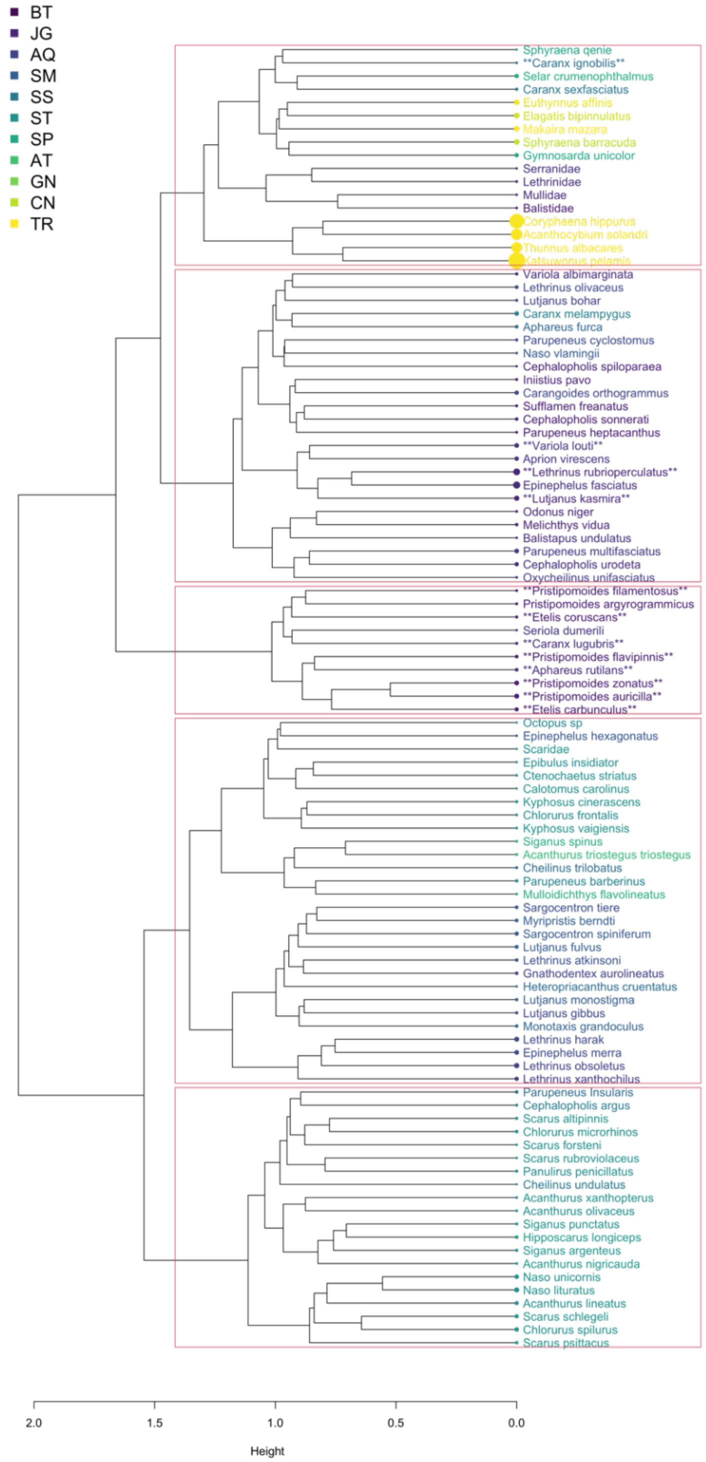


*Figure 2. Dendrogram of the Guam boat-based creel interviews. Color indicates the average method of capture: Bottom fishing (BT), Jigging (JG), Aquarium Fish Collecting (AQ), Mix Spearfishing (SM), Spear/Snorkel (SS), Spear/Scuba (ST) , Spincasting (SP), Atulai Night Light (AT) , Gillnet (GN), Castnet (CN), Trolling (TR). The size of the leaf dot indicates the number of interviews with a presence. ** indicates the species was previously in a bottomfish complex.*

Growth, Mortality, and Reproduction of the Oblique-Banded Snapper (*Pristipomoides zonatus*) in Guam

Deepwater snapper fisheries in the Mariana Archipelago are important commercial, recreational, and subsistence fisheries. *Pristipomoides zonatus* is one of the top four deepwater snapper species harvested in Guam; however, accurate life history information is lacking. To fill this gap, PIFSC Life History Program conducted a comprehensive life history assessment for *P. zonatus* that included age, growth, mortality, and reproduction using samples collected during research cruises and from the biosampling program. The size of *P. zonatus* sampled for life history research ranged from 11.5 cm to 40.4 cm (fork length), and ages ranged from 0.5 to 30 years. Ages were estimated using nascent otolith thin sectioning techniques; an ageing criterion was developed by identifying the first annuli using daily growth rings and comparing estimated ages with bomb radiocarbon estimated ages. Comparisons between all of the samples collected and a proportional sampling design indicated that the collected otoliths were representative of the fishery and suitable for growth estimation. Pooled-sex von Bertalanffy growth model parameters estimates were $L_\infty = 36.91$ cm, $K = 0.29$ (Figure 3). However, sex-specific differences were identified with males obtaining a larger average size and a larger asymptotic size (+3.03 cm) compared to females, whereas K did not differ (Figure 3). A maximum age-based natural mortality estimator resulted in an $M = 0.22$. *Pristipomoides zonatus* matures at a small size and early age ($L_{50} \leq 24.0$ cm and $A_{50} \leq 2.1$ yr) relative to their maximum size (40.4 cm) and age (30 yr) (Figure 4. Physiological and functional maturity classifications, two commonly used criteria that can influence maturity estimates, resulted in similar L_{50} estimates (Figure 5). Additionally, *P. zonatus* has a long spawning season (May through September) and short spawning interval, suggesting high reproductive output. These results expand knowledge on *Pristipomoides* life history (fast early growth, moderately long-lived, high productivity) and provides the necessary information for stock assessments and sustainable management of *P. zonatus* in Guam.

Schemmel E, Nichols RS, Cruz E, Boyer J, Camacho F. *Growth, mortality, and reproduction of the oblique-banded snapper (Pristipomoides zonatus) in Guam*. Mar Freshw Res. In press.

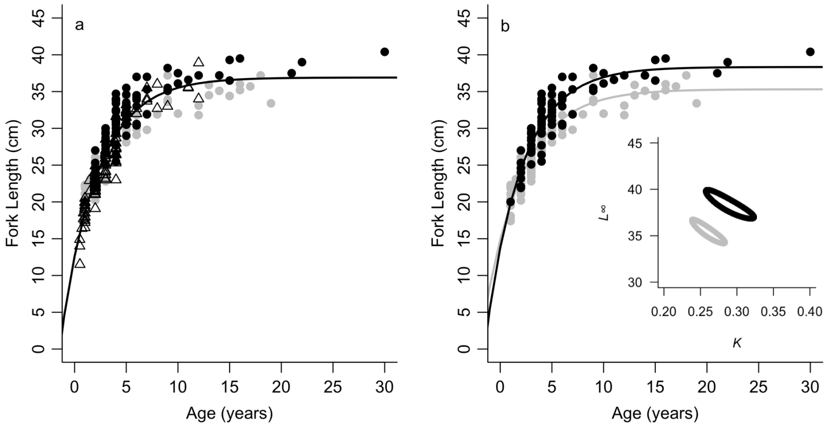


Figure 3. (A) The von Bertalanffy growth curve for all aged Pristipomoides zonatus*, including females (grey; n = 123), males (black, n = 85), and individuals with unknown sex (triangles; n = 108) and (B) the von Bertalanffy growth curves and 95% growth parameter confidence ellipses for females (grey; n = 123) and males (black, n = 85).*

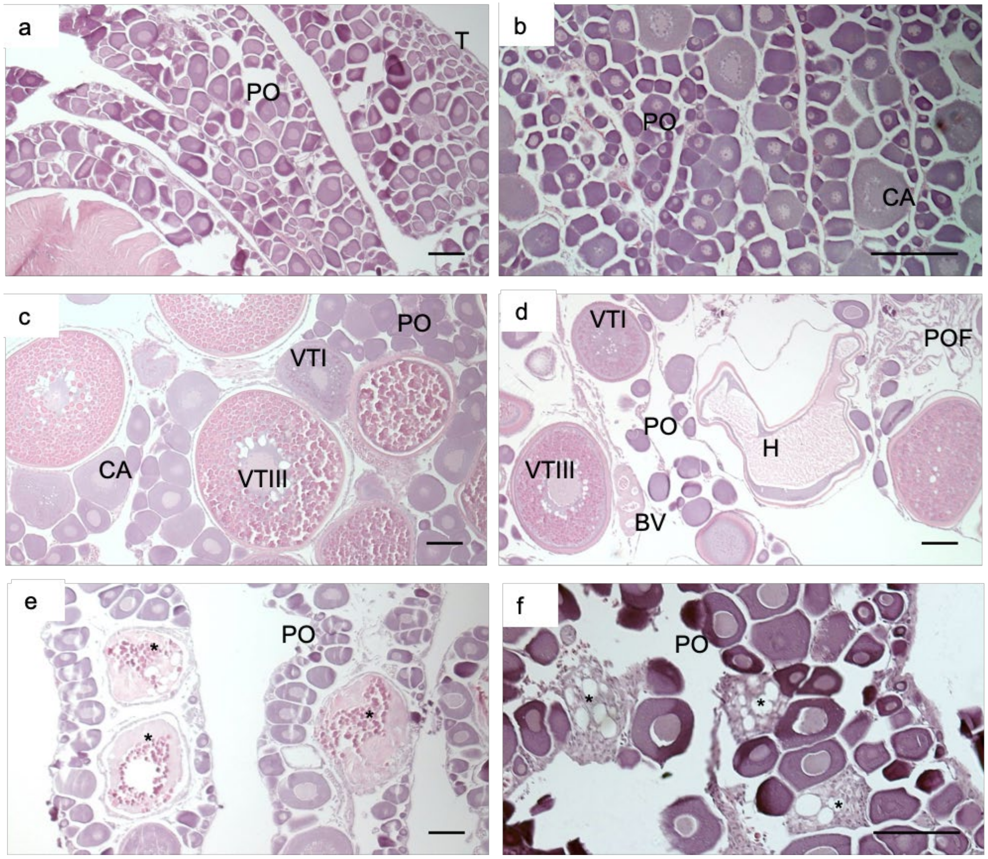


Figure 4. Stages of Guam Pristipomoides zonatus *oogenesis and reproductive phases following Brown-Peterson et al. (2011). (a) Immature female with primary stage oocytes (PO) and a thin tunica (T), (b) developing female with PO and cortical alveoli (CA) oocytes, (c) spawning capable female with stages I and III vitellogenic ooctyes (VTI & VTIII, respectively), (d) actively spawning female with hydrated ooctyes (H), recent post ovulatory follicles (POF), VTIII, VTI, CA, and PO, (e) regressing female with beta atresia (*) and PO, (f) regenerating female with delta atresia (*) and PO. All scale bars are 100 µm.*

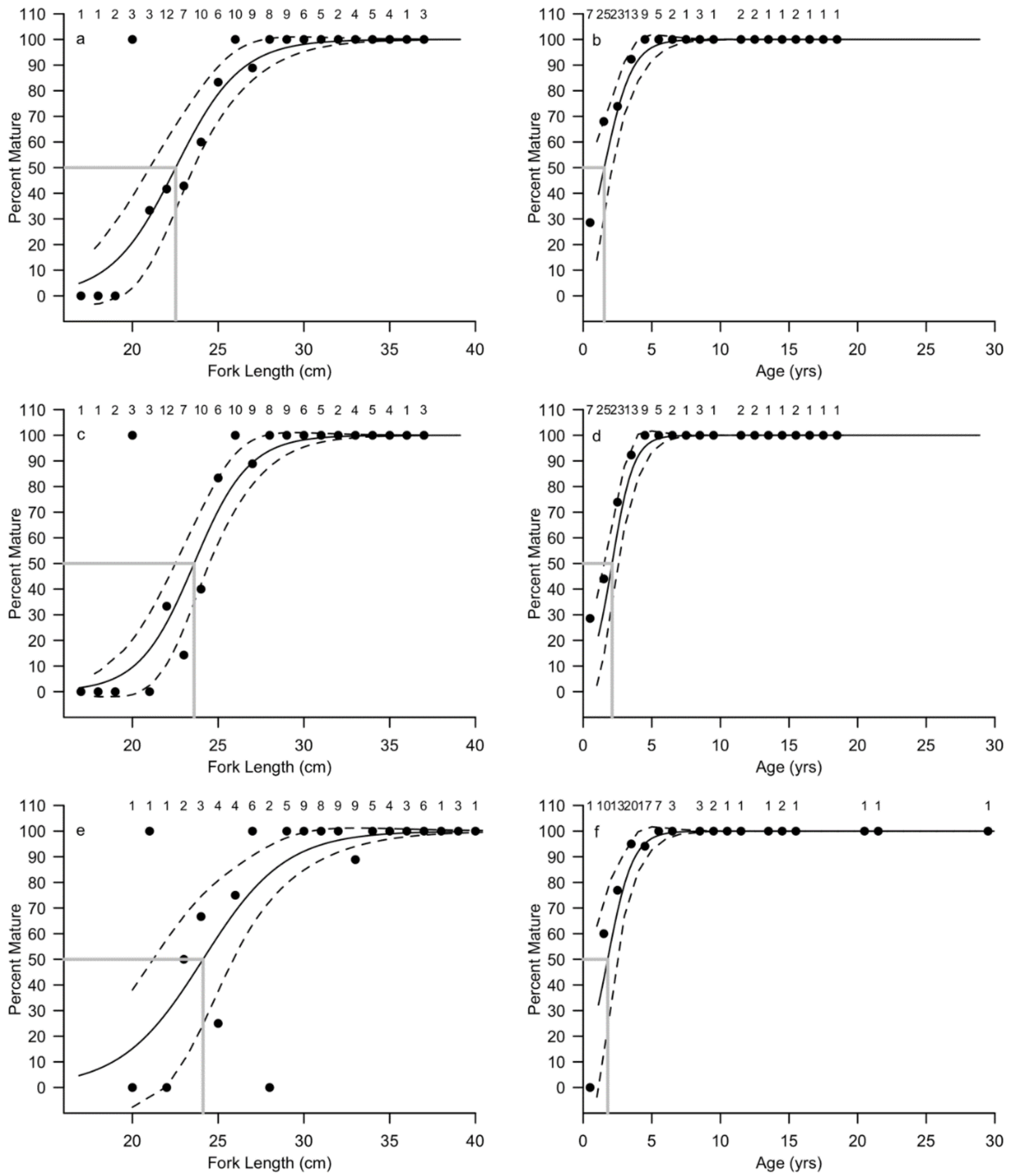


Figure 5. Maturity ogive for Guam Pristipomoides zonatus*. Female physiological length (a) and age at maturity (b), female functional length (c) and age at maturity (d), and male length (e) and age at maturity (f). Dashed lines indicate 95% confidence intervals and gray lines indicate L50 and A50.*

Protected Species Ensemble Random Forest Model Application to U.S. Purse Seine Interactions with Giant Manta Ray

The giant manta (*Mobula birostris*), in the horned ray family Mobulidae, was listed as Threatened under the Endangered Species Act (83 FR 2916; January 22, 2018). Mobulidae are regularly intercepted in U.S. purse seine tuna fishery operations in the western and central Pacific Ocean (WCPO). Since 2010, ~100% observer coverage of the U.S. WCPO purse seine has provided detailed information on these interactions.

Previous work had identified some set characteristics that are associated with large manta interactions. Unfortunately, characteristics associated with giant manta interactions are difficult to determine because identification to species is somewhat problematic and other species in the family can appear physically similar on first inspection. To build on our understanding of interactions with large mobulids, the Protected Species Ensemble Random Forest (PSERF) modeling approach was applied to U.S. purse seine observer data. Each set was aligned with oceanographic characteristics from the appropriate weekly time period along with additional set characteristics recorded in observer data (Table 1). Models were run for individuals reported as *Mobula birostris* as well as for the family Mobulidae.

Performance statistics (Figure 6) suggest that the PSERF model performed well for predicting a positive occurrence for individuals reported as *Mobula birostris* with almost 100% accuracy and a low type 1 error rate. Given the factors selected to include in the model, set type was ranked (Figure 7) as the most important determinant of probability of encounter with unassociated set having a positive contribution (see Table 2 and Figure 8). Higher probability of encounter occurs in the mid-year given the accumulated local effects (ALE) pattern for the sine of Julian day. Encounters appear to occur away from seamounts in areas of higher chlorophyll-a concentrations. Set with a short set time were also associated with a higher probability of encounter.

Table 1. Short code and description of factors used in the random forest model.

Short code	Description
assoc_code	Set type (see Table 2)
sin.julian	Sine of Julian day
set.time	Total time to start and process set
dist.sst.front.ses	Standardized effect size for distance for SST front
chla	Chlorophyll-a (mg/m^3)
dist.chla.front.ses	Standardized effect size for distance for chlorophyll front
current.zonal	West–east current
current.meridonal	North-south current
current.speed	Current speed (m/s)
dist.current.front.ses	Standardized effect size for distance for current front
OkuboWeiss	The sum of the squares of normal and shear strain minus the relative vorticity.
EKE	Eddy kinetic energy

Short code	Description
Eddy	Presence or absence of mesoscale eddy
wind.midpoint.speed	Wind speed
dist.wind.front.ses	Standardized effect size for distance for wind front
lunar_rad	Lunar radius
seamt_ses	Standardized effect size for distance for seamounts

Table 2. Numeric code and set type.

Code	Description
1	Unassociated with any other object or animal
2	Unassociated but feeding on bait fish only
3	Drifting log /debris or a dead animal.
4	Drifting, raft, FAD, or payao
5	Anchored raft, FAD, or payao
6	Live whale
7	Live whale shark
8	Other

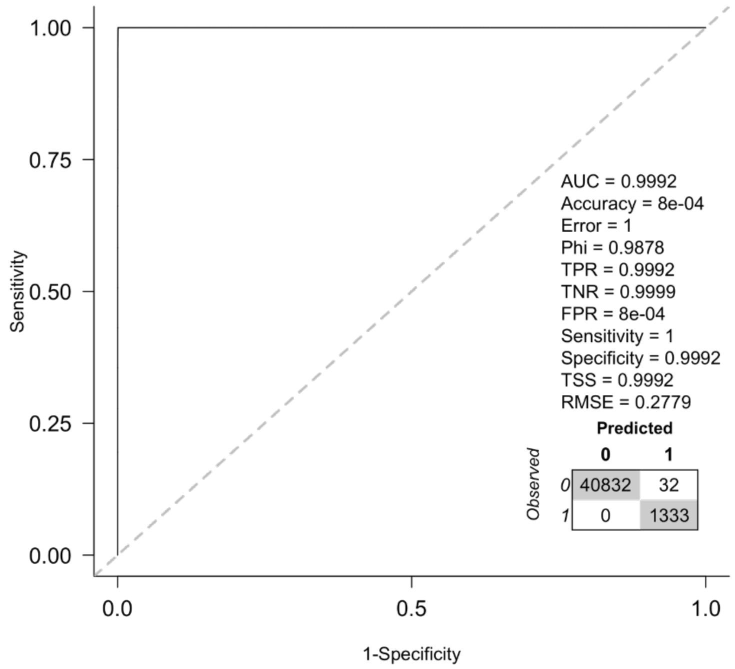


Figure 6. Receiver operator characteristic curve and performance metrics and confusion matrix for the ensemble random forest: area under the curve (AUC—gives the rate of successful classification), true positive rate (TPR), true negative rate (TNR), false positive rate (FPR). Sensitivity is the proportion of occurrences properly identified. Specificity is the proportion of absences correctly identified. True skill statistic (TSS—represents matches and mismatches between observations and predictions). Root mean squared error (RMSE).

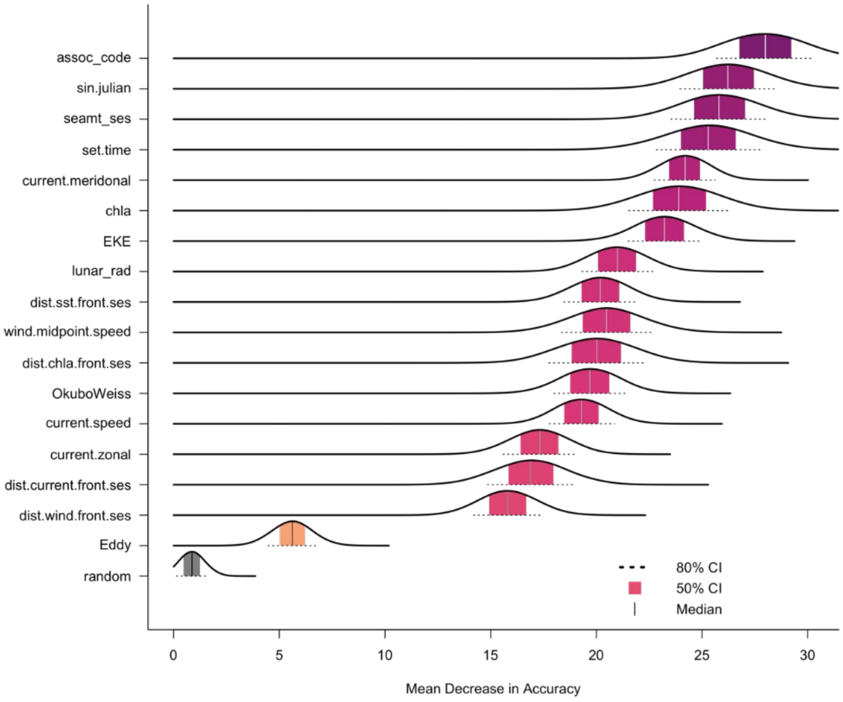
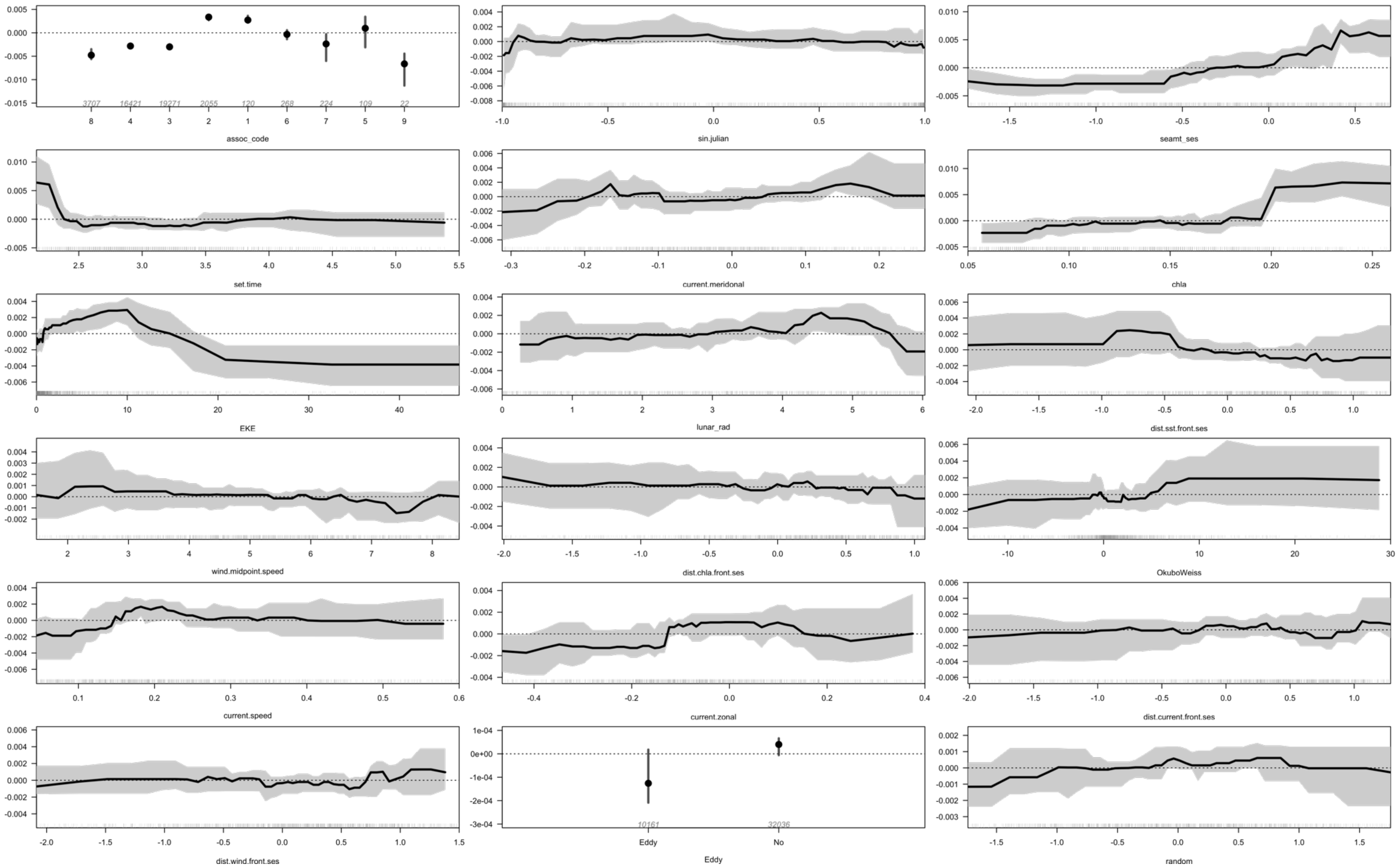


Figure 7. Relative variable performance.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2. Conserve Protected Species

Protected Species Division 2021 Field Season Wrap-up and Preliminary Information

Figure 9. Weaned Hawaiian monk seal pup with plastic ring around his neck at Kamole (Laysan Island) prior to disentanglement. Photo by A. Filardo, ESA/MMPA Permit 22677.

NOAA's assessment and recovery camps form the foundation of our research and recovery efforts for threatened Hawaiian green sea turtles and endangered Hawaiian monk seals in the Papahānaumokuākea Marine National Monument. This year, after numerous special precautions to work safely during the COVID-19 pandemic, field teams were deployed in March (early turtle team at Lalo (French Frigate Shoals)) and July (seal teams at all sites), and returned at the end of September 2021.

A primary priority of the camps is conducting surveys to collect data on animal abundance for stock assessments. Depending on the site, a full survey for monk seals might entail walking several miles through deep sand around an island's perimeter or boating between small islets across an 18–25–mile wide atoll. This year field teams completed 57 full monk seal surveys. At least 171 pups were born in Papahānaumokuākea this year, and field teams managed to tag at least 135 of them. Additionally, teams tagged 43 yearlings and tagged or retagged several older seals with lost or damaged tags.

The Lalo turtle team identified more than 1,000 individual turtles on Tern Island, including 679 females. The average number of females on Tern Island was only 254 over the past three seasons. Across the atoll, East Island still recovers after being washed away by Hurricane Walaka in 2018. The team conducted 109 night surveys and even tagged a loggerhead turtle—the first time we have ever recorded one attempting to nest at Lalo!

At Tern Island at Lalo, aging infrastructure from World War II often poses entrapment threats to wildlife, so teams performed daily entrapment walks. They documented 344 turtles, 2 seals, and 10 seabirds that were entrapped or otherwise unable to get back to the ocean, and released 329 turtles, 1 seal, and all 10 seabirds (11 turtles and 1 seal got out on their own and 4 turtles died).

Additionally, field teams performed 24 other seal interventions at the various sites such as disentanglement from marine debris, administering antibiotics to compromised seals, and collecting a prematurely weaned pup at Kuaihelani (Midway) that required rehabilitation. This seal was released at Kapou (Lisianski Island) after successful recovery at Ke Kai Ola, the monk seal hospital on Hawaii Island.

Increasing Evidence of Connectivity Between Hawaiian Monk Seal Populations within Papahānaumokuākea and the Main Hawaiian Islands

On September 22, an unfamiliar monk seal with grey colored flipper tags was reported on the north shore of Oʻahu. Monk seals from Oʻahu and other main Hawaiian Islands typically have red-colored flipper tags, so the odd tag color spiked curiosity. Through photos and our data records, HMSRP staff were able to confirm the identity of this seal as KG54, a 6-year old female from Hōlanikū (Kure Atoll) situated within the Papahānaumokuākea Marine National Monument in the Northwestern Hawaiian Islands. Our records show that she was last sighted at Hōlanikū on August 14, 2021. This means that KG54 traveled over 1,300 miles, from Hōlanikū to Oʻahu, in just under 5 weeks. That is an impressive journey.

From years of monitoring the population, we know that many monk seals move between neighboring islands and atolls. We have increasing evidence of connectivity between the Northwestern Hawaiian Islands and main Hawaiian Islands regions over the last 5 years, at least 18 seals have journeyed between the two regions. They primarily traveled between the southern end of the Northwestern Hawaiian Islands chain and the northern portion of the main Hawaiian Islands. The most frequently documented trips were between Nihoa Island and Niihau and Lehua Islands, indicating that these are important steppingstones for movement between the regions. Because these areas are only surveyed, at most, 1–2 times each year, the majority of seal movements between these locations are likely unobserved.

While KG54 is the fastest seal on record to cover such a distance, she is not the first monk seal to embark on such a long voyage. A 5-year old female from Kuaihelani (Midway Atoll), RS00, traveled to the main Hawaiian Islands over a period of several years. RS00 left Kuaihelani in 1997, stopped off at Kamole (Laysan Island) in 1998–1999, and arrived in the main Hawaiian Islands in 2000, where she was sighted on Kauai and Molokai. She remained in the main Hawaiian Islands for the rest of her life and gave birth to at least 9 pups. There have been several other noteworthy travelers between these two regions. Seal YF95 was born at Lalo (French Frigate Shoals) in 1988, then moved to Kamole in 1995. He left Kamole in 2016 and was first sighted in on Kauai in August of 2017, then traveled to Molokaʻi, Oʻahu, and Kauai in 2018, and has remained in this region ever since. Seal Y6FD is another Lalo born seal that was last seen at Lalo in 2014, when he was 2 years old then sighted in the main islands on Kahoʻolawe in 2020.

Figure 10. Adult female monk seal KG54 resting on the North shore of Oʻahu after her trip from Hōlanikū within Papahānaumokuākea. Photo by L. Macpherson.

KG54 is still sighted regularly along the north shore of Oʻahu. According to our records, this trip to Oʻahu is the first time she has been sighted outside of Hōlanikū. How long she might stay is anyone’s guess.

3. Research to Support EBFM and Living Marine Resource Management

Maximum Economic Yield and Nonlinear Catchability

Maximum economic yield (MEY) as derived from Schaefer's (1957) bioeconomic model was potentially a major contribution to fishery management, but it has been hard to apply to fishery management in reality. Schaefer's model with fixed catchability and associated linear CPUE does not match the variable nature of catchability resulting from technological progress and schooling behavior, leading to a biased estimation of MEY or economic optimal biomass (B_{MEY}).

A recent manuscript from PIFSC[1] improves on Schaefer's model by incorporating nonlinear CPUE, where MEY depends on biomass relationships with catchability and with CPUE. When CPUE is constant, MEY is shown analytically to be the same as the biological optimal yield (maximum sustainable yield [MSY]) and the related optimal biomasses are equivalent ($B_{\text{MEY}} = B_{\text{MSY}}$). However, in cases of nonlinear CPUE, MEY might be closer to or further away from MSY. The less sensitive the CPUE is in response to changes in biomass, the closer the economic optimum B_{MEY} is to the biological optimum B_{MSY}. When CPUE is sensitive to changes in biomass, the benefit of leaving more fish in water (the stock effect) is more noticeable.

Simulation analyses further illustrate that the traditional Schaefer economic optimum does not apply to all fisheries. This model provides the basis for fishery management to set a total catch limit (as a fishery management reference point) that could achieve MEY but also defines how MEY could be equal to, closer to, or further away from MSY based on characteristics of an individual fishery. For a fishery in overfished status, it helps fishery managers to decide a rebuilding target at B_{MSY} or at a higher abundance than B_{MSY} in order to achieve MEY and still meet biological reference points. In addition to supporting WPFMC Island Fisheries research priority (IF3.1.2) and Human Communities research priority (HC2.1.2), this model can become an important component in matching fishery management goals to the realities of fisheries.

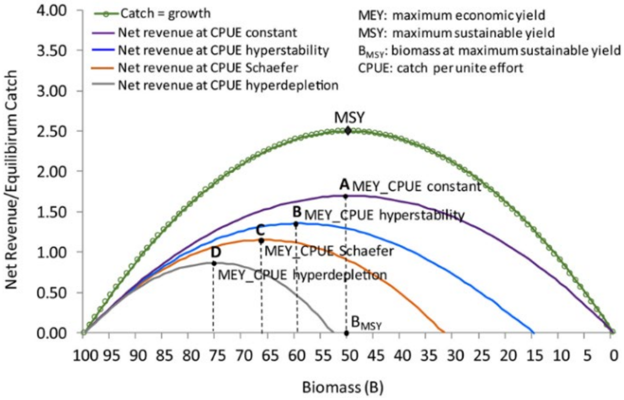

Figure 11. Net return curves and maximum economic yield under four different CPUE relationships.

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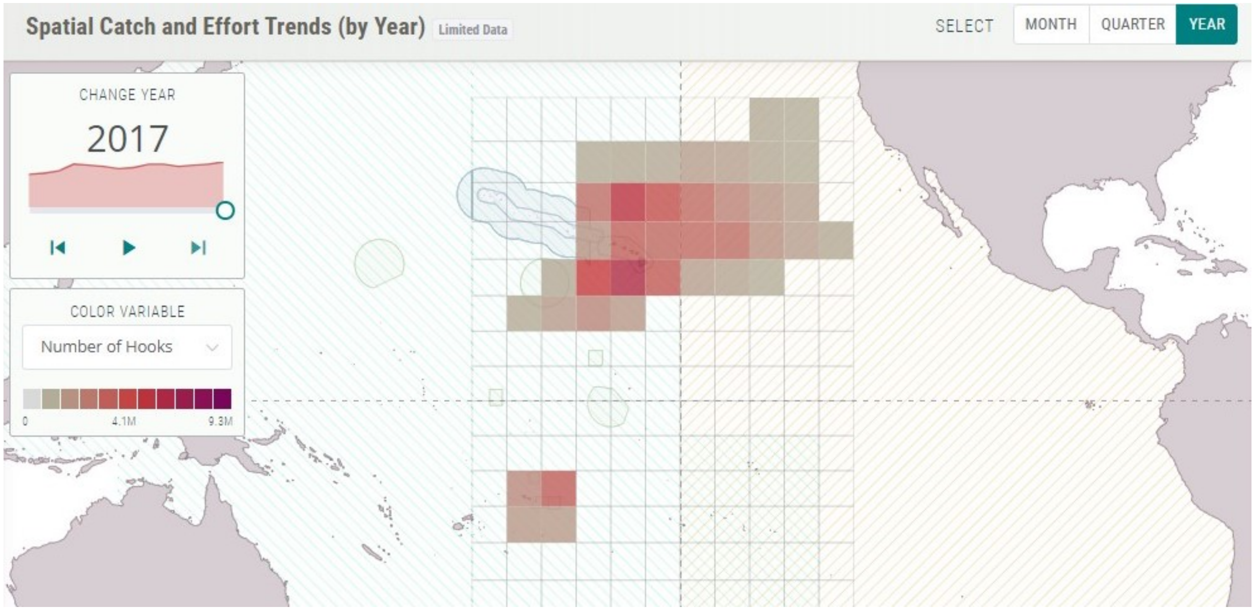
[1] Pan M. (2021) Maximum Economic Yield and Nonlinear Catchability. North American Journal of Fisheries Management. 41(5): 1229–1245. https://doi.org/10.1002/nafm.10661

Fishing Trip Cost Modeling for the Hawaii and American Samoa Longline Fisheries

The costs of fishing are an important element in evaluating the economic performance of fisheries, assessing economic effects from fisheries management alternatives, and serving as input for ecosystem and bioeconomic modeling. However, many fisheries have limited trip-level data due to low observer coverage. PIFSC researchers introduce a generalized linear model (GLM) utilizing machine learning (ML) techniques to develop a modeling approach to estimate the functional forms and predict the fishing trip costs of unsampled trips for regional longline fisheries. This modeling approach is applied to estimate trip-level fishing costs using the empirical sampled trip costs and the associated trip-level fishing operational data and vessel characteristics in the Hawaii and American Samoa longline fisheries. Using this approach to build models is particularly important when there is no strong theoretical guideline on predictor selection. Also, the modeling approach addresses the issue of skewed trip cost data and provides predictive power measurement. As a result, fishing trip costs for all trips in the fishery can be estimated.



CHANGE YEAR 2017

COLOR VARIABLE Number of Hooks

Figure 12. 2017 catch and effort map of the Hawaii longline fishery binned in five degree squares of latitude and longitude.

This study applies the estimated trip cost model to conduct an empirical analysis and evaluate the trip cost impacts of area closures due to reaching the annual bigeye tuna catch limits in the Hawaii longline fleet. Among all the Hawaii deep-set longline trips between 2005 and 2018 (18,894 trips), five trip types were identified and their average costs were estimated. Although only a small percentage of trips (2.9%) were affected by the closures, the percent of affected vessels was high (73%). Trips taken by the affected vessels during the WCPO closures experienced longer travel distances and fishing days than the trips that fished exclusively in the WCPO, the area where vessels were most likely to fish without the WCPO closures. On the other hand, vessels that were affected during the EPO closures experienced the shortest travel distances and longest fishing days. The average cost for trips taken by the affected vessels during the WCPO closures ($29,092) was higher than the regular WCPO trips because of the longer travel distances (+1,667 km) and fishing days (+1 day). Therefore, if the bigeye catch limit in WCPO was reduced further, we could expect trip cost to increase by 14% on average, as affected vessels have to move to the EPO or cease fishing.

In addition to supporting WPFMC Human Community research priorities (HC1.1.1, HC1.1.6), fishery managers can use this information to support regulatory impact analyses, improve monitoring of fishery economic performance, and provide insights into fishing behavior and fisher responses. The findings in this report lay an important foundation for improved understanding of the costs of fishing and profitability for regional commercial longline fisheries.

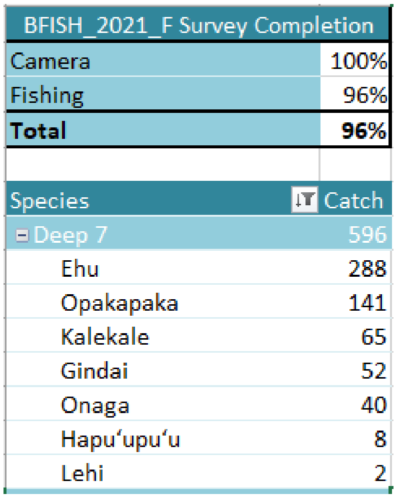
Chan HL, Pan M. 2021. Fishing trip cost modeling using generalized linear model and machine learning methods–A case study with longline fisheries in the Pacific and an application in Regulatory Impact Analysis. PLoS ONE 16(9): e0257027.
https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0257027

4. Organizational Excellence

BFISH Survey and Data Analysis

The fall 2021 BFISH survey is 96% complete as of October 25 (camera sampling: 100%, research fishing: 96%). With the current mean of 13 primarily sampling units completed per day, two additional sampling days should see completion of this year's survey. Ehu, opakapaka, and kalekale constitute the top 3 Deep 7 caught (288, 141, 65 pieces, respectively). Greeneye shark and kahala constitute the primary bycatch species (258 and 103 pieces, respectively).

Table 3. BFISH 2021 percent completion as of October 25, 2021, and species caught.



BFISH_2021_F Survey Completion	
Camera	100%
Fishing	96%
Total	**96%**

Species	Catch
⊟ Deep 7	596
Ehu	288
Opakapaka	141
Kalekale	65
Gindai	52
Onaga	40
Hapu'upu'u	8
Lehi	2

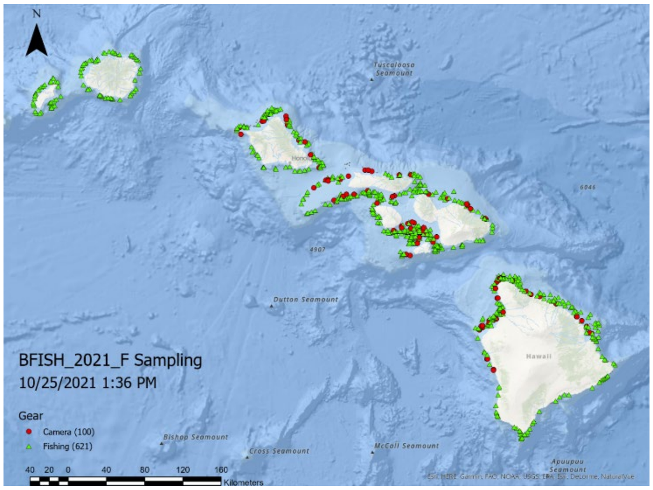


Figure 13: BFISH 2021 sampling map.

5. Publications

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Nichols PK, Timmers M, Marko PB. 2021. Hide 'n seq: Direct versus indirect metabarcoding of coral reef cryptic communities. Environmental DNA. https://doi.org/10.1002/edn3.203

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Technical Memorandums

Rodriguez C, Amir C, Gray A, Asbury M, Suka R, Lamirand M, Couch C, Oliver T. 2021. Extracting coral vital rate estimates at fixed sites using structure-from-motion standard operating procedures. U.S. Dept. of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-120, 90 p. https://doi.org/10.25923/a9se-k649