Testing the Effect of Gear Type on Groundfish Catch

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Fall 2019

Abstract:

The California Collaborative Fisheries Research Program (CCFRP) is a statewide monitoring program designed to evaluate the effectiveness of marine protected areas (MPAs) on local groundfish populations through collaborative fishing trips utilizing the expertise of commercial and recreational anglers. CCFRP incorporates standardized gear within institutions but has some gear variability among institutions across the state. Specifically, Cal Poly San Luis Obispo CCFRP (along with others) does not utilize swimbaits as a sampling gear type, while other CCFRP institutions do utilize swimbaits. This research experiment tested the effectiveness of swimbaits relative to preexisting gear types as a means to quantify differences in catch, by gear type, and to justify whether or not Cal Poly CCFRP should consider incorporating swimbaits into their sampling protocol, thereby increasing gear standardization among CCFRP institutions. Catch data, including catch per angler hour (CPUE), fish length, and species diversity, were collected on four catch-and-release, hook-and-line fishing trips off the central coast of California. Swimbaits had a lower overall CPUE, caught comparably sized fish to other gear types, and did not catch a more diverse suite of species than other gear types. Thus, within the region of study, the swimbait was not a more effective fishing method than preexisting gear types, in regard to CPUE, length, and diversity. Although gear standardization across CCFRP institutions is important to ensure accurate statewide comparisons are made, the incorporation of swimbaits into the Cal Poly CCFRP protocol may not be necessary to the program, as this fishing method does not catch fishes that are not already being targeted and caught by preexisting gear types. CCFRP researchers should consider these results when discussing the potential incorporation of a new gear type, in an effort to balance the benefits of gear standardization with accurately representing fish populations in the California MPA network.

Introduction:

Through the Marine Life Protection Act of 1999 and 2007, a network of 29 MPAs was established in an effort to protect marine biodiversity and provide sanctuaries for marine life, which is relevant to preserve the integrity of marine ecosystems and to sustain recreational, educational, and scientific opportunities in the future (CDFG 2011; Kirlin et al, 2013). Established in 2006, CCFRP is a statewide monitoring program designed to assess the performance of MPAs in California through a collaborative fisheries research model which incorporates fishers, academic scientists, and resource managers. CCFRP field scientists collaborate with local fishing communities to collect fisheries-relevant data to detect and analyze temporal effects of MPAs on nearshore groundfish populations (Yochum et al, 2011). Six California institutions have conducted CCFRP fishing surveys using standardized sampling protocol, allowing researchers to identify spatial differences of marine resources across 14 MPAs and to provide data to state resource managers about the performance of MPAs relative to areas open to fishing (CCFRP website; Yochum et al 2011). It is important that sampling institutions follow consistent sampling protocols to minimize unwanted variation in sampling design and to produce non-objective scientific results that are replicable. Specifically, standardized design and procedure, if properly implemented and maintained, ensure internal consistency among projects studying the same phenomena and yield comparable high-quality results across temporal or spatial settings (Weinberg 2007).

Although general sampling protocol is standardized across sampling institutions, some flexibility in gear type and fishing technique exists between sampling sites (Wendt and Starr, 2009). Because gear type performance and popularity may vary across sampling sites, CCFRP institutions utilize gear types that reflect the common fishing methods used regionally and the fish species they are targeting (Yochum et al. 2011). For example, CCFRP sampling protocol at University of California Santa Barbara, Scripps Institute of Oceanography and Humboldt State University incorporate swimbaits as one of the core gear types used, while Cal Poly San Luis Obispo, Bodega Marine Laboratory and Moss Landing Marine Laboratory do not use swimbaits. This research project specifically discusses the CCFRP sampling protocol at Cal Poly San Luis Obispo, focusing on the effectiveness of swimbaits in the Cal Poly sampling region. Cal Poly does not incorporate swimbaits into sampling protocol as some other institutions do because at the time of CCFRP implementation in 2006, the swimbait was not a commonly-used gear type by central coast groundfishers. Consequently, in collaboration with recreational and commercial anglers, CCFRP researchers designated shrimpflies and lingcod bars as the standard fishing methods for Cal Poly CCFRP sampling protocol.

However, Cal Poly CCFRP technicians and scientists have begun discussing the potential benefit of fishing swimbaits in the Cal Poly sampling region, as there is little to no scientific data assessing the performance of swimbaits relative to other gear types currently being used in the region. As discussed earlier, increasing gear standardization across the sampling institutions is beneficial to minimize variation in sampling design and to more accurately compare data across sampling regions. Although incorporating swimbaits into the Cal Poly sampling protocol would increase gear standardization, it is unknown whether swimbaits would catch different species, sizes, or numbers of groundfish relative to our current suite of standardized gear types. Obtaining this information about the performance of the gear used to catch groundfish by CCFRP will allow the program to make informed decisions about the impact of adding an additional gear type into sampling protocol.

Additionally, a number of volunteer anglers that actively participate on CCFRP surveying trips have increasingly expressed interest about the effectiveness of including swimbaits into the sampling protocol. CCFRP is a collaborative program between scientists and anglers and therefore the program regularly considers angler feedback and opinions. Specifically, through previous CCFRP angler surveys and review platforms, anglers have provided feedback that suggests researchers are missing significant portions of groundfish populations along the central coast by not incorporating swimbaits as a standardized gear type. Incorporating angler feedback and suggestions is integral to the mission statement of CCFRP. Angler knowledge of fishing practices in the adjacent marine community can provide valuable insight into the most successful fishing methods of the region. Thus, it is greatly beneficial to consider suggestions or concerns expressed by volunteer anglers for two prominent reasons: to foster positive collaboration between scientists and anglers and to obtain valuable knowledge of fishing techniques from an inside perspective (Yochum et al 2011).

This project was designed to test the performance of swimbaits against preexisting gear types and to provide information needed to assess the potential significance of incorporating swimbaits into Cal Poly CCFRP sampling protocol. With the provided information, program managers may discuss the trade-offs of incorporating swimbaits, such as whether the additional variability from a newly incorporated gear type is offset by the potential data gaps filled by the new gear type (e.g. larger or more diverse catch). Depending on the relative success of swimbaits in this region, it may benefit the program to include swimbaits in the sampling protocol as this gear type may offer data that is not detected using other gear types, further increasing the breadth of catch data obtained for analysis and supporting overall gear consistency between institutions. However, if swimbaits are not relatively successful and do not offer a substantial amount of original data, it may not be beneficial to increase gear standardization in this way. Researchers may consider whether increasing gear standardization across the state or fishing the most effective gear types specific to each region is more important to the research program.

The primary research question of this project was: How do swimbaits perform relative to jigs and shrimp flies along the central coast? To assess relative swimbait performance, five different metrics were analyzed:

1) The effect of gear type on total catch per unit effort (CPUE)
2) The effect of gear type on CPUE by species
3) The effect of the interaction between gear type and species on CPUE
4) The effect of gear type on fish length (cm)
5) The effect of gear type on species diversity

Ultimately, the testing of swimbaits against preexisting gear types is important to CCFRP for three reasons: 1) to scientifically evaluate the efficiency of gear types used in the sampling region, 2) to identify a potential method of augmenting existing data and expanding the breadth of the database, and 3) to fulfill CCFRP's mission in providing accurate MPA data through the utilization of angler feedback in the design and continued application of CCFRP surveys. This study will provide CCFRP researchers with critical information for determining effective sampling methods that accurately represent local groundfish populations, while actively supporting CCFRP's focus on angler feedback and communication.

Methods:

Data Collection

Sampling area

All fishing surveys were conducted within the Point Buchon State Marine Reserve (SMR), which is located south of Morro Bay and north of Port San Luis in San Luis Obispo County, California (Figure 1). Within the Point Buchon SMR are 11 500m x 500m grid cells, which encompass relatively shallow (<40m) rocky habitats suitable for rockfish populations. For each fishing survey, four of the designated MPA cells were randomly selected and sampled. The research vessel, Cal Poly's *T.L. Richards*, was launched from the Morro Bay public boat launch for all fishing trips. All sampling in the Point Buchon SMR was approved by the California Department of Fish and Wildlife (CDFW) via a CDFW scientific collecting permit (#6681).

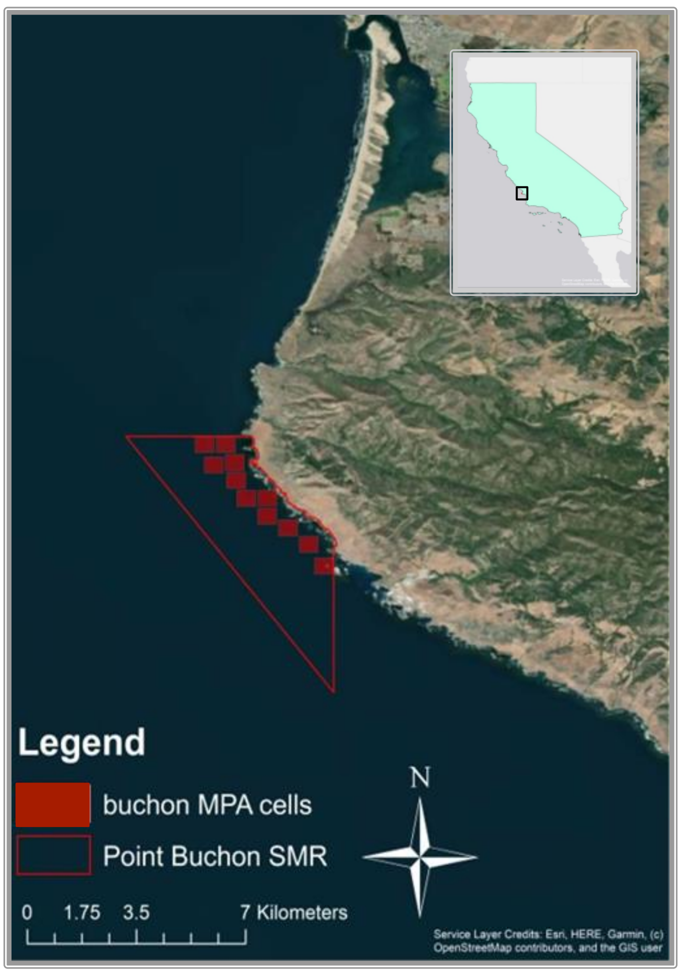

Figure 1. **Location of sampling area**, showing 11 MPA cells within the Point Buchon SMR, located south of Morro Bay in San Luis Obispo, California.

Field methods

Research methods adopted for this field experiment closely paralleled traditional CCFRP sampling protocol, described in detail in Yochum et al 2011. Briefly, volunteer anglers and research scientists collaborated to collect groundfish catch and location data via standardized hook-and-line, catch-and-release fishing trips. On each trip, we sampled four randomly-selected cells for three 15-minute intervals, called fishing drifts. Thus, each trip was ideally comprised of 12 fishing drifts and three hours of active fishing time. These methods are consistent with traditional Cal Poly CCFRP sampling protocol.

However, relative to traditional CCFRP fishing surveys, this research project operated on a smaller-scale, designed to answer concentrated research questions about relative gear type performance in the defined sampling region. Sampling protocol deviated from CCFRP protocol on four basic fronts, described below:

1) The swimbait was used as an additional fishing method in the sampling protocol of this project. On traditional CCFRP sampling trips conducted by Cal Poly researchers, only three gear types were used: shrimpfly with one-pound lead weight, shrimpfly with a squid baited hook and one-pound lead weight, and lingcod bars between four and eight ounces. As the primary goal of this project was to test the effectiveness of swimbaits relative to preexisting gear types, the swimbait was used and evaluated as a fourth gear type. Gear selection for swimbait was based primarily on angler feedback collected from previous CCFRP sampling trips. Big Hammer™ swimbaits between five and six inches were used along with lead heads between two and four ounces. A variety of swimbait and lead head color combinations were provided.

2) All fishing surveys were conducted within the Point Buchon SMR. Traditional CCFRP sampling trips were conducted inside and outside of MPAs, as a prominent project goal of CCFRP is to study MPA effects on fish populations. Additionally, CCFRP sampled MPAs and reference sites at multiple locations throughout California, allowing researchers to analyze regional differences in

fish populations. In contrast, this research project sampled inside a designated MPA in a specific region along the coast for the entirety of the study.

3) All fishing surveys were conducted on the Cal Poly research vessel, *T.L. Richards*, a 26 foot Radon. Traditional CCFRP trips utilized numerous commercial passenger fishing vessels (CPFVs) owned and operated by local commercial fishing companies. CPFVs typically used by CCFRP are much larger (about 50-60 feet) than the 26 foot Radon used in this project. However, in accordance with CCFRP protocol, a licensed commercial fishing captain was hired and present on all fishing surveys, as it was important to include personnel with extensive knowledge about local fish populations and fishing practices specific to the region in order to locate fish aggregations and fish efficiently.

4) Only four volunteer anglers were utilized per fishing trip. Four different gear types were used, allowing each angler to fish a different gear type. On each sampling trip, the anglers rotated gear type station every cell to ensure that all anglers fished all gear types. All anglers had roughly equivalent fishing experience and familiarity with CCFRP protocol. Although we tried to utilize the same anglers throughout the study to minimize variability in angler experience, we did have to pull in four "substitute" volunteer anglers due to scheduling conflicts. In these cases, we still aimed to include anglers with similar fishing experience and familiarity with CCFRP protocol. This sampling method differs slightly from traditional CCFRP protocol, as many volunteer anglers, potentially with varying levels of fishing experience, were utilized on traditional CCFRP fishing trips. On traditional Cal Poly CCFRP fishing trips, multiple volunteer anglers were assigned to fish each gear type, resulting in a maximum of 12 anglers per trip. Thus, this project involved fewer volunteer anglers than a traditional CCFRP trip.

Briefly, the fishing surveys conducted in this research project were truncated versions of traditional CCFRP fishing trips and included the swimbait gear type as an additional fishing method.

Data collected

Location and catch data collected in this study followed traditional CCFRP data collection protocol. Data types particularly important to this study included: fish species, fish length (measured to the nearest whole centimeter), gear type used, cell fished, fishing drift number, trip date, and time spent actively fishing per drift.

Data Analysis

Catch per unit effort

Catch per unit effort (CPUE) was determined by calculating the number of fishes caught per drift and dividing the number of fishes caught by the average number of hours spent fishing per angler from that drift. Each CPUE value represents catch per angler hour from a single fishing drift, thus the unit of replication is fishing drift.

Total CPUE

CPUE was calculated per drift for all species combined. CPUE was log transformed ($\log CPUE + 1$) to satisfy the assumptions of normality and equality of variance. The effect of gear type on total CPUE was assessed using an analysis of variance, generalized linear model (ANOVA, GLM) where: $\log CPUE = gear\ type + Trip\ Cell\ ID$. Variation in CPUE due to trip or cell variation was accounted for by including *Trip Cell ID* as a random effect into the model. When statistically significant differences were detected using the GLM, Tukey HSD post hoc tests were conducted to analyze differences between gear types.

CPUE per species

We determined the top five most commonly caught species, which represented over 95% of the total fish caught by all gear types. CPUE was calculated per drift per species. For each of these five species, we individually tested the effect of gear type on CPUE using a zero-inflated Poisson GLM where: $CPUE = gear\ type + Trip\ Cell\ ID$. We used a zero-inflated Poisson regression model because the data had an excess of zero counts, a result of analyzing the data by species. Variation in CPUE due to trip or cell variation was accounted for by including *Trip Cell ID* as a random effect into the model. When statistically significant differences were detected using the GLM, Tukey HSD post hoc tests were conducted to analyze differences between gear types.

CPUE predicted by the species-gear type interaction

In Starr et al. 2015, researchers used a mixed-model repeated measures ANOVA to analyze fish length and BPUE as a result of the species-area combination. Analogously, in this study, we analyzed CPUE as predicted by the species/gear type combination using a mixed-model repeated measures ANOVA (specifically a zero-inflated Poisson GLM with an interaction) where: $CPUE = species + gear\ type + species * gear\ type + Trip\ Cell\ ID$. Variation in CPUE due to trip or cell variation was accounted for by including *Trip Cell ID* as a random effect into the model. When statistically significant differences were detected using the GLM, Tukey HSD post hoc tests were conducted to analyze differences between species-gear type combinations. This analysis was conducted for the top five fish species that represented over 95% of total catch.

Fish Length

Length analyses were conducted on the top five most frequently caught fish species. The effect of gear type on fish length was assessed individually for each species using a GLM where: $Length = gear\ type + Trip\ Cell\ ID$. Variation in CPUE due to trip or cell variation was accounted for by including *Trip Cell ID* as a random effect into the model. When statistically significant differences were detected using the GLM, Tukey HSD post hoc tests were conducted to analyze differences between gear types.

Species Diversity

The species diversity for each gear type was analyzed using the Simpson's Diversity Index which takes into account the number of species caught (species count) and the amount of fish caught within each species (species evenness) to determine the probability that two fish randomly caught from a population will be from different species, thereby measuring how diverse a suite of fishes is. A higher Simpson's index indicates a more diverse suite of fishes. The equation used to calculate the Simpson's Diversity Index is defined below:

$$D = 1 - \sum (\frac{n_i}{N})^2$$

Where D is the Simpson's diversity index, n_i is the number of individuals from species i, and N is the total sample size.

Diversity indices were calculated for each gear type and trip, where trip (*Trip ID*) was the unit of replication. The effect of gear type on Simpson's diversity index was assessed using an ANOVA where: $D = gear\ type + Trip\ ID$. Variation in CPUE due to trip variation was accounted for by including *Trip ID* as a random effect into the model. There were two outliers that were excluded from the analysis. Justification for these trip/gear type exclusions is the variation caused by trip: for baited shrimpflies and bare shrimpflies, one trip was dominated by one or a few species and resulted in an unusually low species diversity for catch by these gear types. This suggests that species diversity was heavily affected by trip variation, confounding the effect gear type on species diversity. Thus, baited shrimpfly and bare shrimpfly diversity indices from one trip were excluded from the analysis, decreasing the level of trip replication for these two gear types from four to three trips.

Results:

We conducted four hook-and-line fishing trips in the Point Buchon MPA. With the help of eight different volunteer anglers, we caught and released a total of 661 fishes from 17 different fish species. Of the 17 species, five species represented over 95% of the total catch for all fishing gear types used (Table 1).

Table 1. **Species percent composition of fish caught using each gear type**. For each gear type, five species make up over 95% of total catch: Gopher Rockfish, Blue Rockfish, Olive Rockfish, Vermilion Rockfish, and Lingcod.

Species	Common Name	*Gear Type*			
		Baited Shrimpfly (%)	**Bare Shrimpfly (%)**	**Lingcod Bar (%)**	**Swimbait (%)**
Sebastes carnatus	Gopher Rockfish	49.6	29.8	36.5	33.3
Sebastes mystinus	Blue Rockfish	27.8	42.1	30.8	12.2
Sebastes serranoides	Olive Rockfish	6.4	16.9	17.6	2.2
Sebastes miniatus	Vermilion Rockfish	7.3	7.9	7.5	33.3
Ophiodon elongatus	Lingcod	3.4	0.6	4.4	12.2
Sebastes caurinus	Copper Rockfish	1.3	0.6	1.9	1.1
Sebastes melanops	Black Rockfish	-	0.6	0.6	-
Sebastes atrovirens	Kelp Rockfish	-	-	0.6	1.1
Sebastes auriculatus	Brown Rockfish	0.4	-	-	1.1
Scorpaenichthys marmoratus	Cabezon	-	-	-	1.1
Sebastes pinniger	Canary Rockfish	0.4	0.6	-	-
Sebastes nebulosus	China Rockfish	0.4	0.6	-	1.1
Caulolatilus princeps	Ocean Whitefish	0.4	-	-	-
Sebastes rosaceus	Rosy Rockfish	1.3	-	-	-
Sebastes constellatus	Starry Rockfish	0.9	-	-	1.1
Sebastes serriceps	Treefish	0.4	-	-	-
Sebastes flavidus	Yellowtail Rockfish	-	0.6	-	-
Total		**100.0**	**100.0**	**100.0**	**100.0**

Total CPUE

There were significant differences in mean log-transformed CPUE across gear types (Table 2). Specifically, log-transformed CPUE using baited shrimpflies was significantly higher than that of other gear types (Figure 2). Log-transformed CPUE using lingcod bars was significantly lower than that of baited shrimpflies, similar to that of bare shrimpflies, and significantly higher than that of swimbait. Log-transformed CPUE using bare shrimpflies was significantly lower than that of baited shrimpflies, similar to that of lingcod bars and swimbaits. Log-transformed CPUE using swimbaits was lower than that of baited shrimpflies and lingcod bars, and similar to that of bare shrimpflies.

Table 2. **ANOVA effect output**, indicating gear type had a statistically significant effect on mean log-transformed CPUE.

Source	Nparm	DF	DFDen	F Ratio	Prob > F
Gear Type	3	3	185.1	11.0309	<.0001*

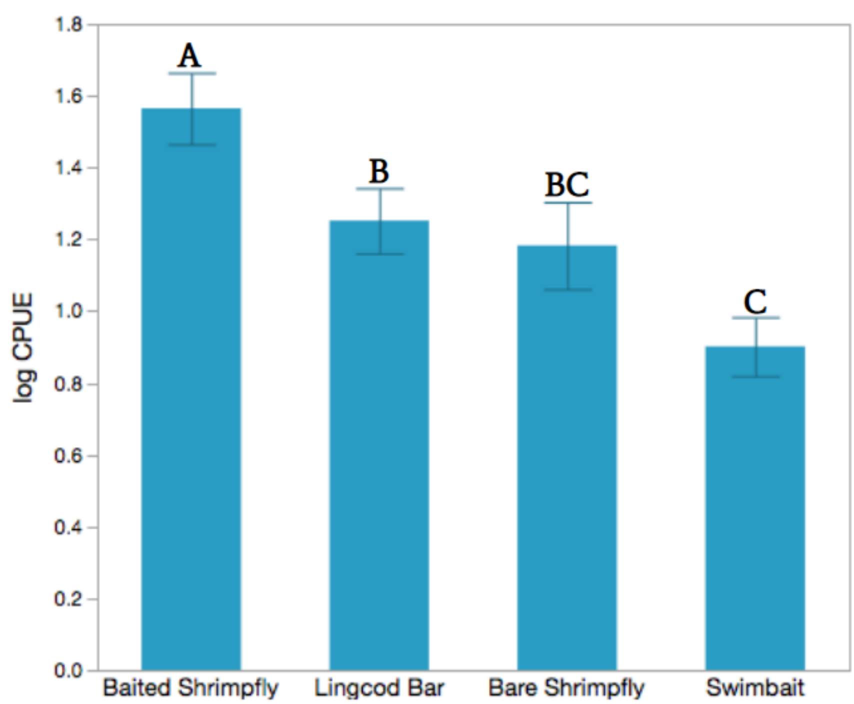

Figure 2. **Effect of gear type on mean log-transformed CPUE for all fishes caught.** Error bars represent ± 1 SE of the mean; n= 51 fishing drifts. Letters above gear type columns represent connecting letters from Tukey HSD pairwise comparisons. Means not connected by the same letter are significantly different (p>0.05, 137 df).

CPUE per Species

There were significant differences in mean CPUE for Blue Rockfish (*Sebastes mystinus*) across gear types (Table 3). Specifically, Blue rockfish mean CPUE using baited shrimpflies, bare shrimpflies and lingcod bars was significantly higher than that of swimbaits (Table 4, Figure 3).

There were significant differences in mean CPUE for Gopher Rockfish (*Sebastes carnatus*) across gear types (Table 3). Gopher rockfish mean CPUE using baited shrimpflies was significantly higher than that of all other gear types. Gopher rockfish mean CPUE using lingcod bars and bare shrimpflies was significantly lower than that of baited shrimpflies, and significantly higher than that of swimbaits. Gopher rockfish mean CPUE using swimbaits was significantly lower than that of all other gear types (Table 4, Figure 3).

There were no significant differences in mean CPUE for Vermilion Rockfish (*Sebastes miniatus*) across gear types (Table 3).

There were significant differences in mean CPUE for Olive Rockfish (*Sebastes serranoides*) across gear types (Table 3). Olive rockfish mean CPUE using swimbaits was significantly lower than that of all other gear types (Table 4, Figure 3).

There were no significant differences in mean CPUE for Lingcod (*Ophiodon elongatus*) across gear types (Table 3).

Table 3. **Zero-inflated Poisson and effects output,** indicating that gear type had a statistically significant effect on mean CPUE for Blue Rockfish, Gopher Rockfish and Olive Rockfish.

Blue Rockfish	**ZI Poisson Distribution Parameter**	**Estimate**	**Std Error**	**Wald ChiSquare**	**Prob > ChiSquare**	**Lower 95%**	**Upper 95%**
	Zero Inflation	0.48384	0.05704	71.953407	<.0001	0.3720475	0.5956402
	Source	**Nparm**	**DF**	**Wald ChiSquare**	**Prob > ChiSquare**		
	TripCellID	15	15	100.3506	<.0001		
	GEAR TYPE	3	3	21.486022	<.0001		
Gopher Rockfish	**ZI Poisson Distribution Parameter**	**Estimate**	**Std Error**	**Wald ChiSquare**	**Prob > ChiSquare**	**Lower 95%**	**Upper 95%**
	Zero Inflation	0	0	0	1	0	0
	Source	**Nparm**	**DF**	**Wald ChiSquare**	**Prob > ChiSquare**		
	GEAR TYPE	3	3	56.911167	<.0001		
	TripCellID	15	15	49.582803	<.0001		
Olive Rockfish	**ZI Poisson Distribution Parameter**	**Estimate**	**Std Error**	**Wald ChiSquare**	**Prob > ChiSquare**	**Lower 95%**	**Upper 95%**
	Zero Inflation	0.44978	0.0895076	25.250564	<.0001	0.2743436	0.6252071
	Source	**Nparm**	**DF**	**Wald ChiSquare**	**Prob > ChiSquare**		
	GEAR TYPE	3	3	14.226319	0.0026		
	TripCellID	15	15	29.999623	0.0119		
Vermilion Rockfish	**ZI Poisson Distribution Parameter**	**Estimate**	**Std Error**	**Wald ChiSquare**	**Prob > ChiSquare**	**Lower 95%**	**Upper 95%**
	Zero Inflation	0.46385	0.0679081	46.655589	<.0001	0.330748	0.5969427
	Source	**Nparm**	**DF**	**Wald ChiSquare**	**Prob > ChiSquare**		
	TripCellID	15	15	23.715025	0.0701		
	GEAR TYPE	3	3	6.6124496	0.0853		
Lingcod	**ZI Poisson Distribution Parameter**	**Estimate**	**Std Error**	**Wald ChiSquare**	**Prob > ChiSquare**	**Lower 95%**	**Upper 95%**
	Zero Inflation	0	0	0	1	0	0
	Source	**Nparm**	**DF**	**Wald ChiSquare**	**Prob > ChiSquare**		
	TripCellID	15	15	3.70E+16	<.0001		
	GEAR TYPE	3	3	6.3222141	0.0969		

Table 4. **Effect of gear type on mean CPUE by species.** Pairwise Comparisons of least squares mean CPUE by gear type for five independent Zero-inflated Poisson analyses by fish species. Levels not connected by the same letter are significantly different (Tukey HSD, p<0.05, 200 df).

Species	Gear Type				Least Squares Mean	Std Error	DF	Lower 95%	Upper 95%
Blue Rockfish	Baited Shrimpfly	A			1.3153405	0.116229	200	1.08615	1.5445313
	Bare Shrimpfly	A			1.3119903	0.116449	200	1.082365	1.5416158
	Lingcod bar	A	B		0.9613025	0.155445	200	0.65478	1.2678248
	Swimbait		B		0.1349127	0.409522	200	-0.672621	0.9424467
Gopher Rockfish	Baited Shrimpfly	A			0.9501217	0.099043	200	0.7548186	1.1454249
	Lingcod bar		B		0.2988166	0.149676	200	0.0036716	0.5939615
	Bare Shrimpfly		B	C	0.2524164	0.153455	200	-0.0501802	0.5550129
	Swimbait			C	-0.3607686	0.202033	200	-0.7591567	0.0376194
Olive Rockfish	Bare Shrimpfly	A			0.587037	0.204604	200	0.183579	0.9904941
	Lingcod bar	A			0.292179	0.230254	200	-0.161858	0.7462162
	Baited Shrimpfly	A			-0.021089	0.344175	200	-0.699766	0.6575878
	Swimbait		B		-1.874815	0.650198	200	-3.156937	-0.592692
Vermilion Rockfish	Swimbait	A			0.0382441	0.248495	200	-0.451763	0.528251
	Baited Shrimpfly	A			-0.5105977	0.336484	200	-1.174109	0.1529139
	Bare Shrimpfly	A			-0.7093317	0.334145	200	-1.368231	-0.0504322
	Lingcod bar	A			-0.8668396	0.359282	200	-1.575306	-0.158373
Lingcod	Swimbait	A			-1.332877	0.627383	200	-2.570011	-0.095744
	Baited Shrimpfly	A			-1.758546	0.669585	200	-3.078897	-0.438194
	Lingcod bar	A			-1.81944	0.6706	200	-3.141793	-0.497087
	Bare Shrimpfly	A			-3.836767	1.148172	200	-6.100844	-1.57269

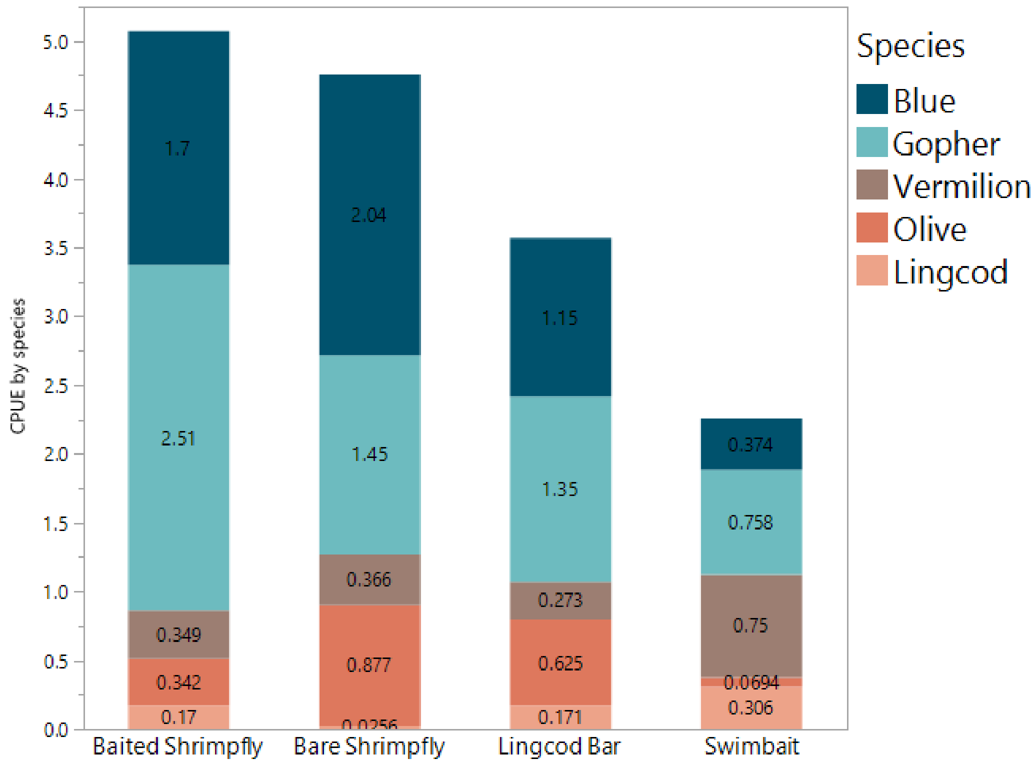

Figure 3. **Effect of gear type on mean CPUE by species**, including five species representing over 95% of total catch. Each color represents a different species, indicated by the species legend on right. N=51 fishing drifts.

CPUE predicted by the species-gear type interaction

There were significant differences in mean CPUE by species across species/gear type interactions (Table 5). Specifically, species-specific mean CPUEs for Gopher Rockfish using baited shrimpflies, lingcod bars and bare shrimpflies were significantly higher than that of swimbaits. Species-specific mean CPUEs for Blue Rockfish using bare shrimpflies, baited shrimpflies and lingcod bars were significantly higher than that of swimbaits. Species-specific mean CPUEs for Olive Rockfish using lingcod bars and bare shrimpflies were significantly higher than that of baited shrimpflies and swimbaits. Species-specific mean CPUEs for Vermilion Rockfish were not significantly different across all gear types. Species-specific mean CPUEs for Lingcod were not significantly different across all gear types (Table 6).

Table 5. **Zero-inflated Poisson and effects output**, indicating the species/gear type interaction had a statistically significant effect on mean CPUE.

ZI Poisson Distribution Parameters	Estimate	Std Error	Wald ChiSquare	Prob > ChiSquare	Lower 95%	Upper 95%
Zero Inflation	0.34712	0.0347978	99.509564	<.0001	0.2789216	0.4153267
Source	**Nparm**	**DF**	**Wald ChiSquare**	**Prob > ChiSquare**		
TripCellID	15	15	128.97019	<.0001		
species*gear type	12	12	67.150934	<.0001		
species	4	4	20.882263	0.0003		
gear type	3	3	7.5889925	0.0553		

Table 6. **Effect of species-gear type interaction on CPUE.** Pairwise comparisons of least squares mean CPUE by species/gear type interaction, including data from five fish species, representing over 95% of total catch. Means not connected by the same letter are significantly different (Tukey HSD, p<0.05, 985 df).

Species (Mean CPUE)	Gear Type							LS Mean
Gopher	Baited Shrimpfly	A						0.837372
Blue	Baited Shrimpfly	A						0.799002
Blue	Bare Shrimpfly	A	B					0.763221
Blue	Lingcod bar	A	B	C				0.324904
Gopher	Lingcod bar	A	B	C				0.285958
Gopher	Bare Shrimpfly	A	B	C				0.283013
Olive	Bare Shrimpfly			C	D			-0.077310
Gopher	Swimbait		B	C	D	E		-0.111476
Olive	Lingcod bar			C	D	E		-0.214202
Vermilion	Swimbait			C	D	E	F	-0.332596
Olive	Baited Shrimpfly			C	D	E	F	-0.743999
Vermilion	Baited Shrimpfly				D	E	F	-0.846815
Blue	Swimbait				D	E	F	-0.896815
Vermilion	Bare Shrimpfly				D	E	F	-1.054237
Lingcod	Swimbait				D	E	F	-1.092650
Vermilion	Lingcod bar				D	E	F	-1.181711
Lingcod	Baited Shrimpfly				D	E	F	-1.557821
Lingcod	Lingcod bar					E	F	-1.611692
Olive	Swimbait						F	-2.591930
Lingcod	Bare Shrimpfly					E	F	-3.447200

Fish Length

For each of the five species individually tested (Blue Rockfish, Gopher Rockfish, Olive Rockfish, Vermilion Rockfish and Lingcod), there were no significant differences in mean length by gear type (Table 7; Figure 4).

Table 7. **ANOVA effect output**, indicating that gear type did not have a statistically significant effect on mean fish length for five species individually tested.

Species	Source	Nparm	DF	DFDen	F Ratio	Prob > F
Blue Rockfish	GEAR TYPE	3	3	185.1	2.3115	0.0776
Gopher Rockfish	GEAR TYPE	3	3	251.4	0.1277	0.9436
Olive Rockfish	GEAR TYPE	3	3	68.49	2.034	0.1172
Vermilion Rockfish	GEAR TYPE	3	3	60.2	0.6201	0.6047
Lingcod	GEAR TYPE	3	3	21.15	0.7465	0.5364

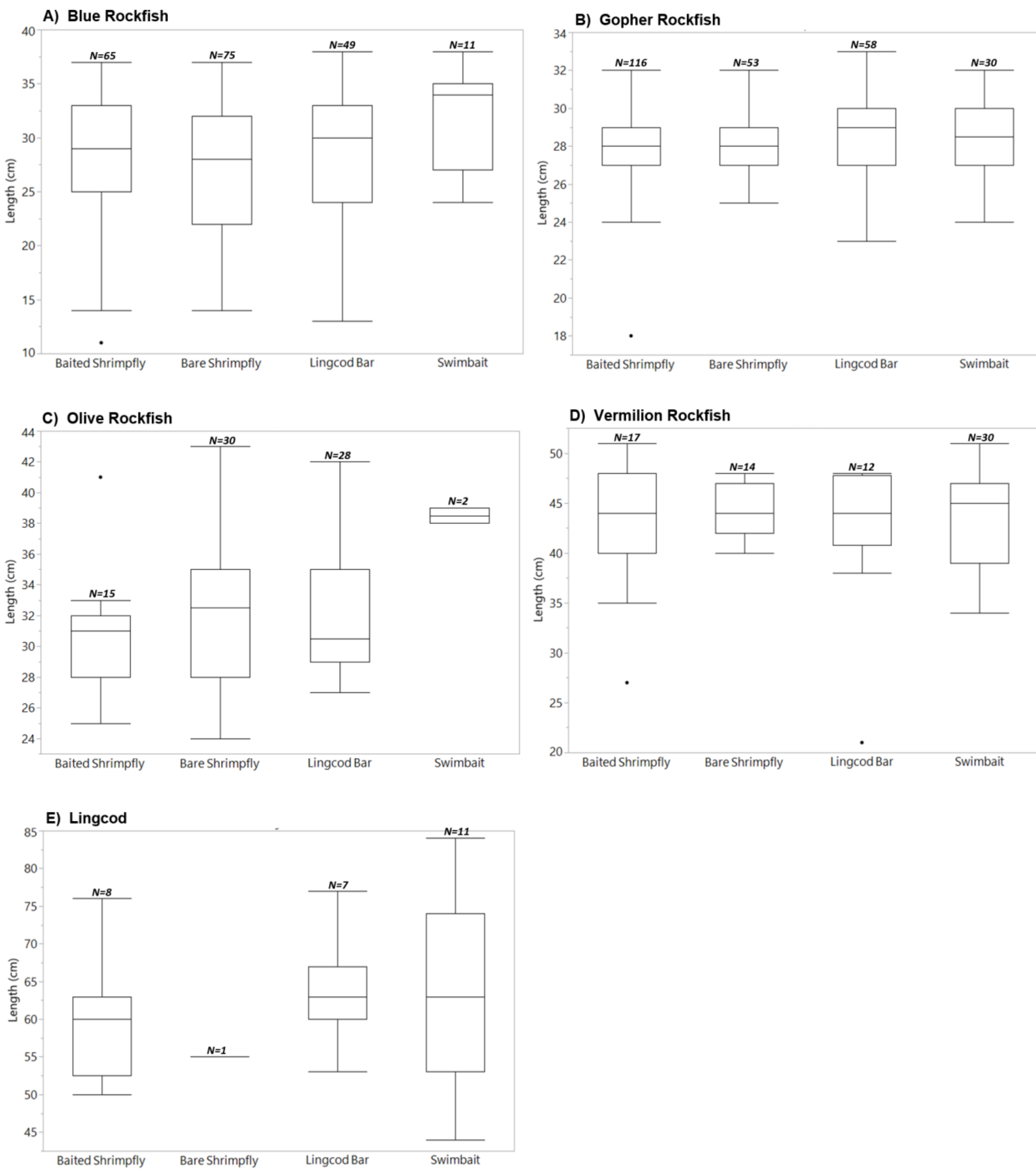

Figure 4. **Effect of gear type on mean fish length (cm) for five species tested**: A) Blue rockfish, B) Gopher Rockfish, C) Olive Rockfish, D) Vermilion Rockfish and E) Lingcod. Dots outside the whiskers of boxplots represent outliers which are data points that lie >1.5 times above or below the interquartile range (Q1-1.5*IQR or Q3+1.5*IQR). For each individual species, sample size per geartype is shown above each gear type box. For all fish species, there were no statistical differences detected across gear types (Table 7).

Species Diversity

There were no significant differences in mean Simpson's Diversity Index by gear type (Table 8; Figure 5).

Table 8**. ANOVA effect output**, showing that gear type did not have a statistically significant effect on Simpson's Diversity Index.

Source	Nparm	DF	DFDen	F Ratio	Prob > F
Gear Type	3	3	11	1.9994	0.1726

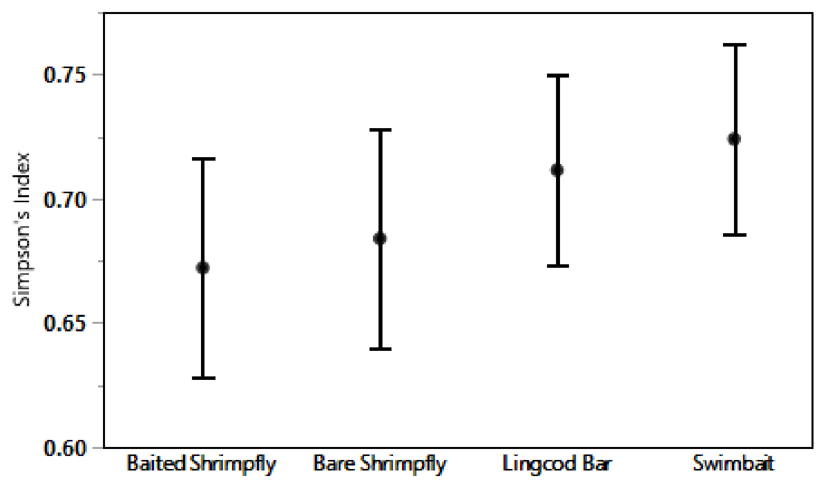

Figure 5**. Effect of gear type on least squares mean Simpson's Diversity Index.** Error bars represent one standard error of the mean. Sample sizes excluding two outliers: Baited Shrimpfly: n=3, Bare Shrimpfly: n=3, Lingcod Bar: n=4, Swimbait: n=4. No statistical differences were detected between the gear types (Table 8).

Discussion:

Relative to preexisting gear types used by Cal Poly CCFRP, swimbaits had a lower overall CPUE and a lower species-specific CPUE for Blue Rockfish, Gopher Rockfish and Olive Rockfish. Swimbaits were observed to have the highest species-specific CPUE for Vermilion Rockfish and Lingcod. However, these results were not statistically significant from the other gear types so we cannot conclude that swimbaits actually yield a higher CPUE for Vermilion Rockfish or Lingcod.

The three preexisting gear types yielded similar CPUE across species, while swimbaits yielded lower CPUEs for certain species. Specifically, swimbaits yielded high CPUE for Vermilion Rockfish and Lingcod, which is similar to that using other gear types, and had lower CPUE for Blue Rockfish, Gopher Rockfish and Olive Rockfish, relative to CPUE by other gear types. Thus, catch using swimbaits does not represent the entire groundfish population as well as preexisting gear types do, as swimbaits may be more selective for Vermilion Rockfish and Lingcod than for other fish species. Because CCFRP is designed to sample the entire nearshore groundfish population in order to provide an accurate representation of marine resources, gear types that have high species-specific CPUE values for the greatest number of species (target the most fish species) are the most useful and important for CCFRP data collection.

Swimbaits caught comparably sized fish (within species) as preexisting gear types. However, fish length was observed to be greatest for fishes caught using swimbaits for 80% of fish species tested. Specifically, there was a trend of increased mean fish length using swimbaits for Blue Rockfish, Gopher Rockfish, Olive Rockfish, and Lingcod. However, these results were not statistically significant, so we cannot confidently conclude that swimbaits catch longer fish (within species) than other gear types. Further studies with a larger sample size may detect statistically significant differences in mean lengths for these species.

Swimbaits did not catch a more diverse suite of fish species than preexisting gear types. Although catch using swimbaits yielded the highest observed mean Simpson's diversity index, differences were not statistically significant. Thus, no one gear type caught a more diverse suite of fish species than another gear type.

Ultimately, these data suggest that catch using swimbaits was already accounted for in catch using preexisting gear types. This conclusion is supported by four predominant findings of this project:

1) Swimbaits yielded lower overall CPUE values and lower species-specific CPUEs for 60% of the species tested.
2) Swimbaits did not represent the entire groundfish population as well as preexisting gear types did, as swimbait CPUE was lower for certain species than that from the preexisting gear types, which had relatively similar CPUE across species.
3) Swimbaits did not catch longer (or smaller) fishes, within species, than other gear types did.
4) Swimbaits did not catch a greater diversity of fish species than other gear types did.

It is important to note the limited sample size of this study, which may have affected the statistical power of the study to detect differences among gear types. Further studies with larger sample size and/or longer sampling period may be able to detect significant differences, supporting the trends found here. Thus, follow-up studies should be conducted in order to further explore relative swimbait performance. Additionally, these conclusions are region-specific and should not be extended to assess swimbait performance in other regions.

In addition to these results, we've generated a few inferences regarding swimbaits and their utilization in the field that may also be important to consider before including swimbaits as a standard CCFRP gear type. These considerations are hypotheses that we've generated after using the gear types side-by-side in the field; none of these points have been statistically examined.

First, swimbaits may not be as durable as other gear types. The soft plastic material of the swimbaits gets chewed up by the fish and damaged fairly quickly, depending on the frequency and behavior of fish biting. Specifically, in this study, we went through an average of six swimbaits per trip, which is 1-2 per person per cell. This is more than the amount of tackle lost or damaged using other gear types. Although it was not determined if the difference in tackle lost between swimbaits and other gear types was statistically significant, swimbait durability is definitely something to consider as it could affect the costs of sampling trips and time spent re-rigging. Formal studies comparing the durability between gear types may be insightful.

Next, utilizing swimbaits may require increased angler skill and fishing experience. Familiarity and experience fishing with swimbaits is necessary to use the gear type properly, as it can affect how well the swimbait performs in the water and subsequently the amount and quality of fish caught using the gear type. Particularly in this study, we were cautious to choose anglers with similar angling ability and sufficient experience using swimbaits, so theoretically, angler experience with swimbaits should not be a factor in this study. However, if swimbaits were to be included into Cal Poly CCFRP sampling protocol, it would be very important to have anglers on board the vessel that have sufficient experience fishing with swimbaits, which may be difficult to judge. Ultimately, CCFRP researchers must be extra cognizant of angler ability when considering the inclusion of swimbaits into sampling protocol.

Finally, swimbaits may be more sensitive to diverse oceanic conditions. For example, swimbaits sink slower and are more affected by ocean currents or boat drift than other gear types may be. To account for the sensitive and tricky nature of swimbaits, anglers may use heavier lead head weight and/or smaller swimbaits. Thus, a wide tackle variety with an array of lead head weights and swimbait sizes may be necessary so that in the event ocean conditions change and a certain swimbait/lead head combination is preferred, the appropriate tackle is available for the angler to switch over to and utilize. However, as discussed previously, angler experience and rod and reel type also affect swimbait performance. For example, a highly experienced angler with a higher-performance rod and reel may be able to effectively fish a lighter swimbait setup in rough oceanic conditions. The effect of angler experience verses specific tackle setup on swimbait performance may be an area for discussion, but it is assumed that both factors affect how well a swimbait "swims" in the water. Nevertheless, in this study, we did find it necessary to increase the amount of tackle variety available to anglers, as heavier lead head weights were requested by the anglers as the study progressed. This is something to consider before including swimbaits into sampling protocol as the amount and variety of tackle may be more extensive than that needed for other gear types, and thus more costly.

CCFRP researchers should consider these statistical results and anecdotal considerations when discussing the potential incorporation of a new gear type, in an effort to balance the benefits of gear standardization with efficient fishing practices that accurately represent the region's fish populations.

Conclusion:

Although gear standardization across CCFRP institutions is important to ensure accurate statewide comparisons are made, the incorporation of swimbaits into the Cal Poly CCFRP protocol may not be necessary to the program, as this fishing method does not catch fishes that are not already being targeted and caught by preexisting gear types. This study provides CCFRP researchers with novel information about the performance of various gear types commonly used in the region of study, which is necessary to determine the most effective and accurate methods of sampling local groundfish populations. Additionally, the design and implementation of this study was greatly influenced by angler feedback and support. This is a fundamental and valued component of CCFRP which allows the program to provide robust scientific data based on collaborative angler participation and expertise in order to effectively monitor the nearshore groundfish populations in California.

Acknowledgements:

This research project was funded by the FROST Undergraduate Research Fund, CSU Council on Ocean Affairs, Science & Technology (COAST) Scholarship Fund, and funding from the Dean E Wendt Laboratory at Cal Poly. We also send our sincere appreciation to the following individuals and groups: Ellie Brauer, Rob Brewster, Noel Clark, Jenny Cruz, Jason Felton, Meghan Fox, Captain John Gavin with Patriot Sportfishing, Ed Gomez, Duane Goudy, Erin Johnston, Jerry's Marine and Tackle, Bill McKinney, Tom Moylan, Callie Perdue, Ian Robbins, Dr. Ben Ruttenberg, John Schumann, Dr. Jeffrey Sklar, Nick Soares, Nahla Sturm-Wang, Dr. Heather Smith, Virg's Landing, Dr. John Walker, Jim Webb, Lauren Zaragoza, and many others who have offered their time and effort in support of this research project.

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