Bait comparison pilot study

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Abstract

A pilot study comparing the IPHC standard survey bait of chum salmon with three alternative bait species was conducted in regions in Area 3A. A major goal of this pilot study was to provide information on variability of catch rates for use in designing a large scale experiment to be carried out in 2012. Secondly, the results allow us to select one of two competing designs. The former is not part of this report, but for the latter, a design in which skates of each bait type are set together is preferred over one in which sets are composed of skates using a single bait type. Analysis of data from this study provided evidence the setline WPUE was different among baits, that U32 catch is affected by bait type, and that catch of common species of bycatch was higher using chum salmon than the alternative baits. There is some concern that some bait types are more likely to fall off the hook, and improvements to bait preparation and baiting technique should be sought for these baits.

Introduction

Currently the International Pacific Halibut Commission (IPHC) uses chum salmon (*Oncorhynchus keta*) as bait for its annual setline survey. The IPHC's minimum quality requirement is #2 semi-bright, Alaska Seafood Marketing Institute (ASMI) grade A through E, H&G (headed and gutted), IQF (individually quick frozen) chum with "meat-colored" flesh. With the price of chum increasing and availability decreasing, we wish to consider alternative baits. Before replacing the current bait, it is important that we compare it with possible alternatives to ensure that the survey index will not be affected by the change, or to estimate a correction factor to apply if there is an effect on the index. In 2011, a small-scale pilot study was undertaken in two setline survey regions with the primary goal of estimating variability among catches in order to determine required sample sizes for a larger-scale bait comparison experiment. Of particular interest are any differences among bait types in weight per unit effort (WPUE) of O32 halibut (those with fork length greater than or equal to 32 inches), as this measure is used to index exploitable halibut biomass. In this report, we outline the pilot study design and present statistical analyses of the data. The use of these data in developing the larger experiment in 2012 will be discussed in a subsequent report on that experiment.

Methods

Experimental design

This pilot study compared four baits using two different designs in two areas. The baits were chum salmon, pink salmon (*Oncorhynchus gorbuscha*), pollock (*Theragra chalcogramma*), and herring (*Clupea harengus*). Two designs were each implemented in two setline survey regions: Fairweather, in eastern Area 3A (Fige 1), an area with high dogfish catch, and Albatross, in western Area 3A (Fige 2). Skippers were provided with maps showing survey WPUE in recent years to help guide where they fished, and were directed to avoid areas of low halibut density. They were otherwise were given wide discretion in their choice of fishing locations. Originally, the Trinity region to the west of Albatross was to be used, but low setline survey catches in that region this year led to the shift eastward out of concern that halibut densities would be too low to allow useful comparisons.

The first design (Design 1) was a randomised block design, with all four baits in a random order on a single set. In this design, sets of seven skates were used as experimental blocks, with each set having one baited skate of each bait type alternating with and so separated by empty skates. Designs were based on two Latin squares with balanced neighbour occurrences, i.e., skates of each bait type were adjacent (not counting empty skates) to skates of each of the other bait types the same number of times. Designs were originally devised with numeric treatment labels (1, 2, 3, 4) and baits were randomly assigned a label. The order of the two squares (day 1 or day 2) was randomised, as was the order of the four sets within each square (day).

Depending on the current in which the gear is set, it is possible for the bait plume of each baited skate to flow across adjacent skates. By having the intermediate unbaited skates, we hoped to reduce interactions among the different baits. The possibility of such interactions (for example, a more attractive bait drawing in fish and leading to higher catches on a nearby less attractive bait) was the principle concern we had with this design. Its big potential advantage is that arranging all treatments on blocks (sets) allows for more precise comparisons and the potential for greater replication for much less effort and cost than the alternative design.

The second design (Design 2) was tested in case there were interactions among baits in the other design. In Design 2, only a single bait was used on each set, and sets were placed far enough apart to avoid interference with each other (>0.75 nmi). Using short (three-skate, all baited) sets allowed greater treatment replication than standard survey sets of five to eight skates. In this design, it was assumed that eight sets of three baited skates could be fished in one day, and therefore four days of fishing would be required to complete the 32 sets in each area. For each fishing day, the sets were divided into two groups of four, with each group getting one set of each bait type. We also used a Latin square design for each group over the four days so that no bait appeared in the same order more than once. The order of the columns (sets) of each Latin square was randomised. Again, designs were originally devised with numeric treatment labels and the same random assignment of baits to labels was used as in Design 1. The order of the two squares (first group or second group) was randomised. The treatment sequences for the experimental designs are given in Tables 1 and 2.

For both designs, a standard skate of gear was defined as an 1800-foot skate with one hundred #3 (16/0) circle hooks spaced 18 feet apart. All baits were purchased frozen, and were then thawed before cutting and baiting. All gear was hand baited. The crew was responsible for cutting the bait into pieces sized between 0.25 and 0.33 pound for baiting the gear. Care was taken to keep the bait size consistent across all sets. IPHC staff monitored bait size during the charter to ensure compliance with charter standards. The chum salmon was of the same size and grade as in standard IPHC grid charters; number 2 semi-bright or better. Herring was not salted, and generally a single herring was used per hook; the exception to this was on the first day of the Fairweather trip, when two herring were used per hook in an attempt to get the weight per hook closer to 0.25-0.33 lb. Pollock were generally cut in halves or thirds to achieve the bait weight standard. The Albatross region was fished by the 17.7 meter *F/V Free To Wander*, while the Fairweather region was fished by the 22.9 meter *F/V Van Isle*.

Statistical analysis

Linear models were fitted to the data using least squares, and the statistical significance of terms in the models was tested using an analysis of variance (ANOVA). All models included bait and relevant variables representing experimental blocks. In the case of Design 1, set and skate number (1st, 3rd, 5th or 7th) were considered as blocking variables: the big benefit of Design 1 was expected to come from grouping the treatments on the same set, so set was expected to be the most important blocking factor. In Design 2, day was likely an important blocking factor, with different areas being fished each day, and with the possibility of fishing conditions changing with time.

Along with O32 halibut WPUE, we modeled U32 numbers, and numbers of common species of bycatch fish. WPUE was computed by dividing the halibut catch by the number of effective skates. The number of effective skates was computed as the number of skates set, adjusted for missing hooks (hook counts less than 100) and missing baits upon setting. Missing baits have not previously been deducted from hook totals when computing setline survey WPUE, but for some bait types in this study, samplers reported a large number of baits flying off the hook when setting, and as these hooks cannot catch fish, the catch would be negatively affected. An analysis of missing baits upon setting is also provided.

We tested for two effects of interactions among adjacent baits in Design 1. Each baited skate could potentially affect the catch of one or both of its neighbours, and so the two effects each accounted for one direction: the first was an effect on the baited skates set immediately after, and the second an effect on the baited skate set before. As discussed in Mead (1988), two tests must be done: the first is a test of the interaction effect after accounting for the bait effect, and the second a test of the bait effect after accounting for the interaction effect. The test of interaction effects was of the combined effect of the two possible directions the effect could have.

O32 WPUE

The O32 WPUE data were analysed using ANOVA. WPUE was square-root transformed prior in order to satisfy the normality and constant variance assumptions of the ANOVA model.

U32 numbers

Counts on U32 fish (those with fork lengths less than 32 inches) were analysed using a generalized linear model (GLIM) with binomial family and logit link function (logistic regression), using the same independent variables as for the O32 WPUE analyses. That is, counts of U32 fish per skate were assumed to have a binomial distribution, with population size being the number of effective hooks on each skate. Similar to the calculation of effective skates for O32 WPUE, the number of effective hooks was the number of hooks set less the number of baits missing while the gear was set. Effects were tested using F tests that allow for over- or under-dispersion often present in such binomial count data.

Bycatch numbers

For each skate in each design, a full count of catch and hook/bait condition was made of the first 20 hooks during haulback. This provides a measure of bycatch numbers, and of the likelihood of empty hooks, baited hooks, and damaged hooks being returned, permitting comparisons of these quantities among the four baits. Over both designs combined, two non-target species had over 100 specimens counted: spiny dogfish (*Squalus acanthias*) and Pacific cod (*Gadus macrocephalus*), and we restrict analysis of bycatch comparisons to these species in this report. As with U32 catch, bycatch counts were modeled as binomial random variables using a GLIM with logit link. Population size for each skate in Design 1 was assumed to be 20 (number of hooks counted per skate during haulback) and 60 for each set for Design 2 (20 hooks counted per skate, three skates/ treatment). Spiny dogfish were rarely caught in the Albatross region, while Pacific cod were almost never captured in Fairweather, so analyses for these species are performed on data from a single region only.

Missing baits and empty hooks

IPHC samplers count the number of hooks without bait during setting. As noted above, there were reports that some baits were more likely to be missing or observed flying off the hook during setting than others. Although we incorporated this into our calculations of WPUE for this study, that is not the case when WPUE is calculated for other purposes (e.g., stock assessment and biomass apportionment), where WPUE estimation would be affected by hooks that cannot catch fish at any time during the set. If missing baits on setting implies baits are less likely to stay on the gear during the set, we would expect more hooks to return empty, and therefore we also examined the proportion of missing hooks recorded in the 20-hook counts.

Results

Fishing in the Albatross region commenced on August 6 and was completed on August 11, 2011. The gear was fished in depths ranging from 35 to 92 fathoms. The gear caught a total of 1,309 O32 halibut with an estimated weight of 22,237 pounds and 1,517 U32 halibut. The Fairweather region was fished from August 10 until August 16, 2011. This gear was fished in depths from 52 to 125 fathoms. The gear caught a total of 1,191 O32 halibut with an estimated weight of 24,967 pounds and 876 U32 halibut.

Analytical results are presented in two ways: statistical test results are tabulated in Tables 3 and 4, and figures showing bait treatment means (back transformed for WPUE) with approximate 95% confidence intervals are presented to allow interpretation of the test results. In the latter, the results of pairwise comparisons of the alternative baits with chum salmon are displayed symbolically above each bar (no symbol means $p>0.1$). No Bonferroni-type adjustment was made to these p-values, as such adjustments increase the probability of Type II statistical errors (incorrectly concluding there is no difference of a given size when there is), which is possibly the more important error to reduce in this study. For Design 1, the means and p-values are obtained from models with the consistently non-significant bait interaction effects omitted, which simplifies computation and interpretation.

The benefit of grouping baits together on the same set in Design 1 is demonstrated by the significance of the set effect in comparisons of halibut catch (Table 3). With set differences accounting for a significant amount of the variability in the data, other comparisons become more precise and the power of tests of bait differences increases. Skate order was not a useful blocking variable except for missing baits: examination of the data showed on average more missing baits on the first skate of a set than subsequent skates (3.8/skate compared with 1.3-2/skate).

There was no evidence that baits were interacting with neighboring baits in Design 1: p-values ranged from 0.21 to 0.94 (Table 3). Note that removal of these non-significant effects from the analyses would result in lower p-values for the remaining effects, including bait.

O32 WPUE

Both designs yielded evidence that WPUE is affected by bait type (Tables 3 and 4). The pattern, however, differed somewhat between designs. WPUE using herring was much lower in both designs (Fig. 3) but only in Design 1 did pollock have significantly greater WPUE than the standard chum salmon bait, which had the highest WPUE in Design 2 (although not significantly higher than other baits).

U32 numbers

Again, there was evidence for differences among baits in the U32 halibut catch in both designs (Tables 3 and 4). Unlike O32 WPUE, the treatment means were consistent between the two designs. Pollock had the highest U32 catch, and herring and pink salmon the lowest (Figure 4).

Bycatch numbers

There was evidence that the amount of bycatch differed among baits for both of the common bycatch species examined here (Tables 3 and 4). The evidence is weak in the case of Pacific cod in Design 1 (p=0.07, Table 3). All three alternative baits had much lower dogfish catch in the Fairweather region than the standard chum salmon bait (Figure 5). For Pacific cod in the Albatross region, both herring and pollock had much lower bycatch than chum on average, while pink salmon was only somewhat lower than chum (Fig. 6).

Missing baits and empty hooks

In both analyses, there was strong evidence for bait differences in the proportion of hooks with missing baits when setting (Tables 3 and 4). Very few of the standard chum salmon baits were missing during setting, while on average the proportion of hooks with missing baits ranged from 0.03-0.05 for herring and pollock, and 0.01-0.02 for pink salmon (Fig. 7).

There was also very strong evidence for differences among the baits in the proportion of empty hooks returned in both designs (Tables 3 and 4), with herring and pink salmon both having significantly more empty hooks than chum salmon (Figure 8).

Discussion

There were two main goals to this small pilot study. The first goal was to get estimates of variability that could be used to design a larger study with sufficient power to detect differences among baits over a wider region, and to precisely estimate any correction factors that may need to be applied to WPUE should chum salmon be replaced by one of the three alternative baits. Although this study was restricted to two regions, and so the results may not be generalizable, halibut catch varied greatly among sets, reflecting that fishing occurred over a range of halibut densities. With comparisons made within sets in Design 1 (using set as a blocking variable), and between sets made relatively close together in Design 2 (using day as a blocking variable), the effect of larger-scale differences in catch is mostly removed, and the information on variability should be appropriate for designing the larger study.

The other goal was to select between the two alternative designs. Design 1 is far more cost effective than Design 2, with one quarter of the sets being required to achieve the same level of treatment replication. The concern was that this design does not replicate the manner in which surveys sets are typically made, with baits combined on a single set, rather than being set as strings of gear all with the same bait. In particular, the potential for baited skates to not act independently, and have catch affected by more or less attractive baits on adjacent skates, was the motivation for also including the less efficient Design 2. That there was no evidence for such interactive effects among baits leads us to conclude that Design 1 should be the preferred design for the larger experiment to be conducted in 2012.

That said, the results of the data analyses of this pilot are themselves interesting and informative. Herring was less effective at catching halibut than other baits, and was the bait most likely to be lost at setting. Although WPUE calculation can easily account for baits lost during setting by simply reducing the number of effective hooks, as we did here, there is a concern that baits may also be more likely to fall off unseen during the set. Indeed, a much larger proportion of empty hooks was returned on gear baited with herring than with chum, something also true of pink salmon. All three alternative baits had higher rates of missing baits when setting than the standard bait, and the results of this study should lead to examination of how the preparation of these baits prior to setting can be improved (such as salting), and whether the method of setting itself can be modified so that these baits are less likely to detach from the hook. Also of interest is that all alternative baits had lower catch than chum salmon of the two most locally common bycatch species, spiny dogfish and Pacific cod. This may be both an operational benefit and a conservation benefit if the results also apply to species of greater concern, such as some rockfish species. The analyses of missing baits and empty hooks, however, suggest that lower bycatch may in part be due to fewer baits being available, or baits being available for less time.

Reference

Mead, R. 1988. The design of experiments: statistical principles for practical application. Cambridge University Press, Cambridge.

Table 1. Design 1: Sets of four baited skates, separated by empty skates, where SA is chum salmon, PS is Pink salmon, PO is pollock and HR is herring

Fairweather

	Day 1				*Day 2*			
	Set 1	Set 2	Set 3	Set 4	Set 1	Set 2	Set 3	Set 4
Skate 1	SA	PO	HR	PS	PO	SA	PS	HR
Skate 3	HR	PS	PO	SA	PS	PO	HR	SA
Skate 5	PS	HR	SA	PO	SA	HR	PO	PS
Skate 7	PO	SA	PS	HR	HR	PS	SA	PO

Albatross

	Day 1				*Day 2*			
	Set 1	Set 2	Set 3	Set 4	Set 1	Set 2	Set 3	Set 4
Skate 1	SA	HR	PS	PO	HR	SA	PS	PO
Skate 3	PO	SA	HR	PS	PO	HR	SA	PS
Skate 5	HR	PS	PO	SA	SA	PS	PO	HR
Skate 7	PS	PO	SA	HR	PS	PO	HR	SA

Table 2. Design 2: Sets of three skates with a single bait, where SA is chum salmon, PS is Pink salmon, PO is pollock and HR is herring

Fairweather

	First group				*Second group*			
	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Set 7	Set 8
Day 1	PO	HR	PS	SA	PO	SA	PS	HR
Day 2	PS	SA	HR	PO	HR	PS	PO	SA
Day 3	SA	PS	PO	HR	PS	HR	SA	PO
Day 4	HR	PO	SA	PS	SA	PO	HR	PS

Albatross

	First group				*Second group*			
	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Set 7	Set 8
Day 1	PS	PO	HR	SA	SA	PS	PO	HR
Day 2	PO	HR	SA	PS	PO	HR	PS	SA
Day 3	SA	PS	PO	HR	HR	PO	SA	PS
Day 4	HR	SA	PS	PO	PS	SA	HR	PO

Table 3. Tests of effects for Design 1.

Effect	O32 WPUE	U32 count	Dogfish	P. Cod	Missing bait	Empty hooks
Set	**$F_{15,36}$=2.46 p=0.014**	**$F_{15,36}$=10.88 p<0.001**	$F_{7,12}$=0.57 p=0.76	$F_{7,12}$=2.21 p=0.11	$F_{15,36}$=1.84 p=0.067	$F_{15,36}$=0.81 p=0.66
Skate	$F_{3,36}$=0.51 p=0.68	$F_{3,36}$=1.29 p=0.29	$F_{3,12}$=0.93 p=0.46	$F_{3,12}$=1.98 p=0.17	**$F_{3,36}$=5.76 p=0.003**	$F_{3,36}$=0.42 p=0.74
Bait	**$F_{3,36}$=3.44 p=0.027**	**$F_{3,36}$=8.10 p<0.001**	**$F_{3,12}$=3.66 p=0.044**	$F_{3,12}$=3.05 p=0.070	**$F_{3,36}$=9.54 p<0.001**	**$F_{3,36}$=12.43 p<0.001**
Interactions	$F_{6,36}$=0.53 p=0.78	$F_{6,36}$=0.76 p=0.60	$F_{6,12}$=0.55 p=0.76	$F_{6,12}$=1.67 p=0.21	$F_{6,36}$=1.19 p=0.33	$F_{6,36}$=0.29 p=0.94

Table 4. Tests of effects for Design 2.

Effect	O32 WPUE	U32 count	Dogfish	P. Cod	Missing bait	Empty hooks
Date	**$F_{7,53}$=8.70 p<0.001**	**$F_{7,53}$=8.14 p<0.001**	**$F_{3,25}$=7.43 p=0.001**	$F_{3,25}$=1.66 p=0.20	**$F_{7,53}$=6.44 p<0.001**	$F_{7,53}$=2.04 p=0.067
Bait	**$F_{3,53}$=3.05 p=0.036**	**$F_{3,53}$=4.45 p=0.007**	**$F_{3,25}$=2.40 p<0.001**	**$F_{3,25}$=4.25 p=0.015**	**$F_{3,53}$=28.41 p<0.001**	**$F_{3,53}$=19.95 p<0.001**

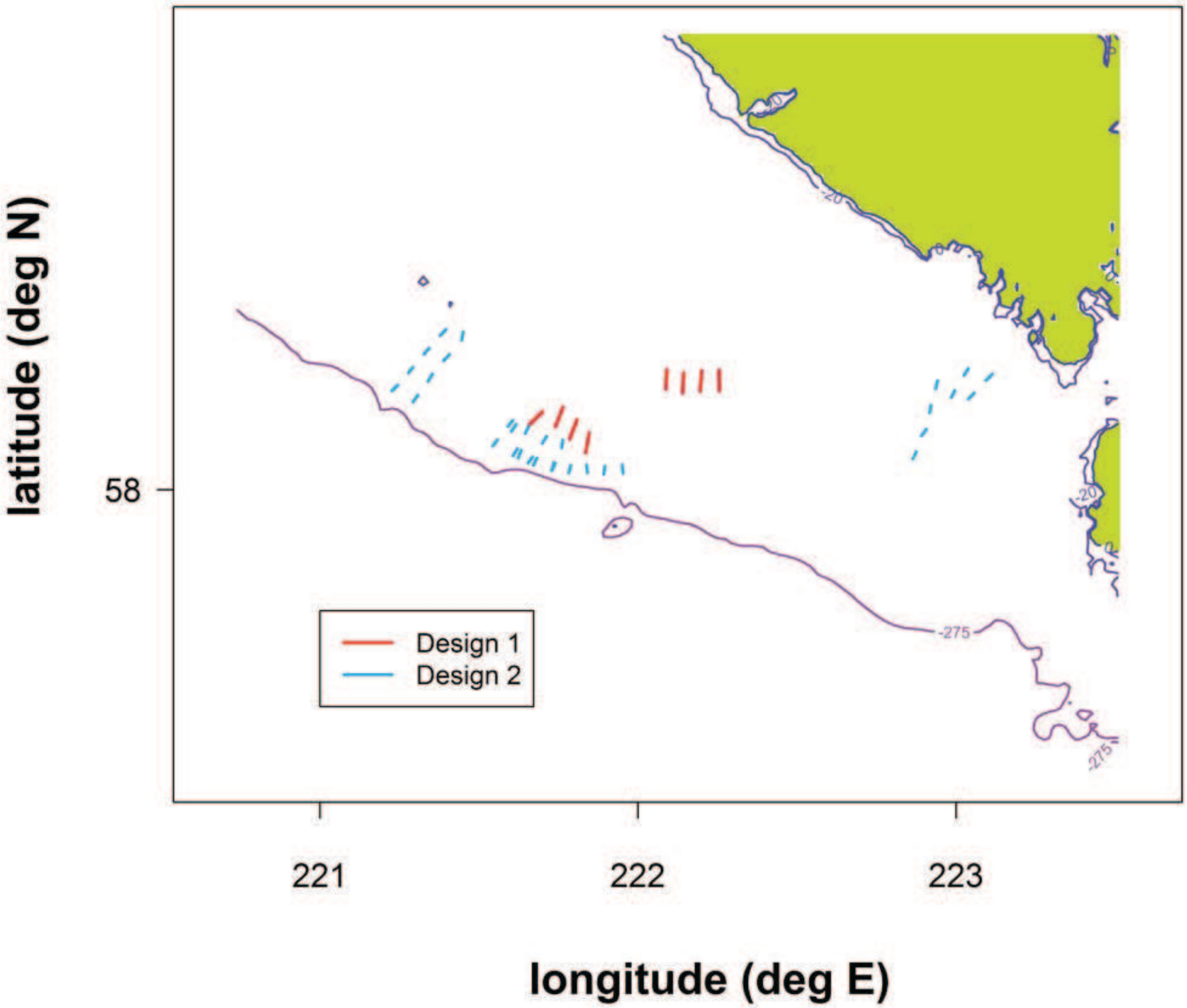

Figure 1. Pilot study set locations in the Fairweather survey region.

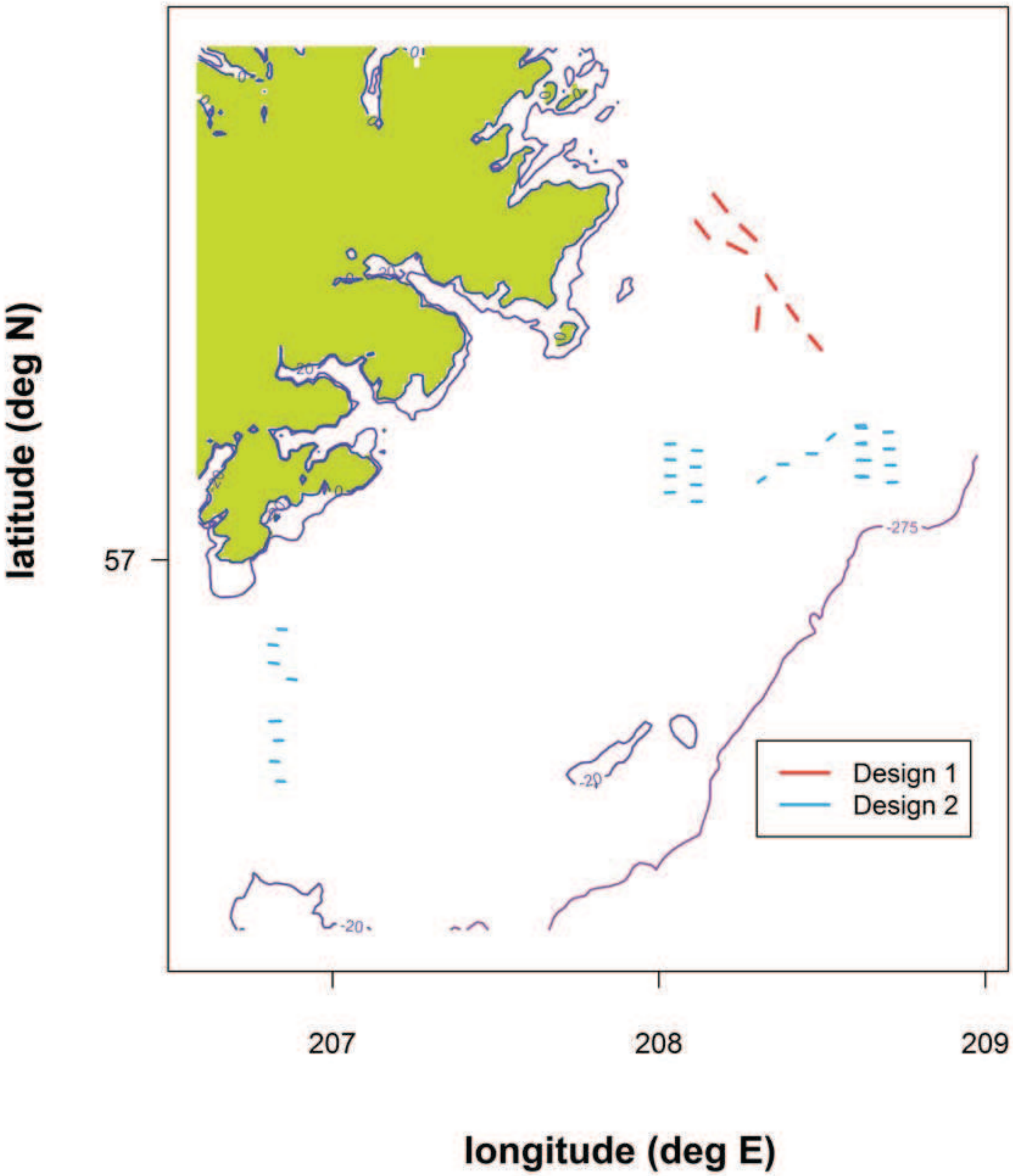

Figure 2. Pilot study set locations in the Albatross survey region.

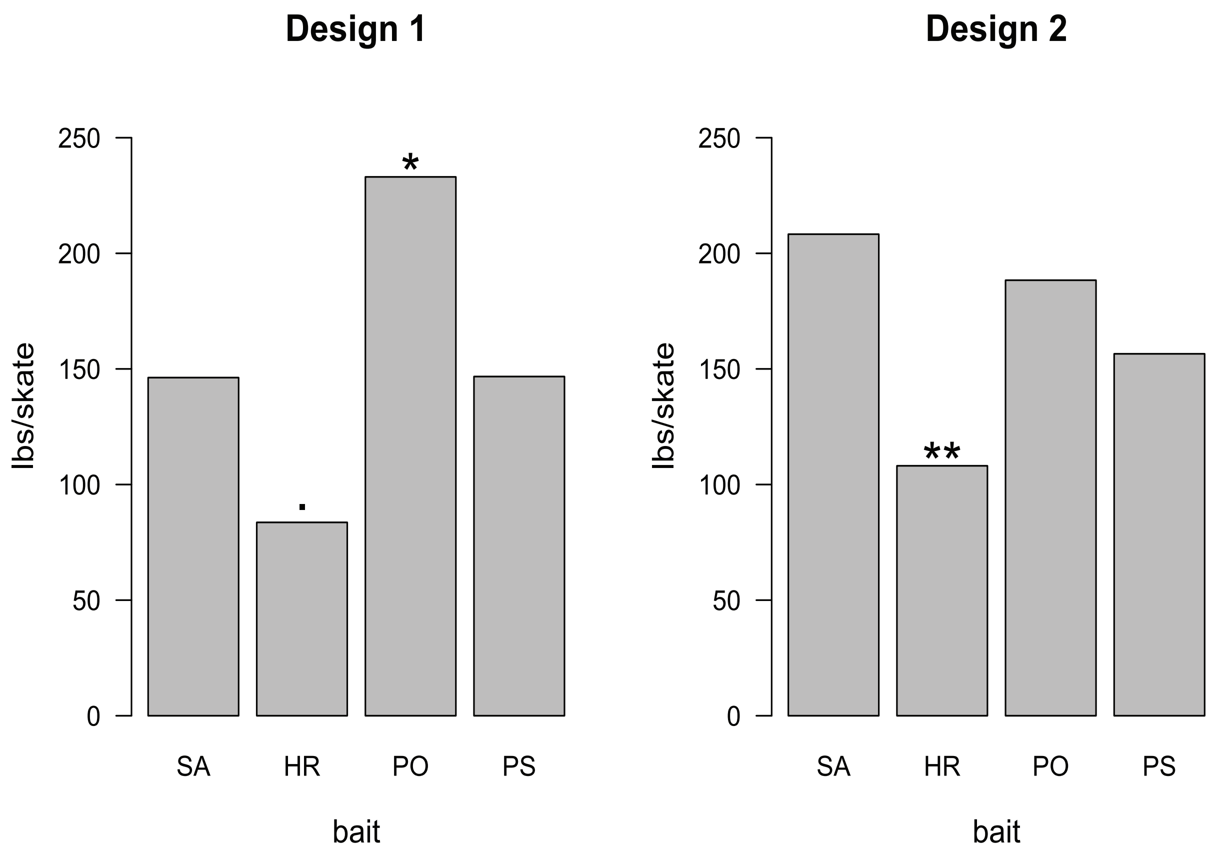

Figure 3. Comparison of mean O32 halibut WPUE (back transformed from square-root scale) among baits and between designs. Symbols above HR, PO, and PS represent range of p-value of pairwise comparison with SA: . 0.05<p<0.1; * 0.01<p<0.05; ** 0.001<p<0.01; *** p<0.001.

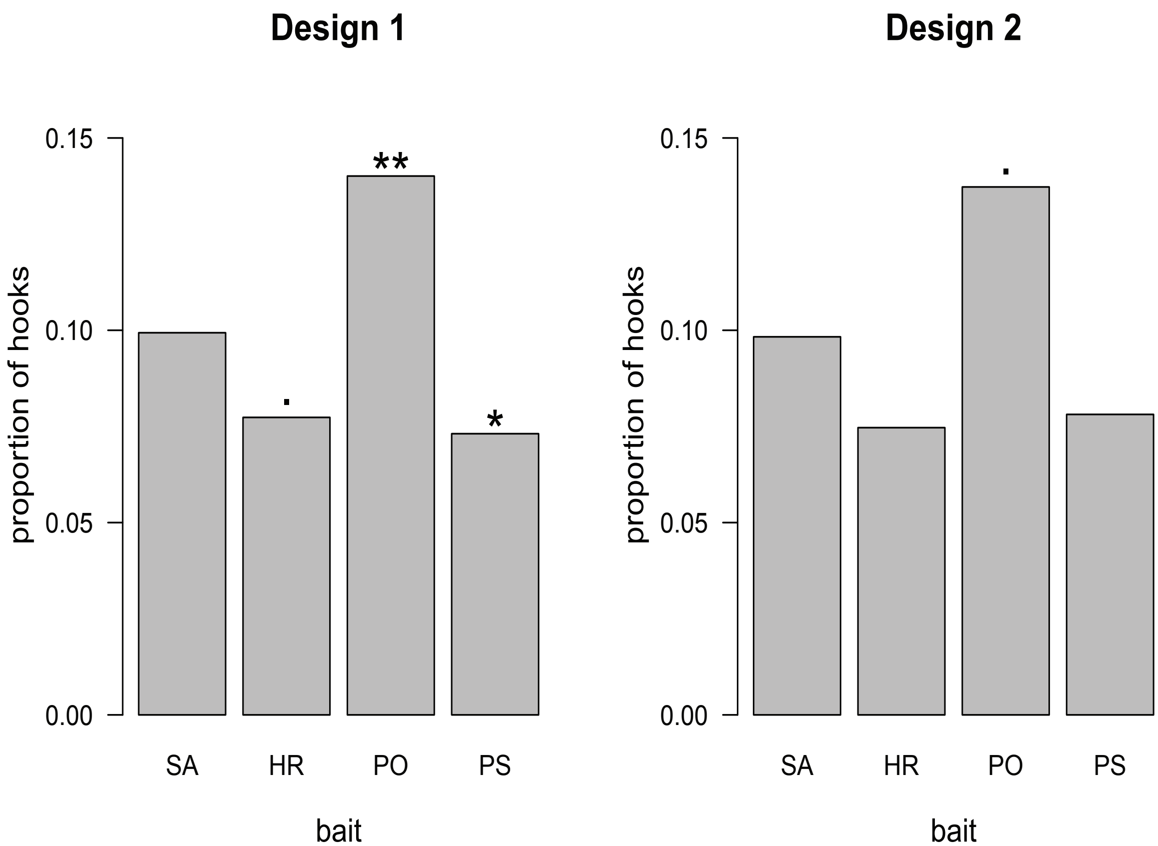

Figure 4. Comparison of the mean proportion of hooks occupied by U32 halibut among baits and between designs. Symbols above HR, PO, and PS represent range of p-value of pairwise comparison with SA: . 0.05<p<0.1; * 0.01<p<0.05; ** 0.001<p<0.01; *** p<0.001.

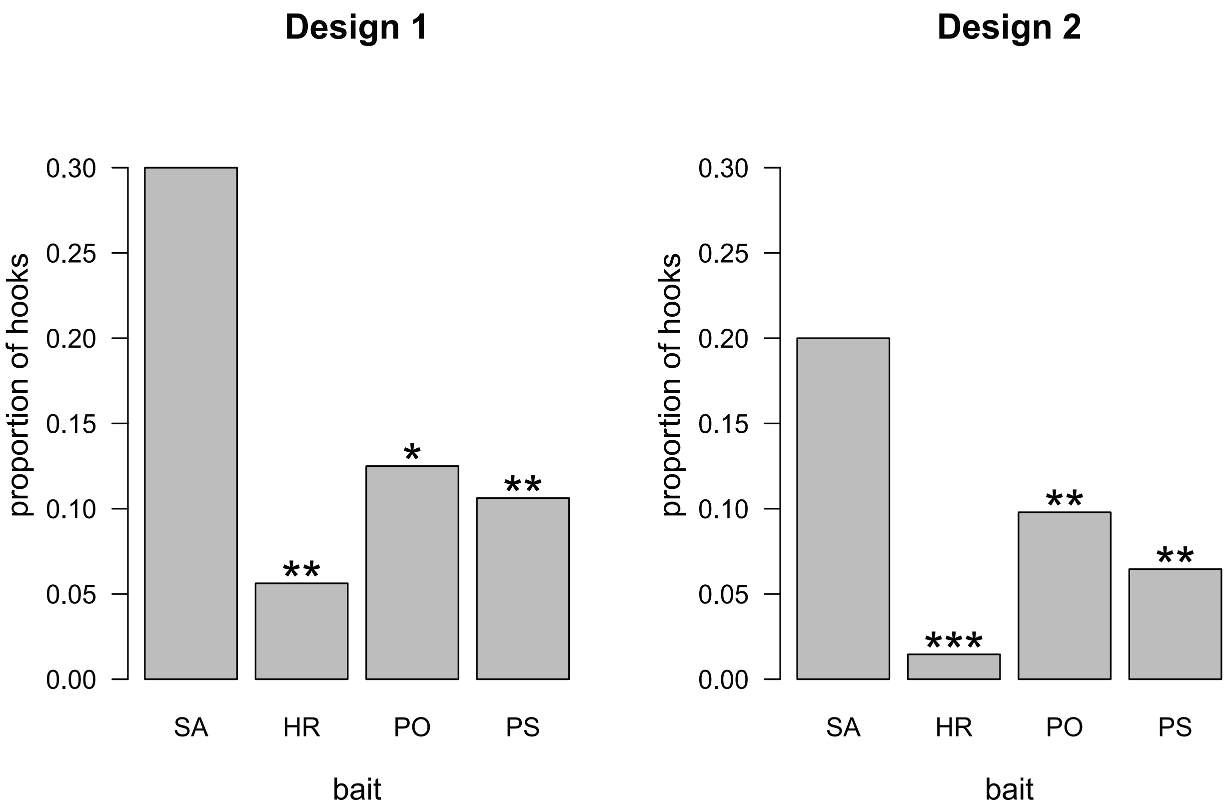

Figure 5. Comparison of the mean proportion of hooks occupied by spiny dogfish among baits and between designs, in Fairweather region only. Symbols above HR, PO, and PS represent range of p-value of pairwise comparison with SA: . 0.05<p<0.1; * 0.01<p<0.05; ** 0.001<p<0.01; *** p<0.001.

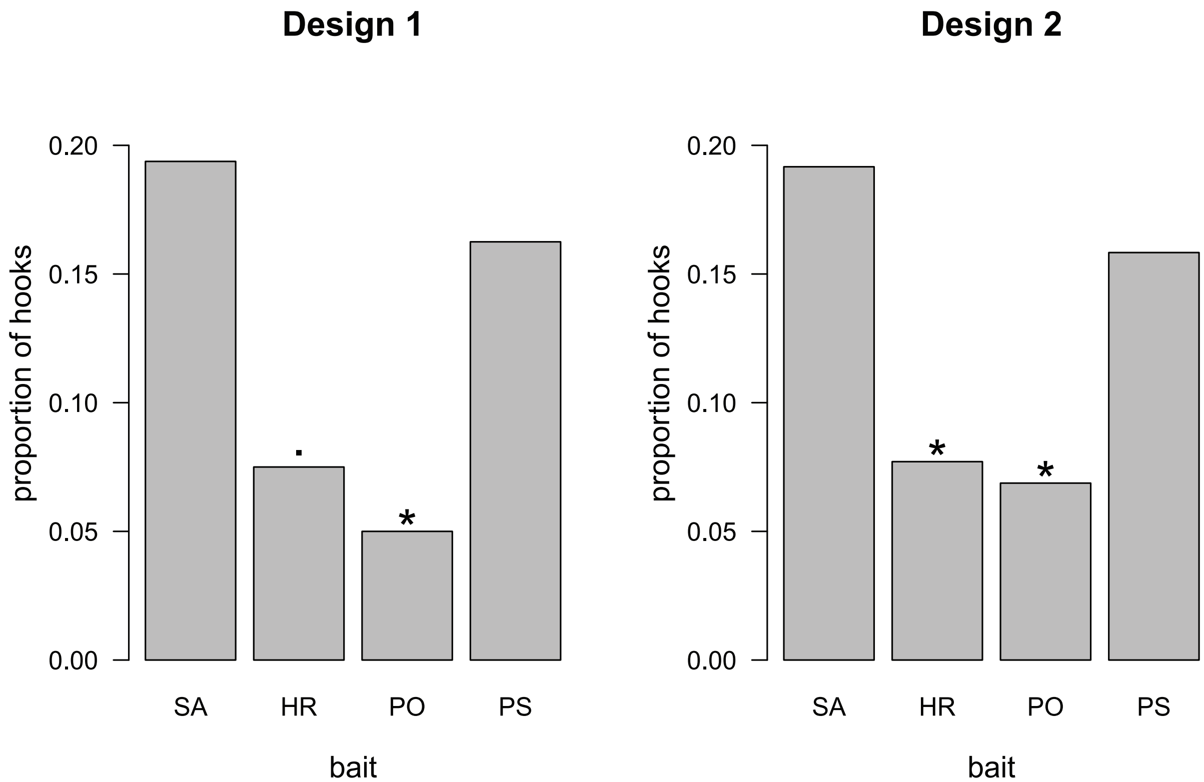

Figure 6. Comparison of the mean proportion of hooks occupied by Pacific cod among baits and between designs, in Albatross region only. Symbols above HR, PO, and PS represent range of p-value of pairwise comparison with SA: . 0.05<p<0.1; * 0.01<p<0.05; ** 0.001<p<0.01; *** p<0.001.

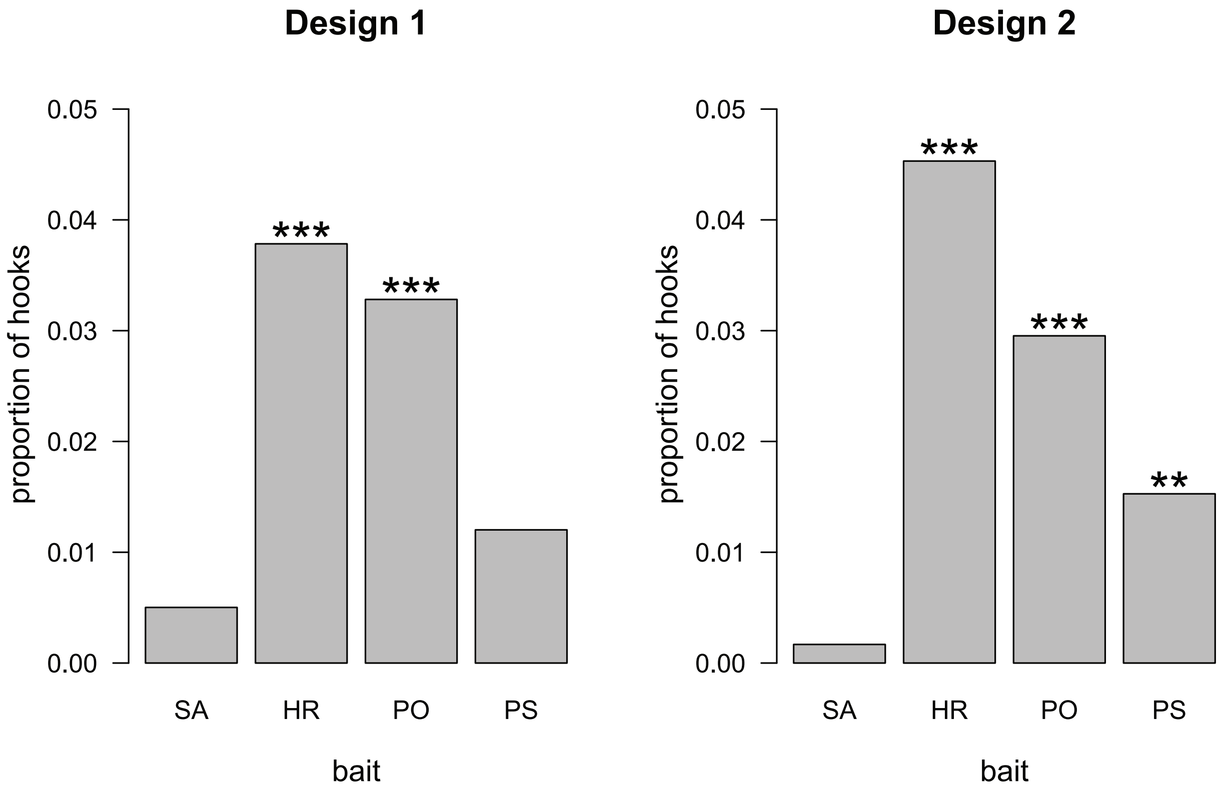

Figure 7. Comparison of the mean proportion of hooks with baits missing during setting among baits and between designs. Symbols above HR, PO, and PS represent range of p-value of pairwise comparison with SA: . 0.05<p<0.1; * 0.01<p<0.05; ** 0.001<p<0.01; *** p<0.001.

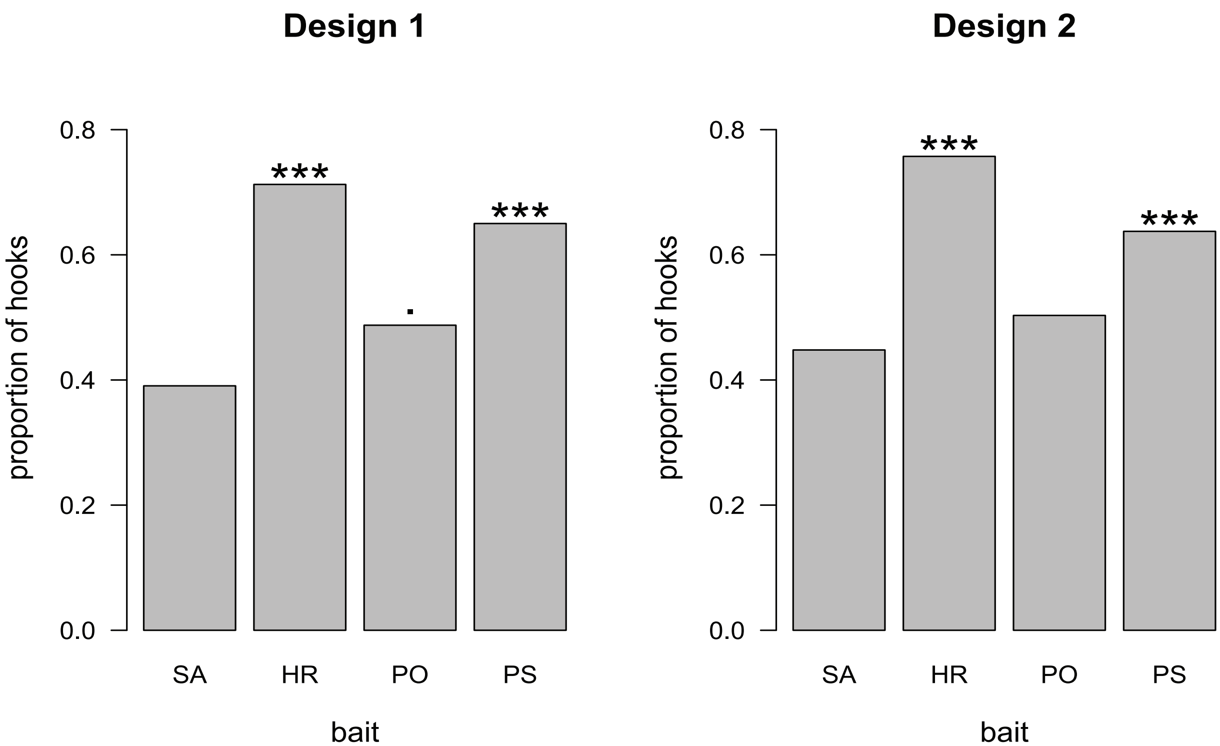

Figure 8. Comparison of the mean proportion of empty hooks on haulback among baits and between designs. Symbols above HR, PO, and PS represent range of p-value of pairwise comparison with SA: . 0.05<p<0.1; * 0.01<p<0.05; ** 0.001<p<0.01; *** p<0.001.