ISSN: 0579-3920

INTERNATIONAL PACIFIC HALIBUT COMMISSION

ESTABLISHED BY A CONVENTION BETWEEN
CANADA AND THE UNITED STATES OF AMERICA

Technical Report No. 48

1998 gear and bait experiments

by

Stephen Kaimmer

SEATTLE, WASHINGTON
2004

The International Pacific Halibut Commission has three publications: Annual Reports (U.S. 0074-7238), Scientific Reports, and Technical Reports (U.S. ISSN 0579-3920). Until 1969, only one series was published (U.S. ISSN 0074-7426). The numbering of the original series has been continued with the Scientific Reports.

INTERNATIONAL PACIFIC HALIBUT COMMISSION
P.O. BOX 95009
SEATTLE, WASHINGTON 98145-2009, U.S.A.
www.iphc.washington.edu

1998 gear and bait experiments

Contents

Abstract

During 1998, the International Pacific Halibut Commission (IPHC) conducted numerous pilot experiments investigating the effects of bait type, size, or quality, hook size, or gear type on the longline CPUE of Pacific halibut. Thirty-six different experiments were completed by a total of nine chartered commercial fishing vessels. Many of the experiments showed significant differences in the catches of either legal- or sublegal-sized halibut. In general, larger hooks or baits caught more legal-sized and fewer sublegal-sized halibut and significant differences were observed between different baits or bait qualities. Results of these pilot experiments will be useful in designing future IPHC gear experiments.

1998 gear and bait experiments

Stephen Kaimmer

Introduction

The International Pacific Halibut Commission (IPHC) conducts an annual assessment of the Pacific halibut (*Hippoglossus stenolepis*) resource in the Pacific Ocean off the U.S. and Canada. Catch per unit effort (CPUE in pounds net weight per 100 hooks[1]) data from the commercial halibut fishery and from standard stock assessment surveys are integral to this assessment. Bait size and type, as well as hook size, have been demonstrated to have significant effects on the catch rate and average size of fish caught on hook and line (Bjordal and Løkkeborg 1996).

Since the mid-1980's, most halibut fishers use a 16/0 sized circle hook (comparable to O. Mustad and Sons, Scotland, Quality 39965) in the directed halibut fishery. Lately, particularly since the adoption of individual fishing quotas for halibut and sablefish (*Anoplopoma fimbria*) in both Canada (1991) and Alaska (1995), a growing proportion of mixed-species longline fisheries are landing halibut caught on smaller, 13/0 or 14/0, hooks. Bait choice by commercial fishers is the result of personal preference, bait availability, and economics. While the IPHC has no control over the baits and hooks used by the commercial fisheries, the baits used in IPHC stock assessment grid surveys since 1993 have been standardized to 0.11 to 0.15-kg (1/4 to 1/3-pound) pieces of chum salmon (*Oncorhynchus keta*) fillet, skin-on. Most bait is purchased frozen, and thawed before using. Chum salmon are often categorized as bright (silver bright), semi-bright or dark according to skin coloration. Bright chums have bright, silver sides. As the fish mature and prepare for entrance into freshwater for spawning, the skin becomes increasingly mottled and watermarked. Semi-bright chums have begun to show darker bars on the sides, and the skin and back begin to dull. Dark chums have well-developed dark bars on the sides which have become a deep red. IPHC grid surveys are standardized to semi-bright chum salmon bait on a 16/0 circle hook. Our minimum bait standard is ASMI[2] grade A through E, H&G, and IQF (headed and gutted, and individually quick frozen).

Changes in commercial or survey CPUE from year to year can affect the resulting stock assessment (Bill Clark, IPHC, personal communication). During the annual IPHC stock assessment grid survey in 1998, the chartered commercial fishing vessels were encouraged to conduct research fishing in addition to that required by the grid survey. This extra fishing was designed to explore questions regarding gear effectiveness, particularly the effects of bait type, quality, and size, and hook size, on halibut CPUE. Vessels were compensated with a share of the sale proceeds from the experimental catch. Fishers were encouraged to suggest experiments that complimented their schedule or fishing gear. These experiments were pilot studies, their results to be used in planning future experiments.

---

[1] IPHC CPUE data for legal-sized halibut is calculated as net weight in pounds, with head and entrails removed.

[2] Alaska Seafood Marketing Institute, 311 N. Franklin Street #200, Juneau, AK 99801-1147

Methods

Experimental design

Experimental fishing was conducted under one of three scenarios: opportunity fishing, where extra sets of gear were fished during IPHC grid fishing operations; extended charters, where specific experiments were conducted during extensions of the grid charters; and, in a few cases, diverted charters, where vessels were diverted from their contracted grid fishing operations into specific experiments. For extended and diverted charters, experiments involved about 15 to 30 sets of gear, and from 5 to 15 days of fishing. For opportunity fishing, as few as 3 or as many as 10 to 15 sets were made. Projects included effects of hook size, bait size, type, and quality, and gear type on catch rates (Table 1). Baits and bait codes used in either the bait or gear type experiments were semi-bright (SA) and silver-bright (SL) chum salmon, pollock (*Theragra chalcogramma*, PO), Pacific herring (*Clupea harengus pallasi*, HR), Pacific cod ('Grey cod', *Gadus macrocephalus*, GC), and squid (*Illex* sp., SQ). In all cases, bait size was carefully controlled. Baits were cut to uniform average size and regularly weighed in batches of 30 to 40 pieces using a spring scale to ensure uniform average bait weights.

Table 1. Experiment types and criteria for 1998 summer experimental fishing.

Experiment	Criteria
Bait size	'Standard' size versus other size baits. Vessels were instructed to carefully control bait size between control and treatment.
Hook size	Large versus small hooks on otherwise identically-rigged conventional gear. Bait size could be varied systematically with hook size, and vessels were instructed to take careful observations of bait size used.
Gear type	Conventional halibut gear versus cod-style gear. Bait could vary between gear types, with instructions to use survey standard bait on halibut gear and either smaller bait or other bait on cod-style gear.
Bait quality	Standard #2 semi-bright chum salmon used on grid surveys with other batches or grades of chum salmon.
Bait type	Different bait types on otherwise identical gear.

Each experiment was based on paired comparisons between two treatments, a test and a control. Each gear set contained both treatment and control skates. Treatment and control skates alternated within each set, with the order (which gear was first in the alternating pair) chosen randomly for each set. There were as many as few as three and as many as five alternating pairs in each set. The instructions suggested that up to 15 to 20 sets be fished for each experiment. All gear fished was fixed-hook, conventional style setline gear, fished wither from tubs or skate-bottoms. While the hook spacing was held constant on halibut-style gear (Hal) at 18-foot and on cod-style gear at 42-inches, the length of gear fished as a skate by each vessel, and therefore the number of hooks, varied (Table 2). In all but the gear type comparisons, treatments had equal lengths of longline within each experiment, and alternating treatments had equal numbers of hooks. In the gear-type experiments, the number of hooks fished in each half of the treatment pair varied. The number of hooks and number of lost baits were observed for each skate. An average for the number of hooks per skate was recorded for each set. Counts of lost baits were recorded for each skate. All halibut caught were enumerated and measured.

Table 2. Vessel codes and skate descriptions. Hook spacing was 18' for halibut gear and 42" for cod-style gear. Gear descriptions are in terms of gear length in feet and (in parenthesis) number of hooks for each skate fished.

Vessel	Code	Halibut gear	Cod-style gear
Angela Lynn	ANL	1500‘ (82-83 hooks)	n/a
Ocean Viking	OCV	750' (40-43 hooks)	n/a
Sand Island	SAI	1500 ‘ (82-83 hooks)	n/a
Western Sunrise	WSU	750' (40-43 hooks)	n/a
Tradition	TDN	1800' (98-100 hooks)	n/a
Lualda	LDA	1500‘ (82-83 hooks)	1225' (350 hooks)
Tyanaa	TYA	900' (48-50 hooks)	n/a
Zenith	ZEN	900' (48-50 hooks)	900' (265 hooks)
Bold Pursuit	BDP	1500' (83 hooks)	n/a

Fishing success

Thirty-six experiments (Table 3) were conducted by a total of nine different vessels, each vessel conducting from one to nine individual experiments. Sets completed totaled 441, and 4,207 'skates' of gear representing over 284,000 hooks were fished. Forty-three, or about one percent, of the skates were retrieved badly snarled. Data from these skates were not used. Catches totaled over one million pounds of legal-sized ($\geq$ 82 cm) and almost 12,000 sublegal-sized halibut (< 82 cm). From 3 to 29 sets were conducted by each experiment.

Three vessels conducted bait-size experiments during nine different vessel trips. In one case, two bait-size experiments were conducted during a single trip, in all others a single bait-size experiment was conducted. Tested against a four-ounce 'standard' bait size were two-ounce (two experiments), three-ounce, six-ounce (three experiments), seven-ounce, and eight-ounce baits.

Table 3. Summary of special experiments conducted during summer 1998.

Experiment type	Number of experiments	Number of sets	Description
Bait size	10	140	Comparing 2, 3, 6, 7, and 8 oz. pieces against a standard size and type of bait, typically a 4 oz. piece of semi-bright chum salmon
Hook size	5	95	Comparing 13/0 (25 sets) and 14/0 (70 sets)against standard 16/0 hook
Gear type	4	33	Blackcod gear to halibut gear, with 4 oz. chum baits (6 sets), or with chum on halibut gear and herring on blackcod gear (27 sets).
Bait quality	12	116	Holding bait size to 4 oz., comparing dark salmon to semi-bright (78 sets), two different batches of semi-bright (18 sets), semi-bright to silver-bright (3 sets) and two batches of silver-bright chum salmon (17 sets).
Bait type	5	57	Comparing Pacific cod to semi-bright chum (43 sets) and pollock to squid (14 sets).
Total	36	441	

Within each of these experiments, different sizes of bait were selected from the same batch of bait and compared. Bait sources varied between experiments. Another experiment compared three-ounce to five-ounce baits. This experiment was further divided into one that compared baits from the same batch and one where the baits came from different batches.

Five vessels conducted hook-size experiments during 1998. Two experiments compared two sizes of hook with the same bait (4-oz. semi-bright chum salmon) on halibut gear with 18-foot spacing. One of these compared a standard 16/0 hook with the smaller 13/0 hook, and the other compared the 16/0 to a 14/0 hook. Two experiments compared the 16/0 to a 14/0 hook on standard halibut gear, but also varied the bait size, putting a 2-ounce bait on the 14/0 hook and a 3-ounce bait on the 16/0 hook. Four experiments compared standard halibut gear, 18-foot spacing, with a 16/0 hook, to blackcod-style gear, with a lighter and shorter gangion and 42-inch hook spacing, and a 14/0 hook. Two of these used 4-ounce chum bait on the halibut gear and 2-ounce herring bait on the blackcod-style gear, while the others used 2-ounce herring bait on both gear types.

Three vessels conducted nine bait quality experiments comparing semi-bright (SA) and dark (DS) chum salmon. Bait-quality experiments used baits purchased randomly from sellers and in ports around the coast, and in only a few instances do we know when two grades of bait being compared were from the same run of salmon, or when the same baits were used in more than one experiment. In addition to the SA/DS comparisons, one vessel also conducted experiments comparing semi-bright and silver-bright (SL) chum, two different batches of semi-bright chum, and two different batches of silver-bright chum.

Two vessels conducted bait type experiments, comparing different types of bait. One vessel compared semi-bright chum salmon to Pacific cod (4 experiments in 3 trips) and the other vessel compared pollock to squid.

Calculations and statistics

Halibut weights were estimated from a length-weight relationship (Quinn et al. 1983)

$$w = \left(6.92 \times 10^{-6}\right) \times l^{3.24}$$

where w = net weight in pounds and l = fork length in cm. Counts of total hooks fished and lost baits during setting were used to standardized the catch by treatment for each set as catch per 100 baited hooks set. *Effort*, the total number of effective hooks set for each treatment j in each set i is calculated as

$$Effort_{ij} = \left(S_{ij} \times H_{ij}\right) - \sum_{s=1}^{S} L_{ijs}$$

where S_{ij} equals the number of skates for treatment j in set i, H_{ij} equals the average number of hooks set for treatment j in set i, and L_{ijs} equals the number of baits lost for skate s in treatment j in set i. Multiplying this by 0.01 gives the number of 100-hook units of effort.

The catch by each treatment j in each set i is calculated as the sum of the individual halibut weights for all k halibut in set i and treatment j.

$$\text{Catch}_{ij} = \sum_{\text{k=1}}^{\text{K}} \text{w}_{ijk}$$

Dividing the catch by effort gives a standardized CPUE per 100 hooks for each treatment *j* in set

$$CPUE_{ij} = \frac{Catch_{ij}}{0.01 \times Effort_{ij}}$$

The catch in terms of number per unit effort, NPUE per 100 hooks, is calculated in a similar manner.

The catch rate of fish at length *l* in a set was determined by summing the number of fish of length *l* in set *i,* then dividing by the number of baited hooks fished in set *i*. The overall length frequency for a treatment group is then the sum of these standardized catch rates of fish of length *l* in each set.

Hypotheses comparing mean catch values for treatments and controls were tested using a paired-sample *t* test on untransformed catch data. This test measured the degree of difference between the two means. Length-frequency distributions were compared using the Kolmogorov-Smirnov (K-S) test. Both of these tests are sensitive to sample size, a larger number of paired samples (sets) giving a higher likelihood of finding a significant difference between test and control groups. Significance for both tests was determined using an alpha level of 0.05. For the *t* tests, we use either one- or two-tailed distributions, depending on the experimental hypothesis. For those tests where we have no idea of the relationship between treatments (such as testing two bait batches, or two types of bait) we are testing the null hypothesis that there is no difference between the population means. In these cases, significance is tested with a two-tailed test. For those tests where we have prior knowledge of the direction the results are likely to take (such as hook size, bait size, or some bait quality tests) we are testing the null hypothesis that one mean is larger than the other, and we use a one-tailed test. For all tests, the degrees of freedom are calculated as *n-1*, where *n* is the number of sets in the comparison. Many of the experiments had small sample sizes. The tables and text identify significant results, but also discuss trends across similar experiments, even when individual experimental results were not significant at 95 percent. Many of the experiments with non-significant results still had probabilities greater than 85 or 90%. I think discussion of non-significant results is further justified by the pilot nature of these experiments.

Results

Descriptions of the experimental effort are given in Appendix Tables 1-4, along with catch ratios and t-test results for CPUE, NPUE, and average length comparisons. At the bottom of each table K-S statistics are presented for each length frequency comparison. Appendix Figures 1-15 present x-y plots of test and control CPUE and NPUE for all experiments, and length frequencies for each comparison. The experiments are further summarized in Tables 4 – 8. CPUE differences were significant in 15 of the 36 experiments.

Bait size

In each case where the two bait sizes were taken from the same batch of bait, the larger bait averaged more pounds of legal-sized ($\geq$ 82 cm) halibut than the smaller bait, usually on the order of 10-40% (Table 4). In five of these nine comparisons, the increase was significant. The difference in catch of sublegal-sized (< 82 cm) halibut was more varied, and was significant in only three of the trials. These three trials were ones where the difference in bait sizes was extreme (2 vs. 4., 4 vs. 7, and 4 vs. 8 oz.), and in all these cases the larger bait caught more sublegal-sized fish than the smaller bait. The average length of fish caught by the larger baits always exceeded that caught by the smaller baits, although usually only on the order of a few

Table 4. Bait size experiments conducted during the 1998 summer experimental fishing. A one-tailed t-test was used to determine significance.

Bait size test vs. ctrl	Bait type	Vessel/ trip	Area[1]	# Sets	*df*	# Pairs	Ratio test/ctrl.[2]	T-test significance		Pounds caught
2 oz vs. 4 oz	Semi-bright Chum	OCV 1	2C	8	7	38	0.53	0.028	+	14,347
2 oz vs. 4 oz	Semi-bright Chum	WSU 1	2B	23	22	123	0.79	0.009	+	22,895
3 oz vs. 4 oz	Dark Chum	OCV 3b	2C	4	3	20	0.66	0.108	-	4,723
3 oz vs. 5 oz	Semi-bright Chum	WSU 8a	2B	29	28	150	0.77	0.023	+	26,823
3 oz vs. 5 oz[2]	Semi-bright Chum[2]	WSU 8b	2B	13	12	59	2.27	0.001	+[3]	8,582
6 oz vs. 4 oz	Semi-bright Chum	OCV 5b	2C	11	10	65	1.46	0.008	+	26,448
6 oz vs. 4 oz	Semi-bright Chum	TDN 11	3A	10	9	29	1.18	0.117	-	23,279
6 oz vs. 4 oz	Semi-bright Chum	TDN 12	3A	7	6	24	1.03	0.432	-	14,544
7 oz vs. 4 oz	Semi-bright Chum	WSU 2	2B	28	27	136	1.12	0.106	-	18,365
8 oz vs. 4 oz	Semi-bright Chum	OCV 6	2C	7	6	51	1.19	0.004	+	29,005
				140		695				189,011

[1] IPHC Regulatory Area

[2]the ratio between the average Test CPUE and the average Control CPUE.

[3] in vessel trip WSU 8a, the bait for both bait sizes was from the same frozen batch. In vessel trip WSU 8b, the 3-ounce bait was from a batch of fresh bait, while the 5-ounce bait was from the same frozen batch used in vessel trip WSU 8a.

Table 5. Hook size experiments conducted during the 1998 summer experimental fishing. All baits used were semi-bright chum. A one-tailed t-test was used to determine significance.

Hook size test vs. ctrl	Bait size (test vs. ctrl.)	Vessel/ trip	Area[1]	# Sets	*df*	# Pairs	Ratio test/ctrl.[2]	T-test significance		Pounds caught
130 vs. 16/0	4 oz	WSU 3	2B	25	24	125	0.95	0.248	-	24,813
14/0 vs. 16/0	4 oz	BDP 9	2C	25	24	102	1.03	0.367	-	50,744
14/0 vs. 16/0	4 oz	BDP 10	2C	19	18	73	0.92	0.252	-	53,722
14/0 vs. 16/0	2 oz vs. 3 oz	TYA 4	2C	6	5	30	0.72	0.020	+	7,438
14/0 vs. 16/0	2 oz vs. 3 oz	TYA 5	2B	20	19	100	0.66	0.001	+	22,324
				95		430				159,041

[1] IPHC Regulatory Area

[2] the ratio between the average test CPUE and the average control CPUE.

percent, and was significant in only one instance. Comparisons of the length-frequency plots for the bait-size experiments using the Kolmogorov-Smirnov test showed a significant difference in only one of nine experiments.

Hook size and mixed gear/bait type

In all but one of the experiments where only hook size was varied, the larger hook averaged a higher CPUE (Table 5). In all cases, the differences were small, on the order of 3-34%, and not significant. In both experiments where both bait and hook sizes were varied, CPUE was significantly higher on the larger hook/bait combinations. Halibut-gear CPUE was higher in all four comparisons where bait, gear, and hook sizes were varied, significantly so in three cases (Table 6). The smallest increases were seen in the tests where only hook size was varied. Increases were larger where both hook size and bait sizes were varied and larger again when bait, hook size, and gear all varied. In this latter case, the halibut gear with the larger hooks caught from 20-80% more pounds per hundred hooks than the blackcod gear. These latter comparisons were made in Area 3, and the fishers observed that the smaller 14/0 hook did not seem to encircle the jawbone as well as the larger hook.

The catch of sublegal-sized halibut on smaller hooks was significantly higher in all three of the comparisons where only hook size was varied on halibut gear: the smaller hooks caught from 27-37% more sublegal halibut. When both hook and bait sizes varied, the smaller hooks and baits caught 9-23% more sublegals, although these increases were not significant. The blackcod gear caught fewer sublegals in all of the four trials where gear type, bait type, and hook size varied, with significant differences in half of these latter trials.

In all cases where the hook size was varied, the average length of fish caught on the larger hooks was greater, the increase ranging from 1-13%. All but one of these increases were significant. Kolmogorov-Smirnov comparisons of the length-frequency plots for the hook-size only comparisons showed no significant difference in relative length distributions, although visual inspection of the plots suggests that the smaller hooks catch more smaller fish and fewer large fish. Length frequencies were significantly different in both trials where hook size and bait size were varied on halibut gear and all four of the trials where both gear type and bait were varied. At all except the smallest halibut lengths, halibut gear caught more fish than blackcod-style gear.

Table 6. Gear type experiments conducted during the 1998 summer experimental fishing (BC = blackcod gear, HAL = halibut gear). A two-tailed t-test was used to determine significance.

Gear and bait type test vs. ctrl	Vessel/ trip	Area[1]	# Sets	*df*	# Pairs	Ratio test/ctrl.[2]	T-test significance		Pounds caught
BC gear, herring vs. HAL gear, chum	LDA 4	3A	9	8	29	0.39	0.000	+	50,498
BC gear, herring vs. HAL gear, chum	LDA 6	3A	11	10	40	0.20	0.000	+	47,026
BC gear, herring vs. HAL gear, chum	LDA 7	3A	7	6	29	0.26	0.000	+	40,766
BC gear vs. HAL gear, 4 oz chum	ZEN 3	3B	6	5	30	0.79	0.110	-	37,231
			33		128				175,521

[1] IPHC Regulatory Area

[2] the ratio between the average test CPUE and the average control CPUE.

Bait quality and bait type

Average differences in legal-sized CPUE ranged from 5-44% between sets of baits being compared (Table 7), with the dark chum out-fishing the semi-bright in five of the nine experiments. Differences were significant in only two of the nine comparisons between dark and semi-bright chum; in one experiment the dark out-fished the semi-bright by about 13%, and in the other, the dark averaged 24% less than the semi-bright. In one experiment, the baits compared were from the same run of fish, purchased fresh on the fishing grounds and sorted by the charter vessel into semi-bright and dark grades. In this case, the semi-bright salmon averaged a substantially higher catch than the dark salmon, although this difference was not statistically significant. Two experiments that compared the same batches of bait had similar results, although again not significant. Differences in catches of sublegal-sized halibut varied from 2-50%. While only one of these comparisons was significant, the sublegal NPUE seemed to follow the trend of legal CPUE: higher legal catches usually mirrored by higher sublegal

Table 7. Bait quality experiments conducted during the 1998 summer experimental fishing. All baits were 4 ounce. A two-tailed t-test was used to determine significance.

Bait type test vs. ctrl	Vessel/ trip	Area[1]	# Sets	*df*	# Pairs	Ratio test/ctrl.[2]	T-test significance		Pounds caught
Dark vs. Semi-bright Chum	OCV 3a[3]	2C	7	6	31	1.44	0.197	-	7,750
Dark vs. Semi-bright Chum	OCV 4[3]	2B	12	11	67	1.37	0.094	-	29,694
Dark vs. Semi-bright Chum	OCV 7	2B	11	10	85	0.76	0.009	+	28,526
Dark vs. Semi-bright Chum	ANL 7	3A	8	7	22	1.13	0.007	+	27,240
Dark vs. Semi-bright Chum	ANL 8	3A	3	2	9	1.25	0.185	-	7,937
Dark vs. Semi-bright Chum	ANL 13	3A	19	18	67	0.93	0.220	-	46,216
Dark vs. Semi-bright Chum	SAI 4	3A	3	2	12	0.81	0.559	-	11,536
Dark vs. Semi-bright Chum	SAI 5	3A	11	10	42	1.05	0.733	-	25,045
Dark vs. Semi-bright Chum	OCV 5a[4]	2C	4	3	24	0.63	0.099	-	9,164
Semi-bright #1 vs. Semi- #2	OCV 7	2C	18	17	125	1.17	0.079	-	50,014
Silver-bright#1 vs. Silver-#2	OCV 8a	2C	17	16	126	0.70	0.001	+	40,547
Semi-bright#1 vs. Silver-#2	OCV 8b	2C	3	2	20	0.72	0.186	-	6,317
			116		630				289,986

[1] IPHC Regulatory Area

[2] the ratio between the average test CPUE and the average control CPUE.

[3] OCV 3a and OCV 4 used the same batches of dark and semi-bright salmon.

[4] the baits compared in OCV 5a were from the same source, purchased fresh on the fishing grounds.

catches. Average length was significantly different in only one comparison. Differences in average length varied from 1-5%, with no specific trend with either bait quality or in respect to which bait had caught greater numbers of halibut. Length frequencies were significantly different in two of the nine dark/semi-bright comparisons, one where the dark caught more halibut, and one where the reverse was true.

Results varied widely in the bait type experiments (Table 8). Comparing a batch of chum salmon to Pacific cod, two experiments by the same vessel showed cod catching 30% less and 39% more than the salmon bait. The latter difference was significant, but the only difference in the experiments was the location of fishing, the vessel having made a major shift in from the Semidi Island area to east of Kodiak Island. A third experiment, returning to the general area of the second experiment, showed essentially no difference in catch between the baits, while a fourth experiment by the same vessel showed a 30% lesser catch by the cod bait. Differences in catch of sublegal-sized halibut were similarly varied, but in all cases the cod bait caught less sublegals than the salmon bait. Only one of these decreases was significant. In all cases, the average length of the halibut caught on cod bait was smaller, although these decreases were not significant. K-S tests indicated that two of the four length-frequency comparisons between halibut caught on cod and salmon baits showed significant differences: in one case cod baits caught more halibut than the salmon bait, and in the other case this relationship was reversed.

Table 8. Bait type experiments conducted during the 1998 summer experimental fishing. A two-tailed t-test was used to determine significance.

Bait type test vs. ctrl.	Vessel/ trip	Area[1]	# Sets	*df*	# Pairs	Ratio test/ctrl.[2]	T-test significance		Pounds caught
Pacific cod vs. chum	ANL 4a	3B	5	4	15	1.30	0.299	-	9,431
Pacific cod vs. chum	ANL 4b	3A	8	7	28	0.61	0.039	+	14,538
Pacific cod vs. chum	ANL 5	3A	14	13	50	1.00	0.998	-	47,021
Pacific cod vs. chum	ANL 6	3A	16	15	56	1.30	0.110	-	55,832
Pollock vs. squid	SAI 3	3A	14	13	52	1.03	0.767	-	61,432
			57		201				188,254

[1] IPHC Regulatory Area

[2] the ratio between the average test CPUE and the average control CPUE.

Discussion

The 1998 experiments were designed as pilots, to investigate relationships between baits, hooks, and gear, and their effects on halibut CPUE. In many cases, the same or similar experiments were conducted by different vessels, in different times, or in different areas. In general when a number of different experiments suggest the same result, that result can be expected to carry more validity than a single experiment conducted by only one vessel or in one time or place. When a series of experiments suggest different results, it is likely that there is a further mechanism effecting the experiment, beyond those parameters controlled in the experimental design. A vessel or fishing power effect has been well documented in various fisheries, one vessel consistently catching more or different fish than another (Hovgård and Lassen, 2000). Inter-vessel differences in efficiency can be caused by vessel characteristics such as type of groundline or ganion used, hauling speed, and crew and skipper skills. Area and time differences might result from changes in season, tide, or species composition in the area fished.

The 1998 experiments demonstrated catch differences with bait size, hook size, bait quality and type. The mechanisms of these differences most likely operate at different stages in the capture process. The capture of any fish on hook and line has three components; arousal, location (search), and food uptake (bait attack and ingestion). Arousal to the presence of food is a distant occurrence; bait odor carried in an odor plume by bottom currents attracting fish from well beyond the immediate area of the baited gear (Atema 1980). This arousal has been shown in sablefish to occur at very large dilutions of the original odor, depending on the recent feeding history of individual fish (Løkkeborg et al 1995), and thus is capable of occurring at long distances from the odor source. More successful bait would release a higher concentration of whatever scent a fish might respond to. This could be through being larger, having a more concentrated amount of odor material (as from a larger bait), having a more concentrated or more effective amount of material (as from a different batch or quality or type of bait), or possibly releasing the odor material more quickly, effectively creating a stronger odor trail. Once a fish is aroused to the bait presence, it follows the odor trail to the bait, following prevailing currents to locate the source of the bait odor. Løkkeborg (1998) demonstrated this for codfish (*Gadus morhua*). Halibut have been shown to most often approach baited hooks swimming upcurrent, presumably following a bait odor (Kaimmer 1999). Catch differences could arise from differences in bait-attack rates. While attack rates have been shown to vary with fish size as well as bait type and size for a number of species (Bjordal and Løkkeborg 1996) this has not yet been demonstrated for halibut. The capture process is complete when the fish has been successfully hooked. Kaimmer (1999) showed that halibut hooking success on 16/0 circle hooks varies with fish length, smaller fish having a lower probability of hooking than larger individuals, probably related to the relative dimensions of the bait/hook and the fish's mouth.

Larger baits caught significantly more pounds of legal-sized fish than smaller baits in the 1998 experiments, with only a slight non-significant increase in average length. There was a significant difference in the relative number of sublegal-sized halibut in only three of the nine bait size experiments, the direction of the difference influenced by the absolute size of the baits being compared. For bait sizes over 4 oz. there appeared to be a larger bait/fewer small fish pattern, although K-S tests indicated no significant change in the relative size composition of the compared catches. The larger bait was either attracting more large fish (by a more intensive odor plume) or stimulating more bait attacks (by presenting a larger visual cue). Kaimmer (1999) observed a mechanism for size selection through hooking success, where smaller fish would become hooked less often than larger fish on a given combination of hook and bait size. There could be a combination of effects, where all sizes of fish are more strongly attracted to larger baits, but differences in hooking success result in higher catches only for the larger-size fish. It is also possible that a greater catch of larger fish is the result of greater foraging ranges for these fish, resulting in higher encounter rates with the odor plume and therefore a higher probability of encountering baited gear (Løkkeborg and Bjordal 1992, Engås and Løkkeborg 1994, Bjordal and Løkkeborg 1996).

The CPUE of legal-sized halibut was generally not significantly affected by hook size, although a small decrease in overall average length was seen with the smaller hooks. In contrast, the NPUE of sublegal-sized halibut was significantly increased on smaller hooks. The mechanism for size selection through hook size is likely through differing hooking success.

When bait size and hook size were both varied, or when different types or sizes of baits were fished on different gear types, significant differences were seen in average CPUE of legal-sized halibut, average length of halibut, and in the K-S comparisons of length frequencies. The smaller baits, fished on gear with smaller hooks and closer spacing, caught significantly fewer pounds of halibut per 100 hooks, ranging from 60-80% less, and those fish caught on the smaller hooks were of a significantly smaller average length. It is probable that these differences result from a combination of factors, including a greater attraction from larger baits, a higher hooking

success for smaller halibut on smaller hooks, and possibly a gear-saturation effect due to the greater density of hooks across the fishing ground with the blackcod-style gear.

Different catches by different bait types probably are also the result of mechanisms acting throughout the capture process, including different type and intensity of odor plumes, bait preferences in stimulating bait attacks, and possible different effects of bait size or texture on hooking success.

Conclusions

The results of the 1998 experiments clearly show some significant interaction between halibut catch and bait type and size, hook size and gear type, and fishing location. The interpretation of CPUE data clearly must consider these factors. The experiments conducted in the summer of 1998 were intended to provide information that would help identify and design future IPHC experiments. The experiments conducted, and their results, give an insight into the types of factors which can be tested, and the range of their effects. It is clear that varying bait quality, type or size, or hook size can have dramatic effects on the catch of small or large halibut. Surveys to determine or monitor setline catch rates should do everything possible to adjust for or otherwise standardize for these effects. Models which use this type of data should be aware of the dramatic effects small changes in bait can have on overall catch rates for a survey. For halibut management, experiments need to be conducted to determine more finely the effects of bait quality or size on halibut CPUE. Once this is done, the variation in these from survey to survey should be kept within bounds that minimize their effects. The variability of the 1998 results between different trials of the same experiment should serve as a caution in both designing and interpreting results of single-trip fishing experiments.

Acknowledgements

Steve Hoag and Bob Trumble were invaluable in the design of experiments and coordination of their application on the chartered vessels. The experiments resulted in a great amount of additional data-entry effort. IPHC port samplers Rhonda Miller and Binget Nilsson did primary data entry for most of the experimental data. Our Seattle data-entry staff, Linda Shen, Aragash Tesfatsion, and Jin-Hwa Chon did all data verification. Bob Trumble gave many detailed comments and extremely helpful reviews on this report as it was being developed and written. I would like to especially thank all the IPHC staff and the crews of the chartered commercial vessels who implemented the experimental designs in the field.

References

Atema, J. 1980. Chemical senses, chemical signals and feeding behavior in fishes. *In* Fish behavior and its use in the capture and culture of fishes. *Edited by* J. E. Bardach, J. J. Magnuson, R. C. May, and J. M. Reinhart. Int. Center for Living Aquatic Resources Management, Manila. pp. 57-101.

Bjordal, Å, and Løkkeborg, S. 1996. Longlining. Fishing News Books, Oxford.

Engås, A., and Løkkeborg, S. 1994. Abundance estimation using bottom gillnet and longline - the role of fish behavior. *In* Marine fish behavior in capture and abundance estimation. *Edited by* A. Fernö and S. Olsen. Fishing News Books, Oxford. pp. 9-27.

Hovgard, H. and Lassen, H. 2000. Manual on estimation of selectivity for gillnet and longline gears in abundance surveys. FAO Fisheries Tech. Paper 397.

Kaimmer, S. 1999. Direct observations on the hooking behavior of Pacific halibut. Fish. Bull. 97(4): 873-883.

Løkkeborg, S. 1998. Feeding behaviour of cod, *Gadus morhua*: activity rhythm and chemically mediated food search. Anim. Behav. 56: 371-378.

Løkkeborg, S., and Bjordal, Å. 1992. Species and size selectivity in longline fishing: a review. Fish. Res. 13: 311-322.

Løkkeborg, S, Olla, B.L., Pearson, W.H., and Davis, M.W. 1995 Behavioural responses of sablefish, *Anoplopoma fimbria*, to bait odour. J. Fish. Biol. 46(1): 142-155.

Quinn II, T., Best, E., Bijsterveld, L., and McGregor, I. 1983. Sampling Pacific halibut (*Hippoglossus stenolepis*) landings for age composition: history, evaluation, and estimation. Int. Pac. Halibut. Comm. Sci. Rep. 68.

Appendix. CPUE, NPUE, mean length, and length frequency results from 1998 Summer Experiments

The appendix contains detailed results of the statistical tests for the 1998 summer experiments. Appendix tables present information on CPUE, NPUE, mean length, and K-S tests for differences in length frequency. Appendix figures present x-y plots of CPUE and NPUE and length frequency plots by experiment.

Appendix Tables

Appendix Figures

Appendix Table 1. Bait size effects on catch per 100 16/0 hooks of legal-sized halibut by total weight (CPUE) and sublegal-sized halibut by number caught (NPUE), and mean length. Boxes around the probability estimate (P) indicate significant differences from t and k-s tests. Unless otherwise indicated, the bait type and quality used within each vessel trip differ only in bait size. For each vessel trip, the bait sizes are presented as a/b, where 'a' is the test size, and 'b' the control (ctrl) size in ounces.

	Test/Ctrl (oz.)	2/4	2/4	3/4	3/5	6/4	6/4	6/4	7/4	8/4	3/5[1]
	Bait	SA	SA	DS	SA	SA	SA	SA	SA	SA	SA[1]
	Vessel and trip	OCV1	WSU1	OCV3b	WSU8a	OCV5b	TDN11	TDN12	WSU2	OCV6	WSU8b
	Number of sets	8	23	4	29	11	10	7	28	7	13
	Number of pairs	38	123	20	150	65	29	24	136	51	59
	IPHC Region	2C	2B	2C	2B	2C	3A	3A	2B	2C	2B
	Pounds caught	14,347	22,895	4,723	26,823	26,448	23,277	14,544	18,365	29,005	8,582
≥ 82 cm	Mean Ctrl	575.0	244.9	346.2	250.9	394.1	303.1	259.4	147.4	598.5	101.9
CPUE	Mean Test	302.3	193.5	227.3	199.8	575.7	358.2	267.2	165.2	710.1	231.4
	ratio Test/Ctrl	0.53	0.79	0.66	0.77	1.46	1.18	1.03	1.12	1.19	2.27
	% change	-47.4%	-21.0%	-34.4%	-22.7%	46.1%	18.2%	3.0%	12.1%	18.6%	127.1%
	t Stat	2.290	2.542	1.559	2.093	-2.906	-1.275	-0.178	-1.277	-3.950	-4.250
	P 1-tail	0.028	0.009	0.108	0.023	0.008	0.117	0.432	0.106	0.004	0.001
	t Critical 1-tail	1.895	1.717	2.353	1.701	1.812	1.833	1.943	1.703	1.943	1.782
< 82 cm	Mean Ctrl	4.2	3.5	2.9	2.1	1.5	3.5	5.2	1.7	5.1	0.8
NPUE	Mean Test	2.8	3.5	4.5	1.9	1.6	2.9	3.4	1.1	3.9	2.3
	ratio Test/Ctrl	0.68	1.00	1.55	0.91	1.05	0.82	0.66	0.66	0.77	2.88
	% change	-32.3%	-0.1%	55.0%	-3.1%	4.9%	-18.0%	-34.4%	-33.9%	-23.1%	188.1%
	t Stat	2.739	0.009	-1.314	0.622	-0.277	1.811	1.723	2.215	2.194	-4.325
	P 1-tail	0.014	0.496	0.140	0.269	0.394	0.052	0.068	0.018	0.035	0.000
ALL	Mean Ctrl	103.3	96.2	111.4	100.2	106.4	99.2	92.6	102.1	101.9	106.3
Mean	Mean Test	100.9	95.3	95.8	98.8	111.5	103.3	95.8	104.7	105.7	103.2
Length	Ratio Test/Ctrl	0.98	0.99	0.86	0.99	1.05	1.04	1.03	1.03	1.04	0.97
	% change	-2.4%	-0.9%	-14.0%	-1.4%	4.8%	4.1%	3.5%	2.5%	3.7%	-2.8%
	t Stat	0.645	0.282	1.891	0.710	1.648	1.717	1.520	1.224	2.255	1.410
	P 1-tail	0.270	0.390	0.078	0.242	0.065	0.060	0.090	0.116	0.033	0.092
≥82 cm	Mean Ctrl	112.0	102.2	121.6	106.5	111.4	105.5	101.9	109.4	107.9	113.6
Mean	Mean Test	109.4	100.3	112.9	103.9	114.3	107.6	104.7	110.6	110.3	112.0
Length	Ratio Test/Ctrl	0.98	0.98	0.93	0.98	1.03	1.02	1.03	1.01	1.02	0.99
	% change	-2.3%	-1.8%	-7.2%	-2.4%	2.6%	2.0%	2.7%	1.1%	2.2%	-1.5%
	t Stat	0.938	0.652	1.166	1.125	1.054	1.335	0.870	0.525	0.978	0.694
	P 1-tail	0.190	0.261	0.164	0.135	0.158	0.107	0.209	0.302	0.183	0.250
< 82 cm	Mean Ctrl	74.9	76.5	74.4	77.2	76.5	74.5	74.3	75.5	75.2	77.2
Mean	Mean Test	73.7	75.8	73.0	76.8	77.5	75.3	75.4	76.4	75.8	75.4
Length	ratio test/ctrl	0.98	0.99	0.98	0.99	1.01	1.01	1.01	1.01	1.01	0.98
	% change	-1.6%	-1.0%	-1.9%	-0.6%	1.3%	1.1%	1.5%	1.2%	0.8%	-2.3%
	t Stat	1.196	1.370	0.712	0.714	1.380	2.671	1.372	1.053	1.336	1.575
	P 1-tail	0.135	0.094	0.275	0.242	0.100	0.014	0.110	0.152	0.126	0.077
65-165	k-s statistic	0.267	.0693	.0891	.0792	.1386	.0891	.0891	.1782	.0693	.2970
Cm	p-value	0.001	0.930	0.739	0.847	0.235	0.739	0.739	0.063	0.930	0.000

[1]In vessel trip WSU8a, the bait for both bait sizes was from the same frozen batch. In vessel trip WSU8b, the 3-ounce bait was from a batch of fresh bait, while the 5-ounce bait was from the same frozen batch used in vessel trip WSU8a.

Appendix Table 2. Hook size and mixed gear type/bait effects on catch per 100 hooks of legal-sized halibut by total weight (CPUE) and sublegal-sized halibut by number caught (NPUE), and mean length. Boxes around the probability estimate (P) indicate significant differences from t and k-s tests. For each vessel trip, test and control variables are presented as a/b, where 'a' is the test and 'b' the control treatment.

	Test/Ctrl Gear	Hal/Hal	Hal/Hal	Hal/Hal	Hal/Hal	Hal/Hal	BC/Hal	BC/Hal	BC/Hal	BC/Hal
	Test/Ctrl Hk Size	13/16	14/16	14/16	14/16	14/16	14/16	14/16	14/16	14/16
	Test/Ctrl Bait	SA/SA	SA/SA	SA/SA	SA/SA[1]	SA/SA[1]	HR/SA	HR/SA	HR/SA	HR/HR
	Vessel and trip	WSU3	BDP9	BDP10	TYA4[1]	TYA5[1]	LDA4[2]	LDA6[2]	LDA7[2]	ZEN3[2]
	Number of sets	25	25	19	6	20	9	10	7	6
	Number of pairs	125	102	73	30	100	29	40	29	30
	IPHC Region	2B	2C	2C	2C	2B	3A	3A	3A	3B
	Pounds caught	24,813	50,744	53,722	7,438	22,324	50,498	47,026	40,766	37,231
≥ 82 cm	Mean Ctrl	230.9	275.9	442.0	275.3	264.5	665.1	695.8	654.8	313.1
CPUE	Mean Test	218.4	283.6	406.8	196.5	174.0	262.5	138.5	171.1	247.6
	Ratio Test/Ctrl	0.95	1.03	0.92	0.72	0.66	0.40	0.20	0.26	0.79
	% difference	-5.4%	2.8%	-8.0%	-28.6%	-34.2%	-60.5%	-80.1%	-73.9%	-20.9%
	t Stat	0.692	-0.343	0.683	2.738	3.499	5.922	7.678	3.944	1.464
	P 1-tail	0.248	0.367	0.252	0.020	0.001	0.000	0.000	0.004	0.109
	t Critical 1-tail	1.711	1.711	1.734	2.015	1.734	1.860	1.833	1.943	2.132
< 82 cm	Mean Ctrl	2.9	3.2	2.0	1.1	1.8	5.8	2.7	4.2	6.3
NPUE	Mean Test	4.1	4.4	2.6	1.2	2.2	4.4	1.7	2.5	5.8
	Ratio Test/Ctrl	1.38	1.36	1.27	1.09	1.23	0.76	0.62	0.61	0.91
	% difference	37.6%	36.1%	27.0%	9.1%	23.0%	-24.2%	-38.2%	-38.9%	-8.9%
	t Stat	-4.445	-3.656	-2.197	0.473	-1.131	1.552	2.698	2.111	0.926
	P 1-tail	0.000	0.001	0.021	0.328	0.136	0.080	0.012	0.040	0.203
ALL	Mean Ctrl	95.8	100.6	107.0	110.6	106.4	102.6	112.4	109.0	95.3
Length	Mean Test	92.5	97.4	104.8	103.4	100.5	89.7	101.3	96.0	94.0
	Ratio Test/Ctrl	0.97	0.97	0.98	0.94	0.94	0.87	0.90	0.88	0.99
	% Change	-3.4%	-3.2%	-2.0%	-6.5%	-5.5%	-12.5%	-9.9%	-11.9%	-1.4%
	t Stat	2.999	3.309	2.186	2.676	2.326	8.811	7.269	7.051	0.905
	P 1-tail	0.003	0.001	0.021	0.022	0.016	0.000	0.000	0.000	0.204
≥ 82 cm	Mean Ctrl	102.3	111.8	111.2	115.1	114.6	111.7	117.8	115.4	104.4
Mean	Mean Test	99.6	109.3	109.7	110.2	110.6	106.2	110.3	106.1	104.0
Length	Ratio Test/Ctrl	0.97	0.98	0.99	0.96	0.97	0.95	0.94	0.92	1.00
	% Change	-2.6%	-2.2%	-1.3%	-4.3%	-3.5%	-4.9%	-6.4%	-8.0%	-0.3%
	t Stat	2.111	1.841	1.584	1.981	1.705	4.480	7.129	7.775	0.232
	P 1-tail	0.023	0.039	0.065	0.052	0.053	0.001	0.000	0.000	0.413
< 82 cm	Mean Ctrl	76.3	73.8	74.7	110.6	73.8	74.4	74.8	75.9	74.2
Mean	Mean Test	75.9	72.5	74.4	73.6	72.3	72.2	72.7	74.2	74.8
Length	Ratio Test/Ctrl	1.00	0.98	1.00	0.67	0.98	0.97	0.97	0.98	1.01
	% Change	-0.4%	-1.7%	-0.4%	-33.5%	-2.0%	-3.0%	-2.8%	-2.2%	0.8%
	t Stat	0.564	1.820	0.454	8.928	1.386	3.275	2.649	2.859	-1.066
	P 1-tail	0.290	0.041	0.328	0.000	0.093	0.006	0.017	0.018	0.167
65-165	K-s statistic	.1287	.1584	.0792	.1980	.2277	.2772	.7030	.4851	.2277
Cm	p-value	0.310	0.126	0.847	0.029	0.008	0.001	0.000	0.000	0.008

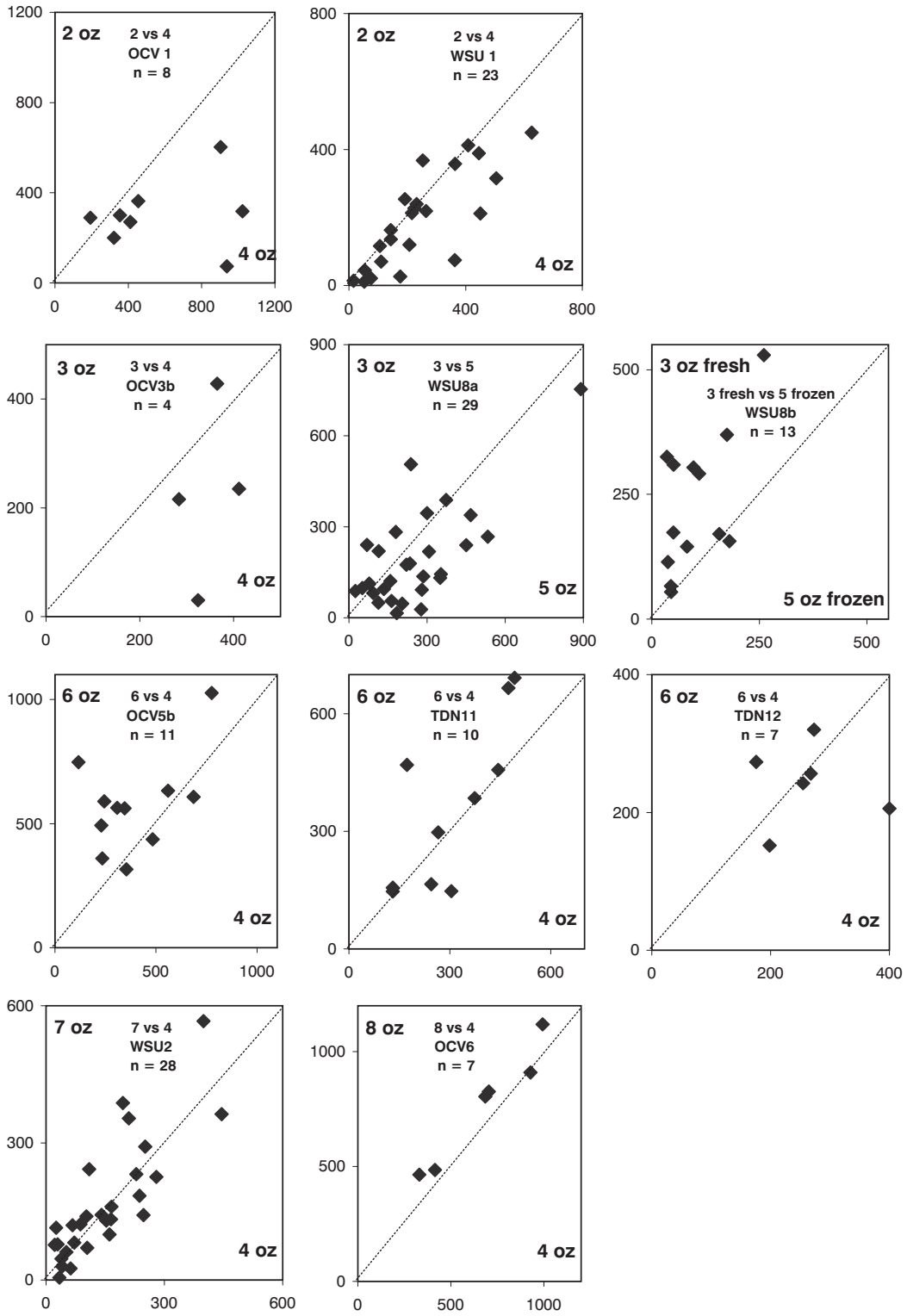
[1]TYA trips 4 and 5 varied bait size and hook size, matching 14/0 hooks with 2-oz baits and 16/0 hooks with 3-oz baits.
[2]LDA and Zen trips varied gear type and hook size, fishing 14/0 hooks on blackcod gear and 16/0 hooks on halibut gear.

Appendix Table 3. Bait quality effects on catch per 100 16/0 hooks of legal-sized halibut by total weight (CPUE) and sublegal-sized halibut by number caught (NPUE), and mean length. Boxes around the probability estimate (P) indicate significant differences from t and k-s tests. For each vessel trip, test and control variables are presented as a/b, where 'a' is the test and 'b' the control treatment.

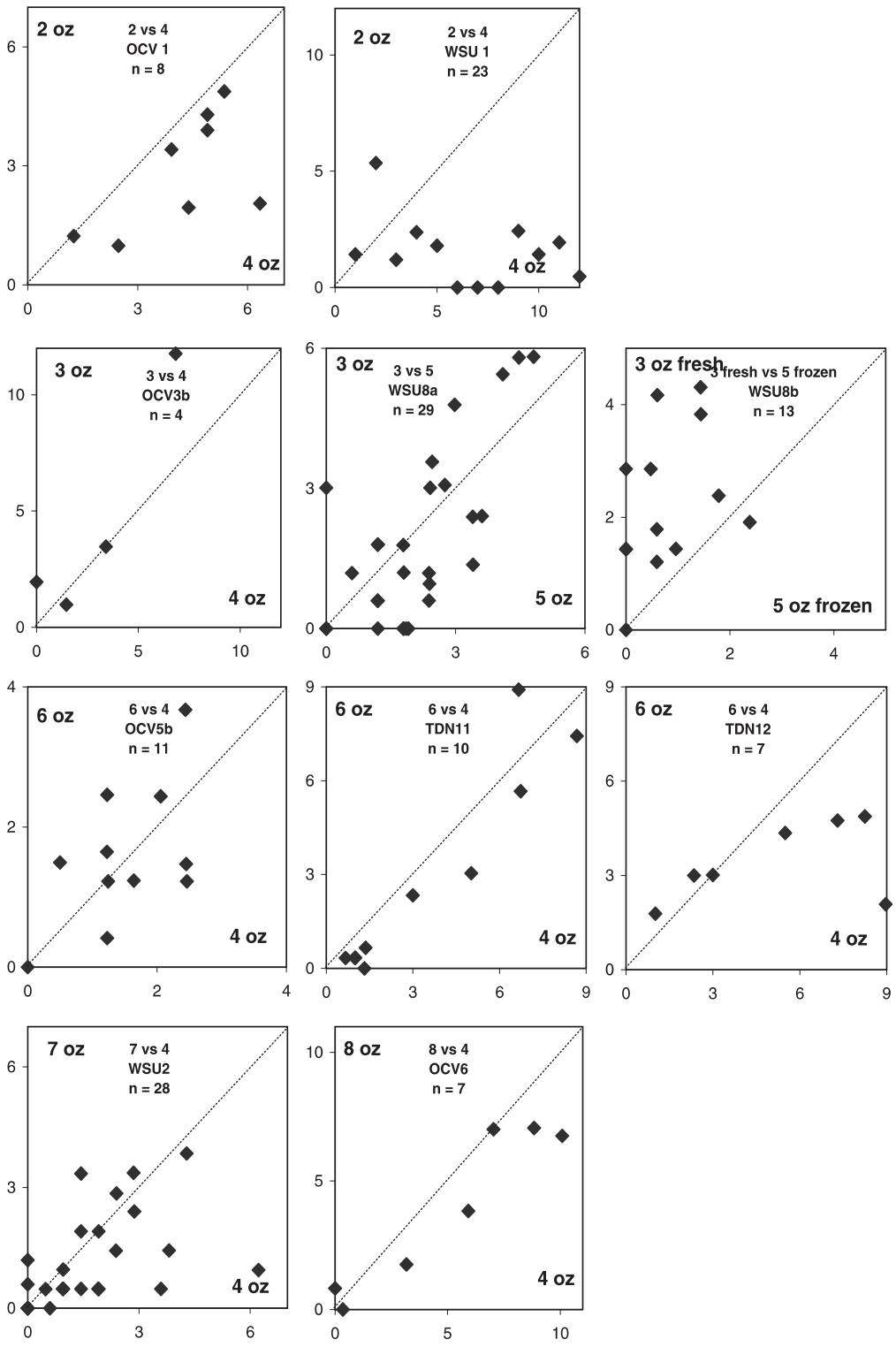
	Test/Ctrl bait	DS/SA	DS/SA	DS/SA	DS/SA	DS/SA	DS/SA	DS/SA	DS/SA	DS/SA	SA1/SA2	SL1/SL2	SA/SL2
	Vessel and trip	OCV3a	OCV4	OCV6	ANL7	ANL8	ANL13	SAI4	SAI5	OCV5a	OCV7	OCV8a	OCV8b
	Number of sets	7	12	11	8	3	19	3	11	4	18	17	3
	IPHC Region	2C	2B	2B	3A	3A	3A	3A	3A	2C	2C	2C	2C
	Pounds caught	7,750	29,694	28,526	28,240	7,937	46,216	11,536	25,045	9,164	50,014	40,547	6,317
≥ 82 cm	Mean test	365.7	726.2	335.1	638.8	558.1	376.1	408.6	325.8	357.0	497.8	320.1	322.6
CPUE	Mean Ctrl	254.8	531.6	443.8	564.2	447.3	405.0	503.5	310.9	568.8	426.9	454.5	449.9
	ratio test/ctrl	1.44	1.37	0.76	1.13	1.25	0.93	0.81	1.05	0.63	1.17	0.70	0.72
	% change	43.6%	36.6%	-24.5%	13.2%	24.8%	-7.1%	-18.8%	4.8%	-37.2%	16.6%	-29.6%	-28.3%
	t Stat	1.451	1.831	-3.205	3.743	1.992	-1.269	-0.694	0.351	-2.368	1.867	-3.929	-1.984
	P 2-tail	0.197	0.094	**0.009**	**0.007**	0.185	0.220	0.559	0.733	0.099	0.079	**0.001**	0.186
	t Critical 2-tail	2.447	2.201	2.228	2.365	4.303	2.101	4.303	2.228	3.182	2.110	2.120	4.303
< 82 cm	Mean test	2.4	8.7	1.2	3.6	5.2	3.5	7.1	1.9	1.4	8.1	5.3	5.1
NPUE	Mean Ctrl	1.6	7.4	1.3	3.1	4.8	3.7	7.0	1.7	1.5	8.2	5.7	7.0
	ratio test/ctrl	1.51	1.17	0.89	1.15	1.08	0.96	1.01	1.12	0.93	0.98	0.93	0.73
	% change	50.7%	17.4%	-11.4%	15.2%	8.0%	-4.4%	1.0%	11.8%	-7.2%	-1.9%	-7.1%	-26.6%
	t Stat	2.667	1.662	-0.607	0.576	0.353	-0.396	0.094	0.553	-0.2292	-0.325	-0.755	-1.797
	P 2-tail	**0.037**	0.125	0.558	0.583	0.758	0.697	0.933	0.592	0.8335	0.749	0.461	0.214
ALL	Mean ctrl	104.9	102.4	114.5	102.8	104.7	100.0	91.9	113.5	111.3	95.3	102.8	101.9
Mean	Mean test	104.7	103.1	108.8	103.3	103.0	99.4	89.5	115.6	106.5	97.5	103.0	100.6
Length	ratio test/ctrl	1.00	1.01	0.95	1.01	0.98	0.99	0.97	1.02	0.96	1.02	1.00	0.99
	% change	-0.2%	0.7%	-4.9%	0.5%	-1.6%	-0.6%	-2.6%	1.9%	-4.3%	2.3%	0.1%	-1.3%
	t Stat	-0.076	0.343	-4.950	0.380	-0.257	-0.440	-1.655	0.533	-1.471	1.781	0.097	-0.796
	P 2-tail	0.942	0.738	**0.001**	0.715	0.822	0.665	0.240	0.606	0.238	0.093	0.924	0.509
≥ 82 cm	Mean ctrl	111.2	110.5	117.9	107.9	113.7	107.1	97.5	120.1	114.2	106.5	112.8	107.9
Mean	Mean test	114.0	111.3	112.1	108.8	113.0	107.8	94.5	121.8	110.4	108.3	111.9	110.6
Length	ratio test/ctrl	1.02	1.01	0.95	1.01	0.99	1.01	0.97	1.01	0.97	1.02	0.99	1.02
	% change	2.5%	0.7%	-5.0%	0.8%	-0.6%	0.7%	-3.1%	1.4%	-3.3%	1.7%	-0.8%	2.5%
	t Stat	1.042	0.440	-5.708	0.553	-0.112	0.484	-1.225	0.318	-1.676	1.478	-0.705	1.087
	P 2-tail	0.337	0.669	**0.000**	0.598	0.921	0.635	0.345	0.757	0.192	0.158	0.491	0.391
< 82 cm	Mean ctrl	77.3	75.3	76.9	75.5	75.1	75.6	77.6	78.6	78.5	74.9	74.1	73.2
Mean	Mean test	75.8	75.4	77.3	77.3	75.1	76.1	78.0	77.1	77.5	74.4	75.0	74.2
Length	ratio test/ctrl	0.98	1.00	1.01	1.02	1.00	1.01	1.01	0.98	0.99	0.99	1.01	1.01
	% change	-1.9%	0.2%	0.5%	2.4%	0.0%	0.6%	0.5%	-2.0%	-1.3%	-0.7%	1.1%	1.4%
	t Stat	-1.779	0.206	0.947	1.609	0.027	0.835	2.831	-1.443	-2.949	-0.994	1.128	0.555
	P 2-tail	0.125	0.842	0.380	0.152	0.981	0.415	0.105	0.209	0.060	0.334	0.278	0.677
65-165	k-s statistic	.1980	.1386	.1584	.1287	.0792	.1089	.1584	.1386	.1980	.0693	.1980	.2079
Cm	p-value	**0.029**	0.235	0.126	0.310	0.847	0.506	0.126	0.235	**0.029**	0.930	**0.029**	**0.019**

Appendix Table 4. Bait type effects on catch per 100 16/0 hooks of legal-sized halibut by total weight (CPUE) and sublegal-sized halibut by number caught (NPUE), and mean length. Boxes around the probability estimate (P) indicate significant differences from t and k-s tests. For each vessel trip, test and control variables are presented as a/b, where 'a' is the test and 'b' the control treatment.

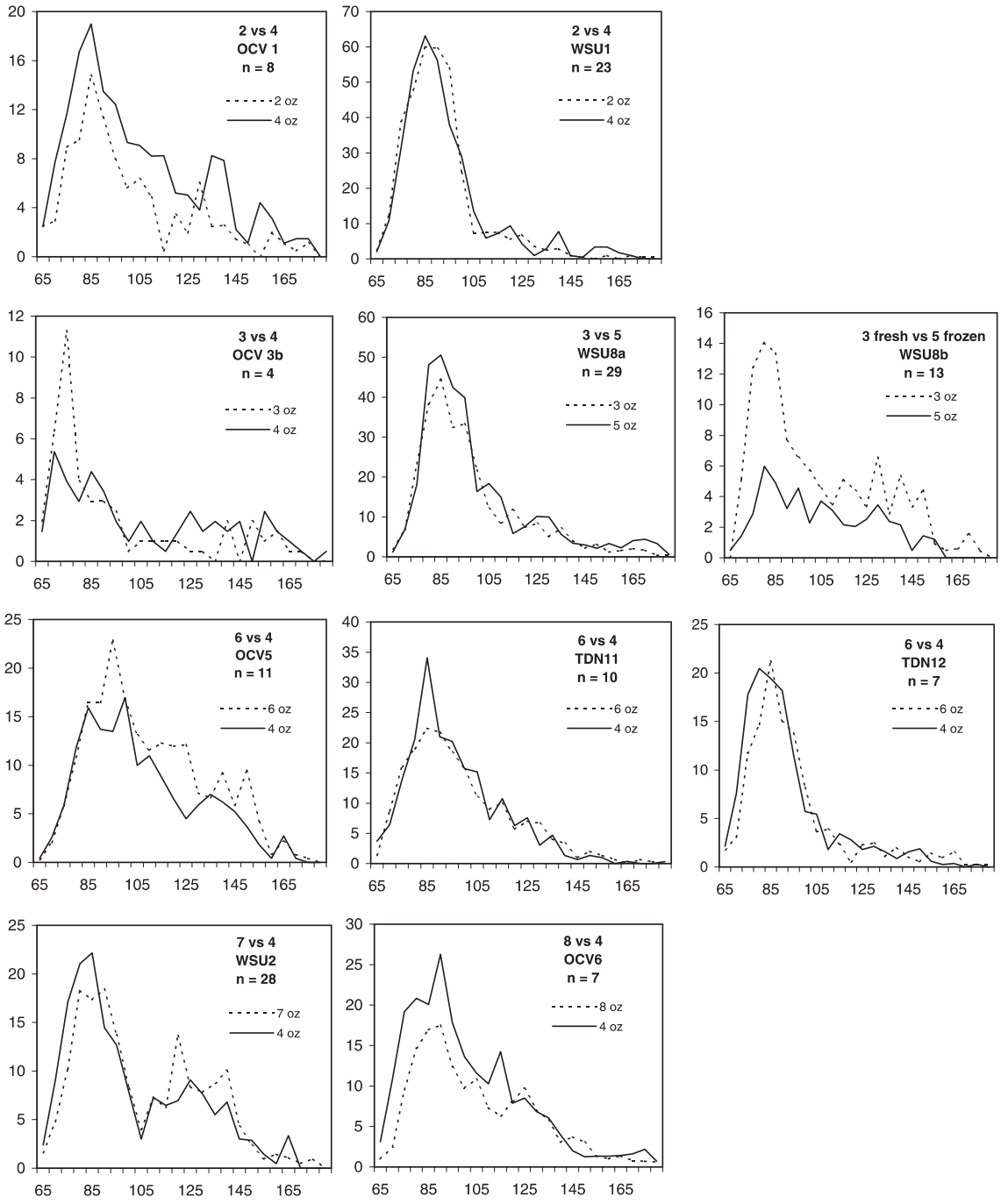
	Test/Ctrl bait	**GC/SA**	**GC/SA**	**GC/SA**	**GC/SA**	**PO/SQ**
	Vessel and trip	ANL4a	ANL4b	ANL5	ANL6	SAI3
	Number of sets	5	8	14	16	13
	IPHC Region	3B	3A	3A	3A	3A
	Pounds caught	9,431	14,538	47,021	55,832	61,432
≥ 82 cm	Mean Ctrl	255.9	347.9	480.1	446.1	602.5
CPUE	Mean Test	333.9	212.3	479.9	581.3	618.2
	Ratio Test/Ctrl	1.30	0.61	1.00	1.30	1.03
	% difference	-30.5%	39.0%	0.0%	-30.3%	-2.6%
	t Stat	1.193	-2.538	-0.003	1.701	0.303
	P 2-tail	0.299	**0.039**	0.998	0.110	0.767
	t Critical 2-tail	2.776	2.365	2.160	2.131	2.179
< 82 cm	Mean Ctrl	4.1	4.3	4.3	2.5	4.3
NPUE	Mean Test	3.5	1.3	3.2	2.3	4.7
	Ratio Test/Ctrl	0.84	0.31	0.75	0.95	1.09
	% difference	15.6%	69.1%	25.0%	5.0%	-9.1%
	t Stat	-1.360	-3.238	-2.142	-0.320	0.749
	P 2-tail	0.245	**0.014**	0.052	0.754	0.469
ALL	Mean Ctrl	91.7	96.5	104.2	101.5	101.6
Mean	Mean Test	93.9	98.1	106.5	102.1	102.1
Length	Ratio Test/Ctrl	1.02	1.02	1.02	1.01	1.01
	% difference	2.4%	1.6%	2.2%	0.6%	0.5%
	t Stat	1.510	0.562	1.586	0.515	0.437
	P 2-tail	0.205	0.592	0.137	0.614	0.670
≥ 82 cm	Mean Ctrl	99.7	104.9	108.5	106.2	106.4
Mean	Mean Test	101.1	102.5	109.3	105.6	107.6
Length	Ratio Test/Ctrl	1.01	0.98	1.01	0.99	1.01
	% difference	1.4%	-2.3%	0.7%	-0.6%	1.1%
	t Stat	2.960	-1.130	0.753	-0.476	1.205
	P 2-tail	0.060	0.296	0.465	0.641	0.251
< 82 cm	Mean Ctrl	74.8	74.6	76.1	76.1	74.4
Mean	Mean Test	76.5	76.3	76.8	76.7	76.3
Length	Ratio Test/Ctrl	1.02	1.02	1.01	1.01	1.03
	% difference	2.2%	2.2%	0.9%	0.8%	2.6%
	t Stat	1.508	1.635	0.629	0.866	1.955
	P 2-tail	0.229	0.146	0.547	0.401	0.074
65-165	k-s statistic	.0693	.2772	.0792	.2376	.0792
Cm	p-value	.9304	**.0006**	.8471	**.0047**	.8471



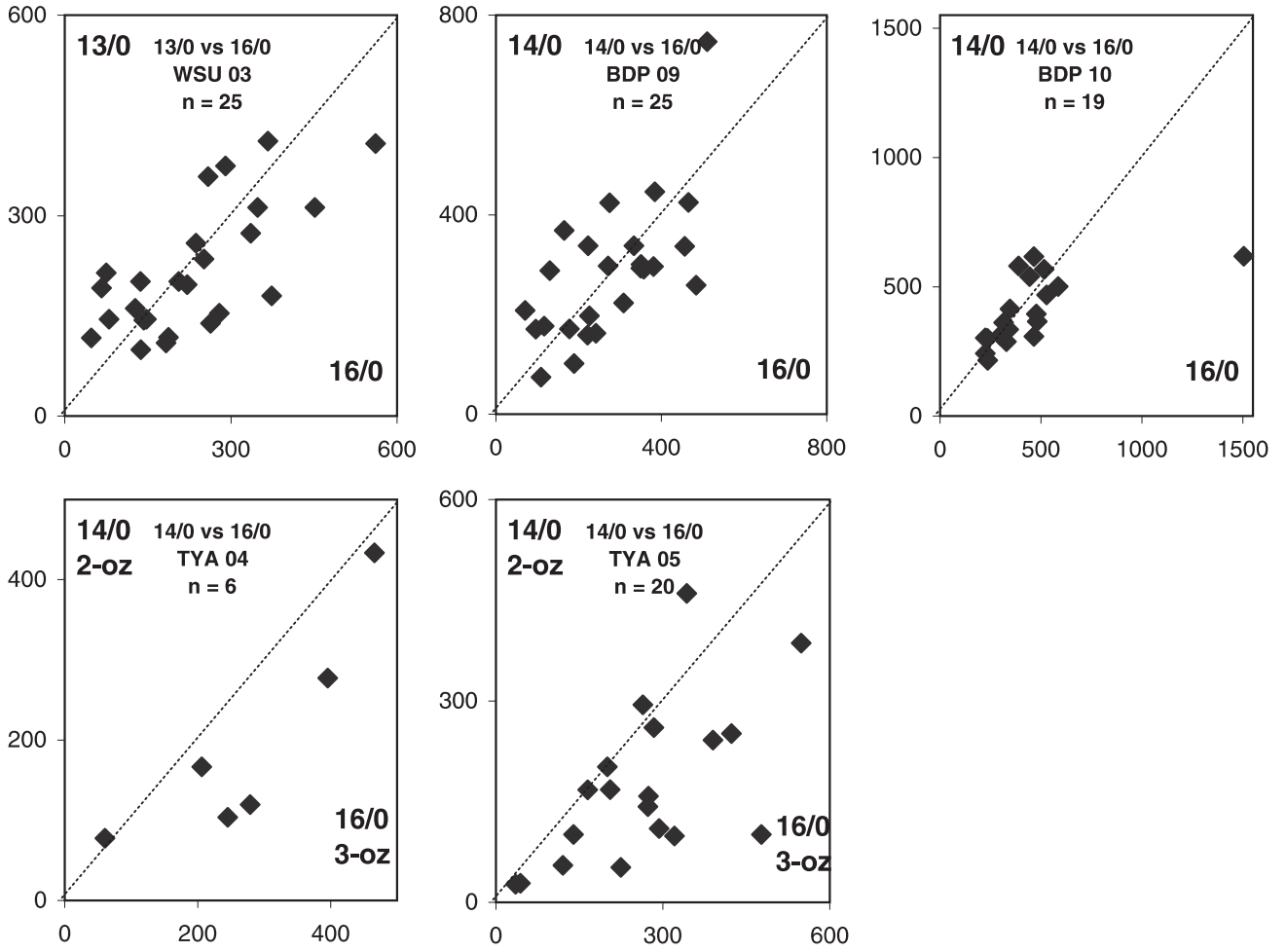
Appendix Figure 1. Paired observations of legal-sized halibut CPUE (lbs. per 100 hooks) in bait-size experiments. Unless otherwise indicated, the baits used within each vessel trip differ only in bait size.



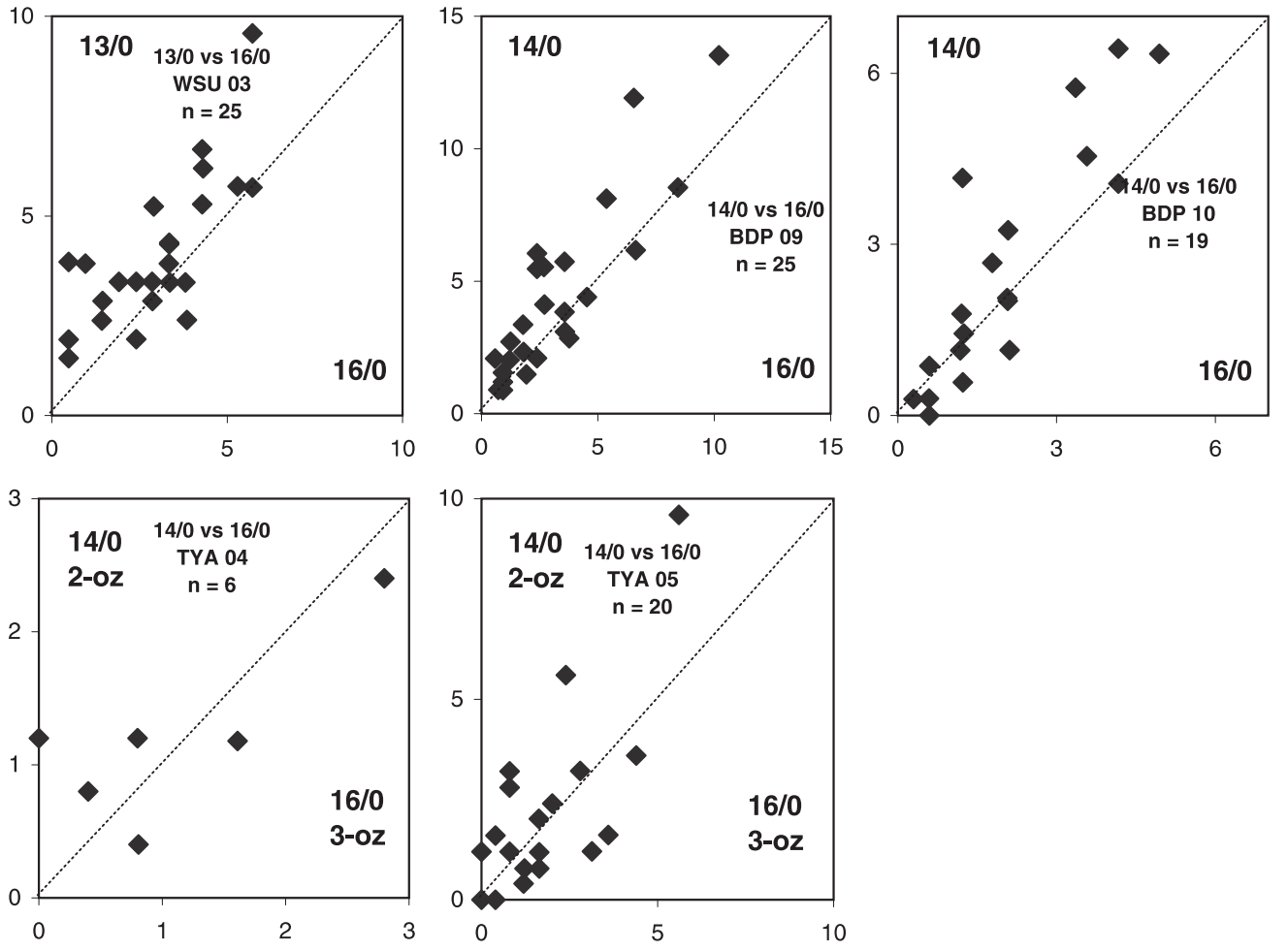
Appendix Figure 2. Paired observations of sublegal-sized halibut NPUE (no. per 100 hooks) in bait-size experiments. Unless otherwise indicated, the baits used within each vessel trip differ only in bait size.



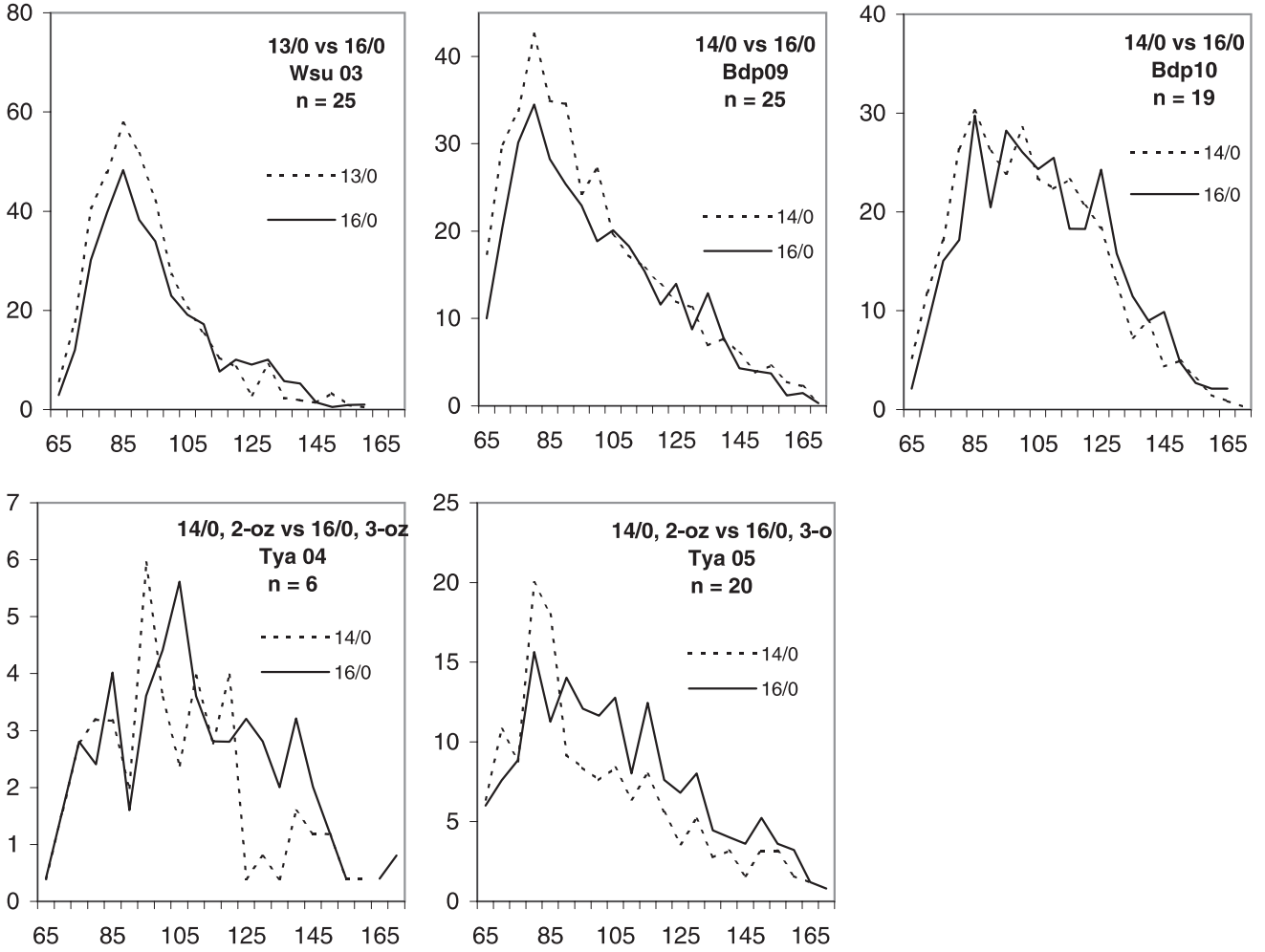
Appendix Figure 3. Length-frequency results in bait-size experiments. Vertical axis is number per experiment, summed from number per standardized 100-hook set. Horizontal axis is 5-cm length group.



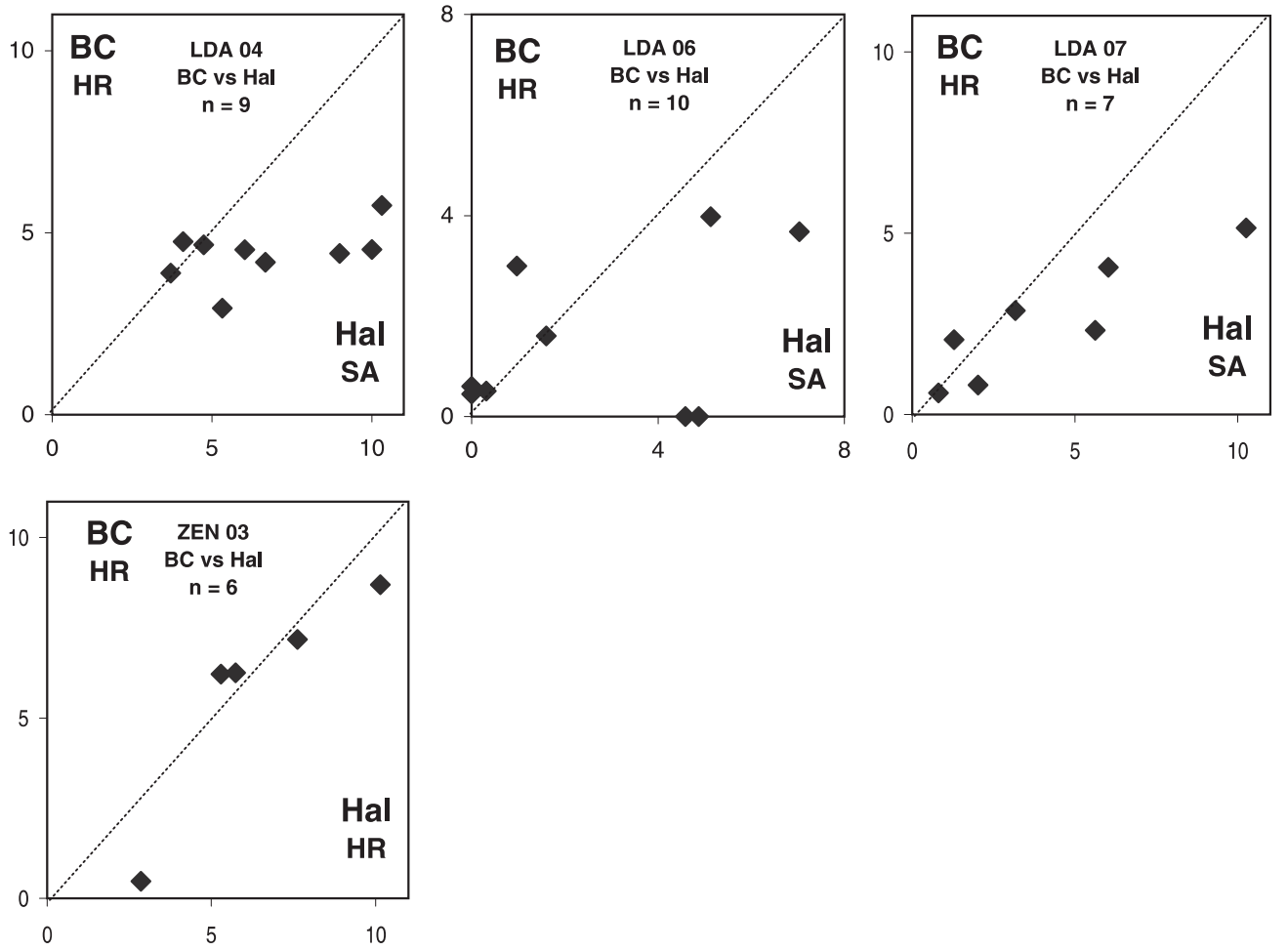
Appendix Figure 4. Paired observations of legal-sized halibut CPUE (lbs. per 100 hooks) in hook-size and mixed hook-size/bait-size experiments. The baits used within each vessel trip are of the same type and quality, and differ in bait size only as indicated.



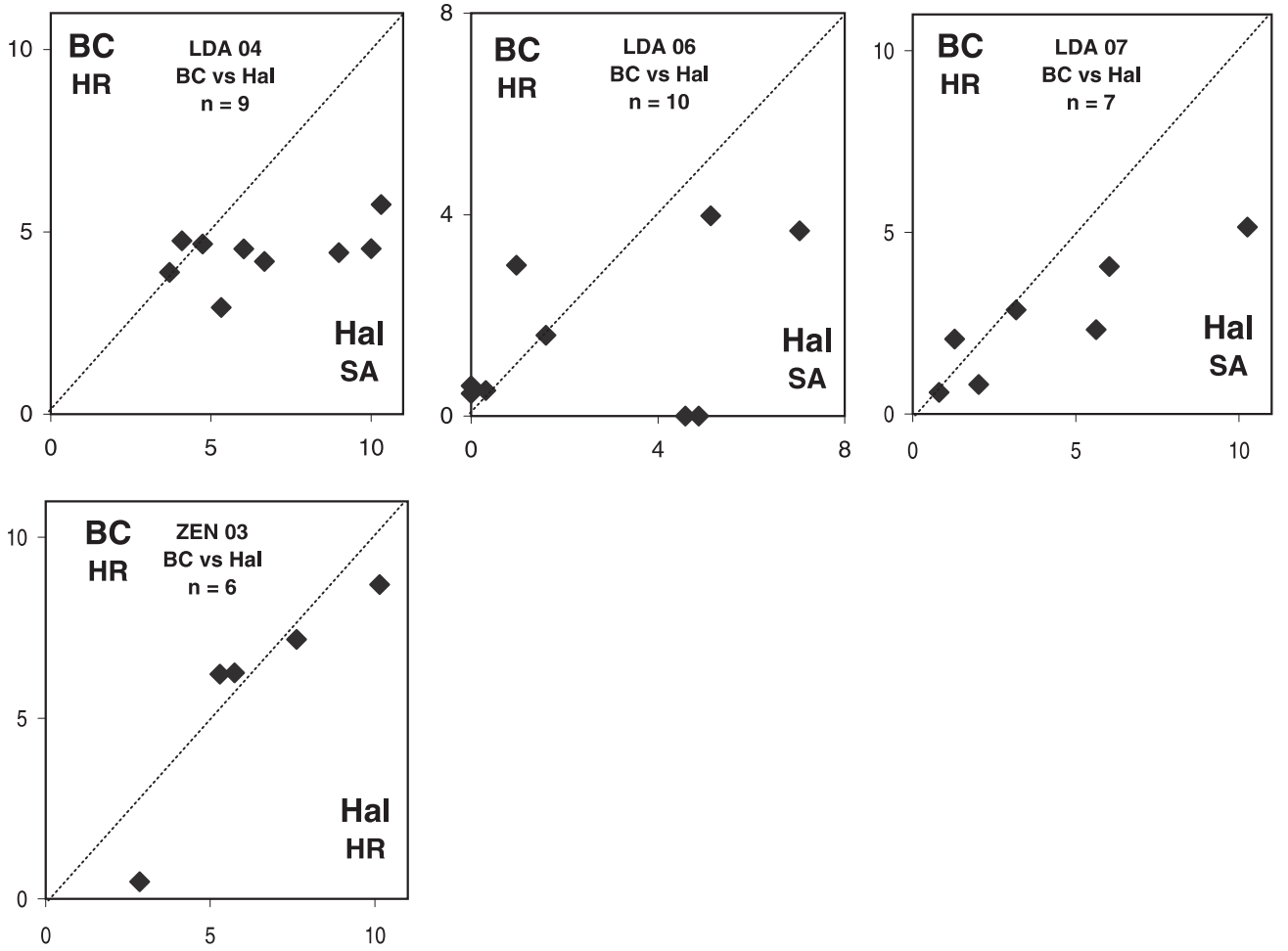
Appendix Figure 5. Paired observations of sublegal-sized halibut NPUE (no. per 100 hooks) in hook-size and mixed hook-size/bait-size experiments. The baits used within each vessel trip are of the same type and quality, and differ in bait size only as indicated.



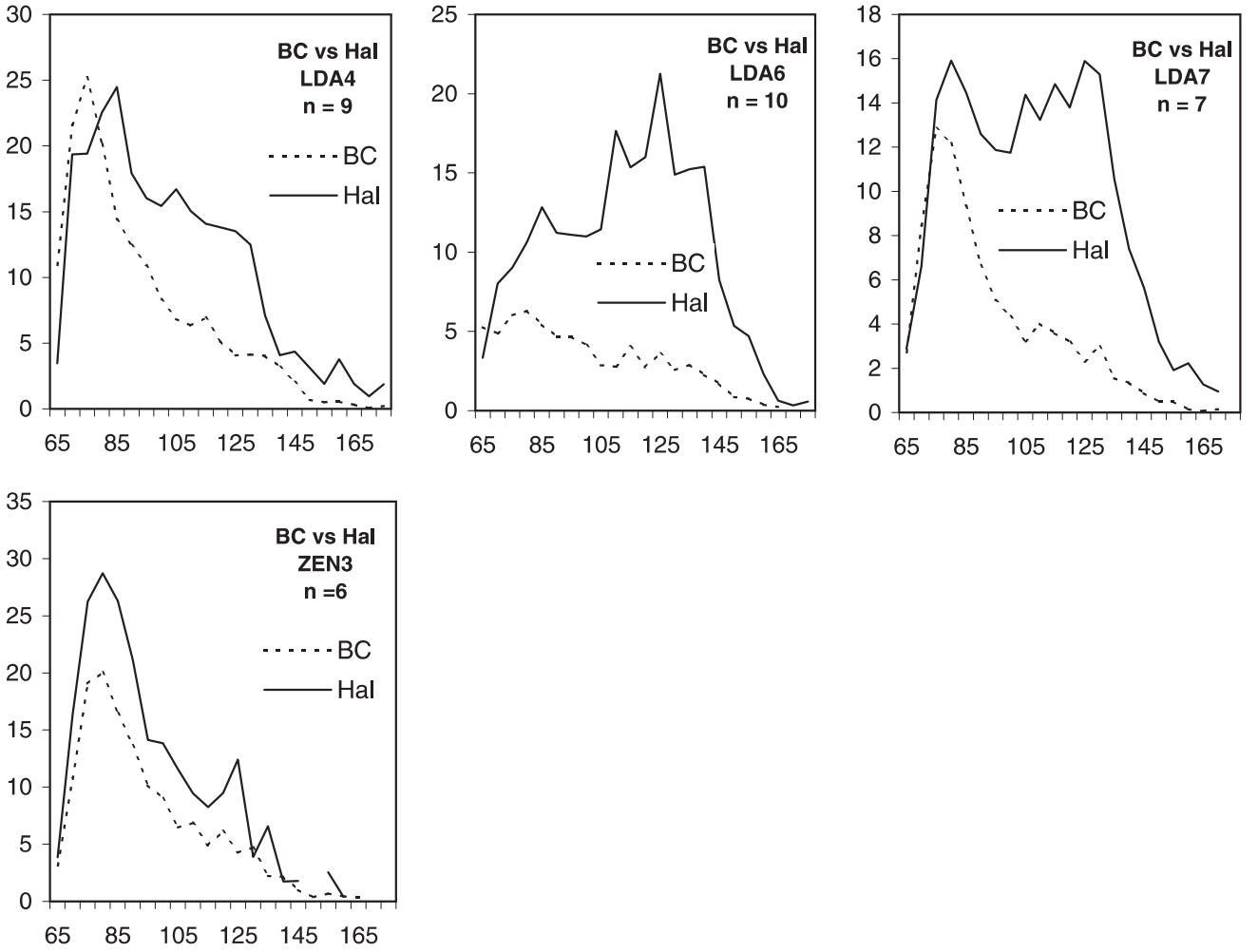
Appendix Figure 6. Length-frequency results in hook-size and mixed hook-size/bait-size experiments. Vertical axis is number per experiment, summed from number per standardized 100-hook set. Horizontal axis is 5-cm length group.



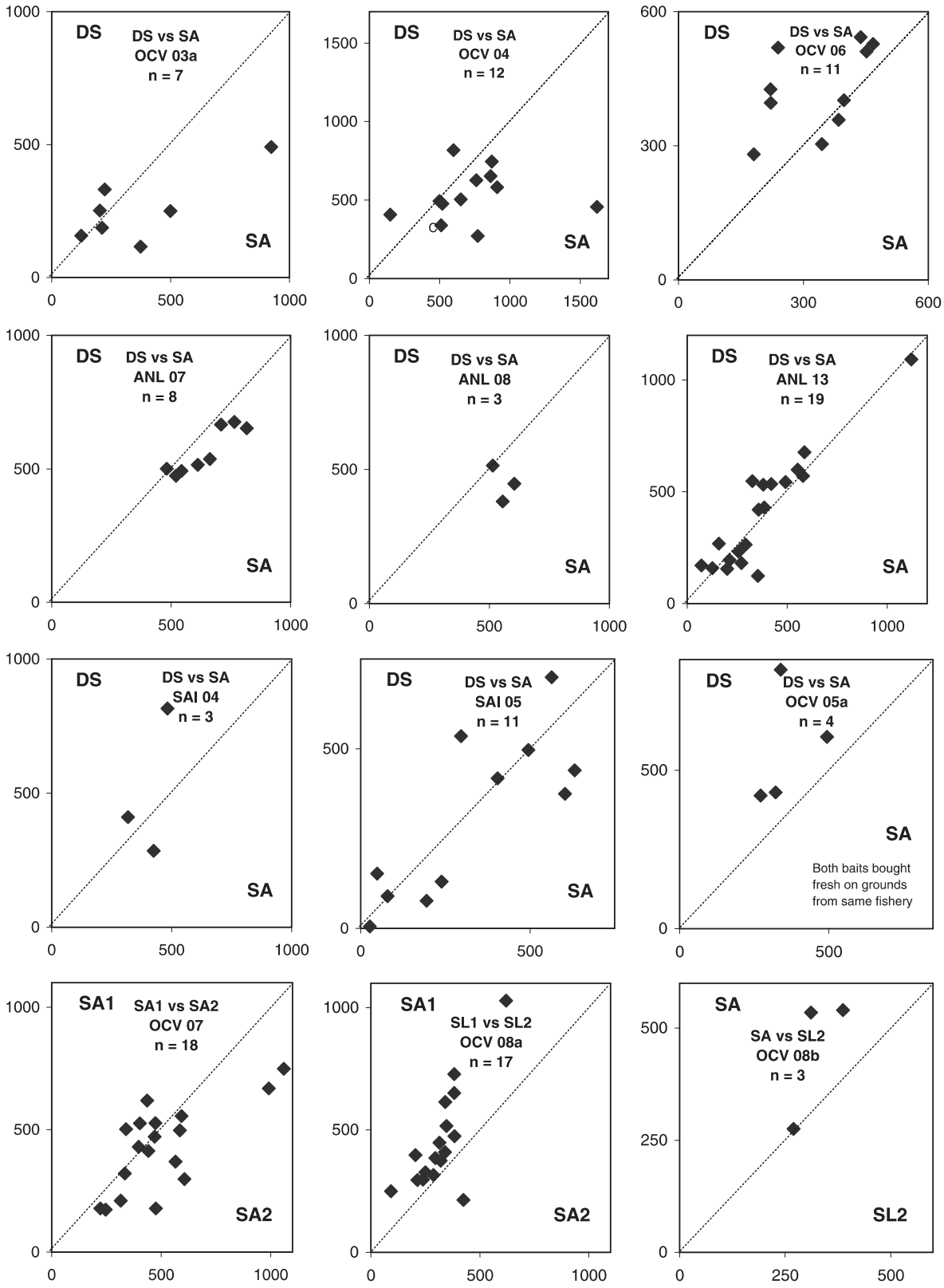
Appendix Figure 7. Paired observations of legal-sized halibut CPUE (lbs. per 100 hooks) in mixed gear-type/bait-type experiments.



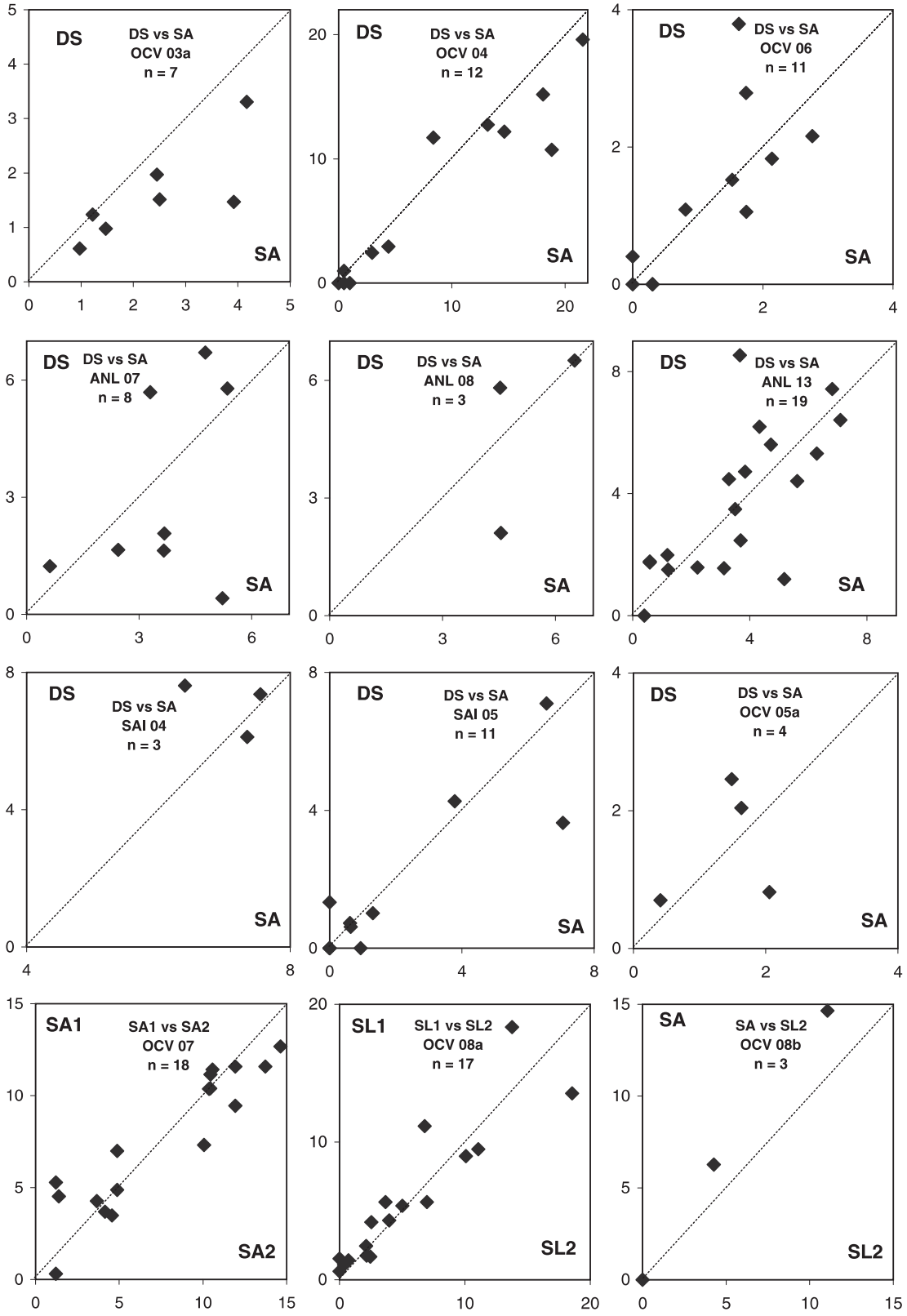
Appendix Figure 8. Paired observations of sublegal-sized halibut NPUE (no. per 100 hooks) in mixed gear-type/ bait-type experiments.



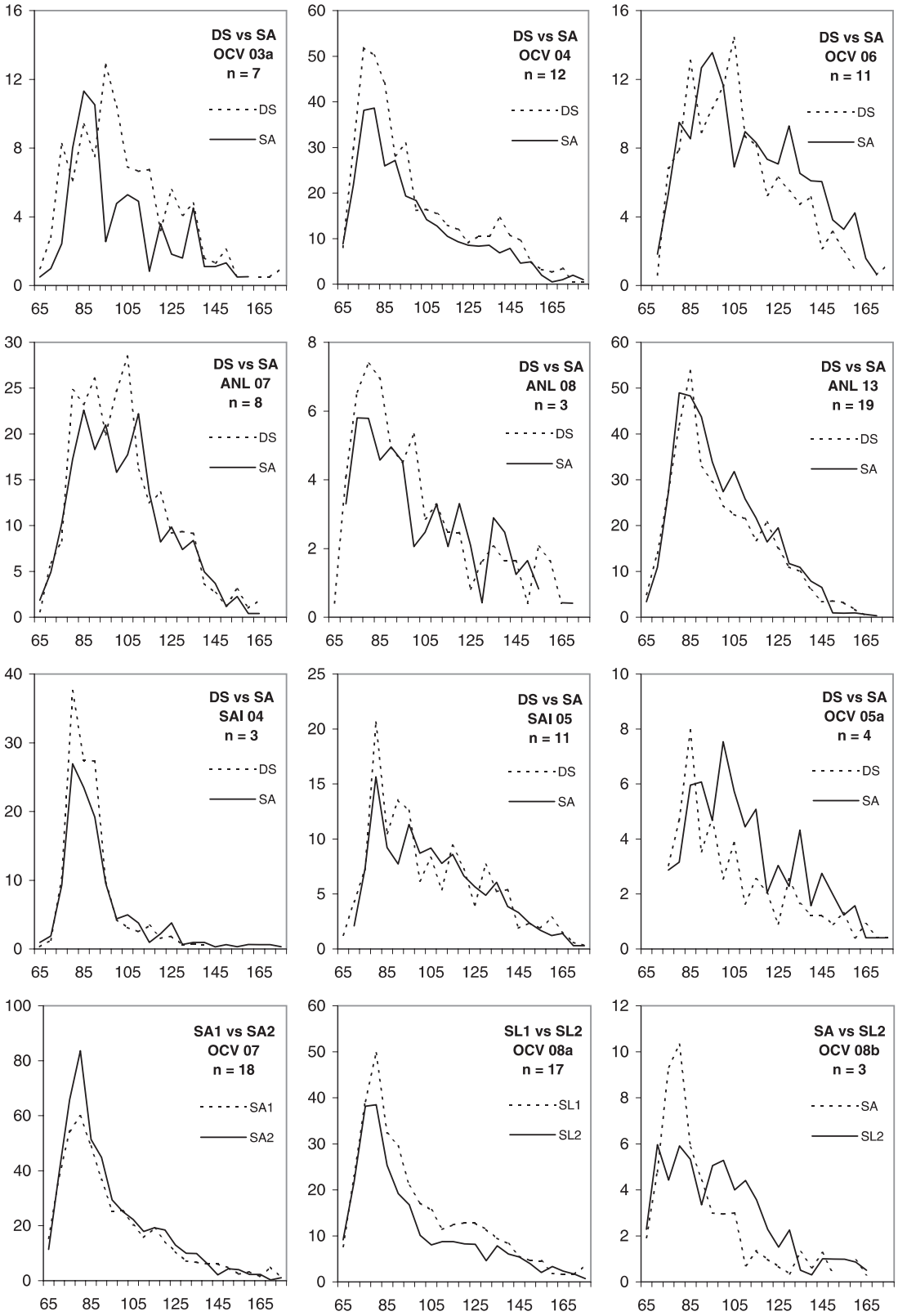
Appendix Figure 9. Length-frequency results in mixed gear-type/bait-type experiments. Vertical axis is number per experiment, summed from number per standardized 100-hook set. Horizontal axis is 5-cm length group.



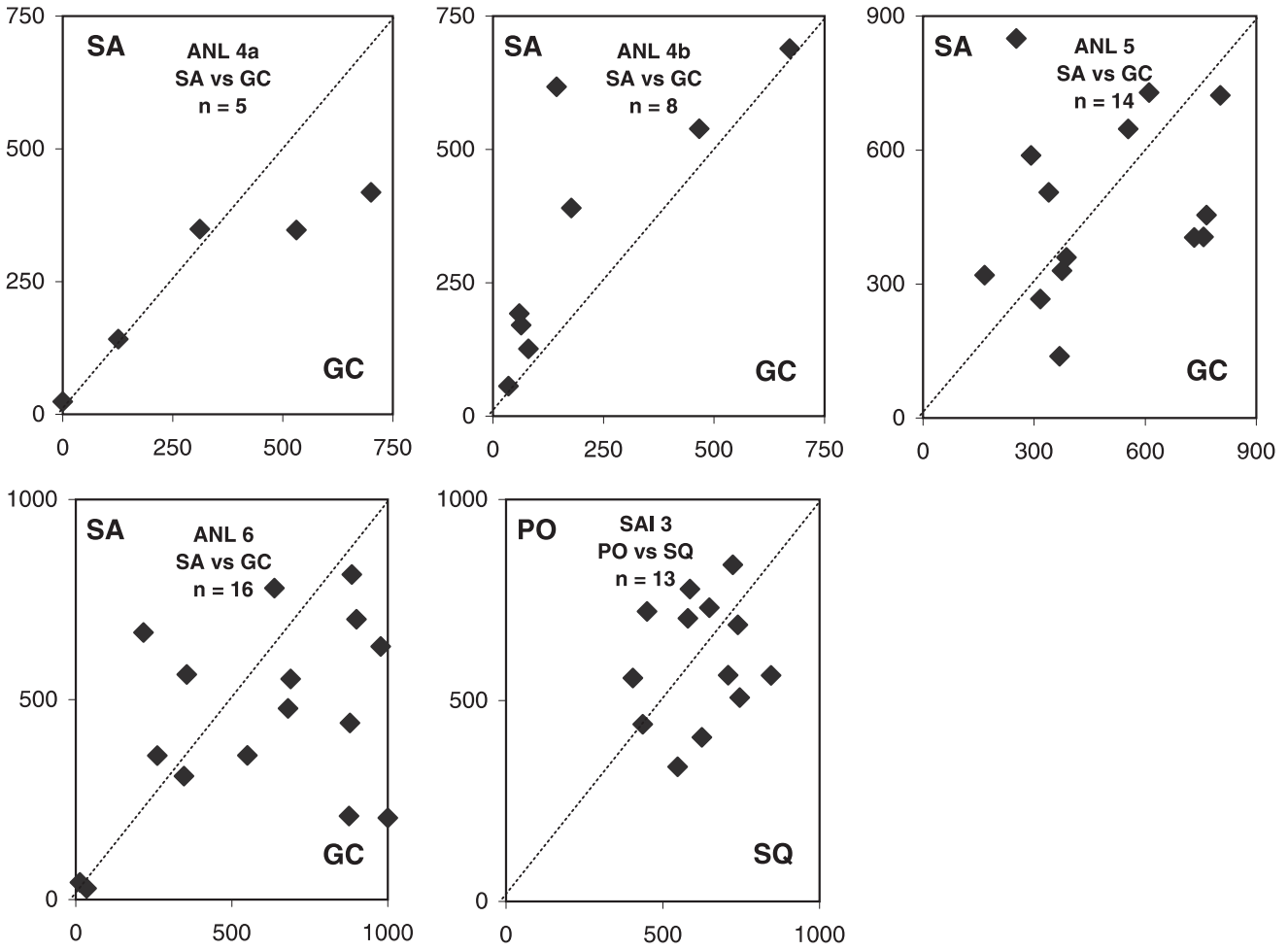
Appendix Figure 10. Paired observations of legal-sized halibut CPUE (lbs. per 100 hooks) in bait-quality experiments. Bait size is the same within each vessel trip.



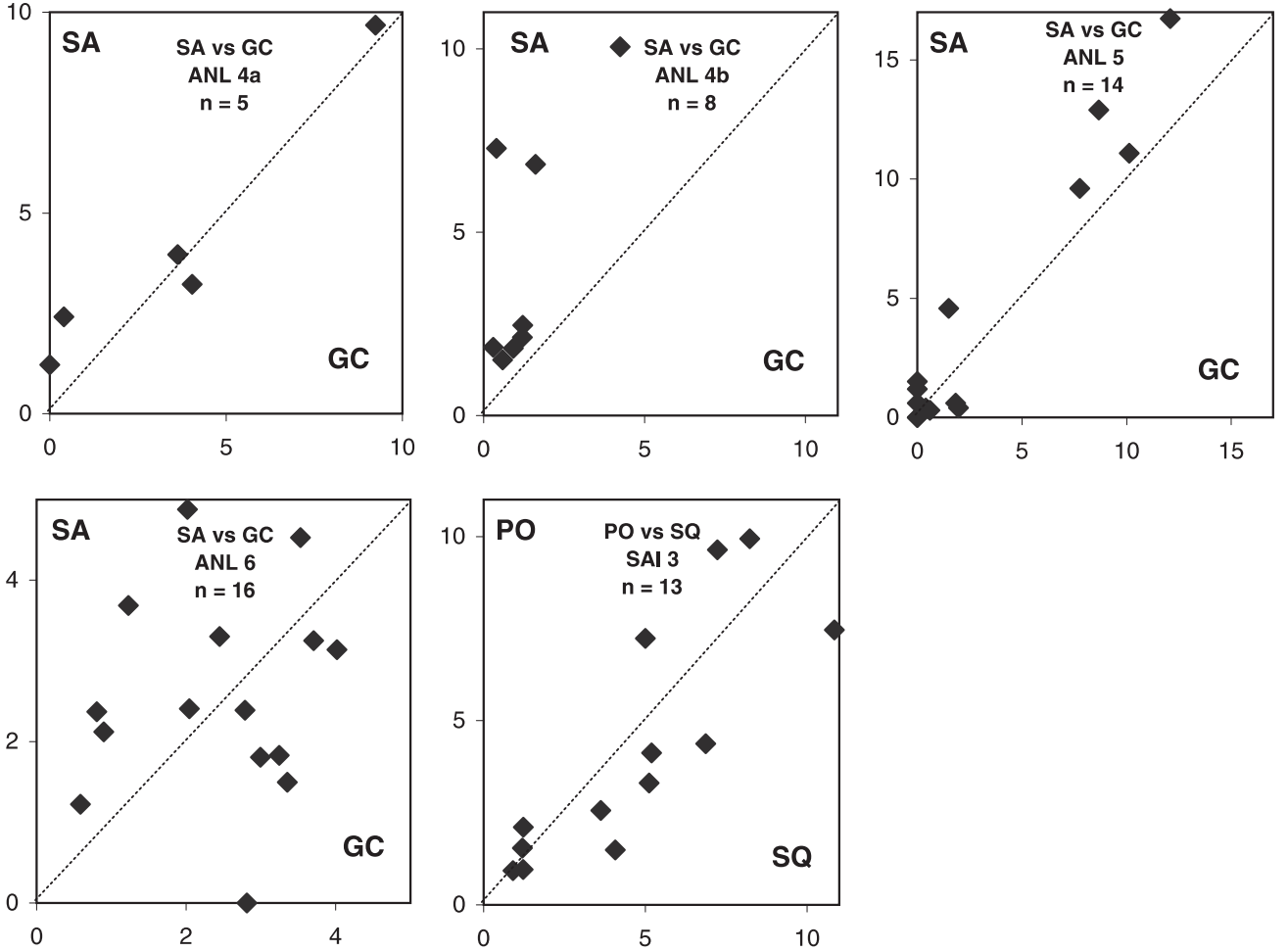
Appendix Figure 11. Paired observations of sublegal-sized halibut NPUE (no. per 100 hooks) in bait-quality experiments. Bait size is the same within each vessel trip.



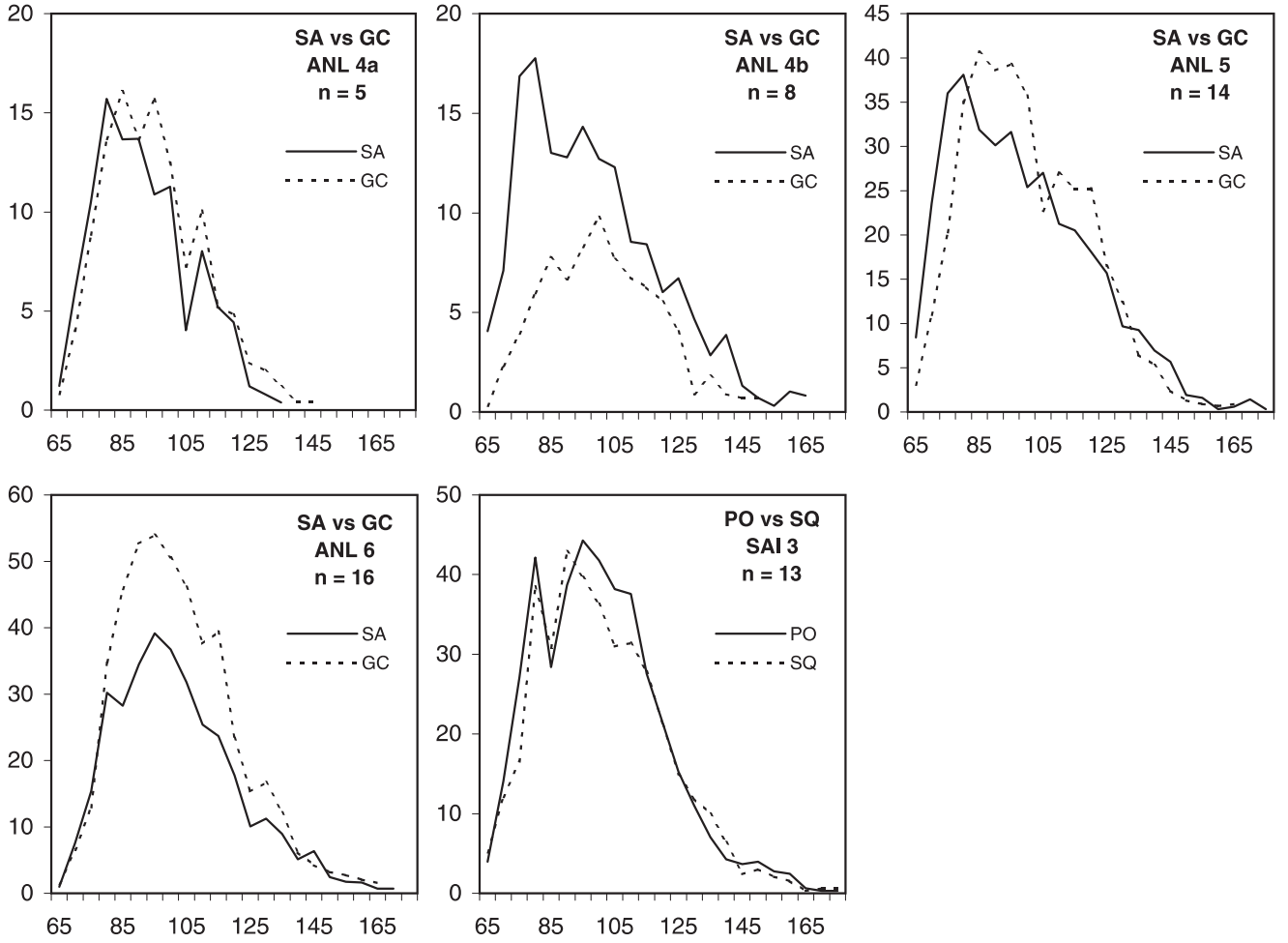
Appendix Figure 12. Length-frequency results in bait-quality experiments. Vertical axis is number per experiment, summed from number per standardized 100-hook set. Horizontal axis is 5-cm length group.



Appendix Figure 13. Paired observations of legal-sized halibut CPUE (lbs. per 100 hooks) in bait-type experiments.



Appendix Figure 14. Paired observations of sublegal-sized halibut NPUE (no. per 100 hooks) in bait-type experiments.



Appendix Figure 15. Length-frequency results in bait-type experiments. Vertical axis is number per experiment, summed from number per standardized 100-hook set. Horizontal axis is 5-cm length group.