ISSN: 0074-7246

INTERNATIONAL PACIFIC HALIBUT COMMISSION

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

Scientific Report No. 69

Comparison of Efficiency of Snap Gear to Fixed-Hook Setline Gear for Catching Pacific Halibut

by
Richard J. Myhre and Terrance J. Quinn II

SEATTLE, WASHINGTON
1984

The International Pacific Halibut Commission has three publications: Annual Reports (U.S. ISSN 0074-7238), Scientific Reports, and Technical Reports (U.S. ISSN 0579-3920). Until 1969, only one series was published (U.S. ISSN 0074-7246). The numbering of the original series has been continued with the Scientific Reports.

INTERNATIONAL PACIFIC HALIBUT COMMISSION
POST OFFICE BOX 95009
SEATTLE, WASHINGTON 98145-2009

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ABSTRACT

Conventional fixed-hook setline gear tends to catch more halibut per unit of effort than snap gear in the commercial fishery. During 1982 and 1983 experiments were carried out to compare the relative efficiency of snap gear to conventional gear. The two types of gear were fished in a parallel manner in three separate areas: southeastern Alaska, the western Gulf of Alaska, and the Kodiak region. Snap gear caught 80% as much halibut by weight as conventional setline gear in the western Gulf of Alaska, while there were no differences in the catch by the two gears in southeastern Alaska or Kodiak. Possible reasons for the discrepancy include hauling speed and bait size. The snap vessel in the western Gulf of Alaska hauled its gear faster and cut bait smaller than the vessel with fixed-hook gear, while there was no difference in hauling speed or bait size between the vessels in southeastern Alaska or Kodiak. Fish length, depth, fish density, bottom contour, and bottom type were not significant factors in the relative efficiency of the two gears. Based on these results, there appears to be no intrinsic difference in the efficiency of fixed-hook halibut gear and snap gear, but hauling speed appears to be an important factor in the efficiency of both types of halibut gear.

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INTRODUCTION

The International Pacific Halibut Commission (IPHC) is responsible for management of the Pacific halibut fishery on behalf of Canada and the United States. In fulfilling its responsibilities, the Commission must assess the condition of the resource and determine the kinds of regulations required to maintain the stocks of halibut at their optimum condition. An important statistic used by IPHC in measuring stock size is catch per unit of effort (CPUE) (Myhre et al. 1977). CPUE is assumed to be positively correlated with the density of halibut (Quinn et al. 1982), and provides a useful measure of relative abundance for stock assessment purposes (Thompson and Bell 1934; Chapman et al. 1962; Quinn et al., in press). This statistic is based on a standard unit of fishing effort, an 1800-foot skate with 100 hooks spaced at 18-foot intervals. The Commission collects logbook information from commercial halibut vessels to determine the number of skates fished and the number of pounds caught in the different regulatory areas. Commission research has provided conversion factors so that gear fished with different hook spacings can be converted to the equivalent number of IPHC standard skates (Hamley and Skud 1978).

The traditional halibut skate has hooks attached by gangions or branch lines tied to the groundline as shown in Figure 1. In this report, this gear will be referred to as fixed-hook gear. During the 1950's a modification called snap-on gear, or snap gear, was introduced, in which the gangions were attached to the groundline by metal snaps (Figure 1). Because the gangions were not permanently tied to the groundline, the interval between gangions could be varied with fishing strategy. Fishermen using snap gear commonly use a wider spacing when "prospecting" for fish and a narrower spacing when good fishing is encountered. During hauling, the gangions are unsnapped and the groundline is wound on a drum; while fixed-hook gear must be hand-coiled by a fisherman. Snap gear is particularly well suited for vessels with limited deck space and accommodations, and the number of vessels using snap gear has increased with time. Today, most of the vessels that fish for halibut with setline gear use snap gear. In contrast, most of the catch is taken by larger vessels, many of which continue to use fixed-hook gear.

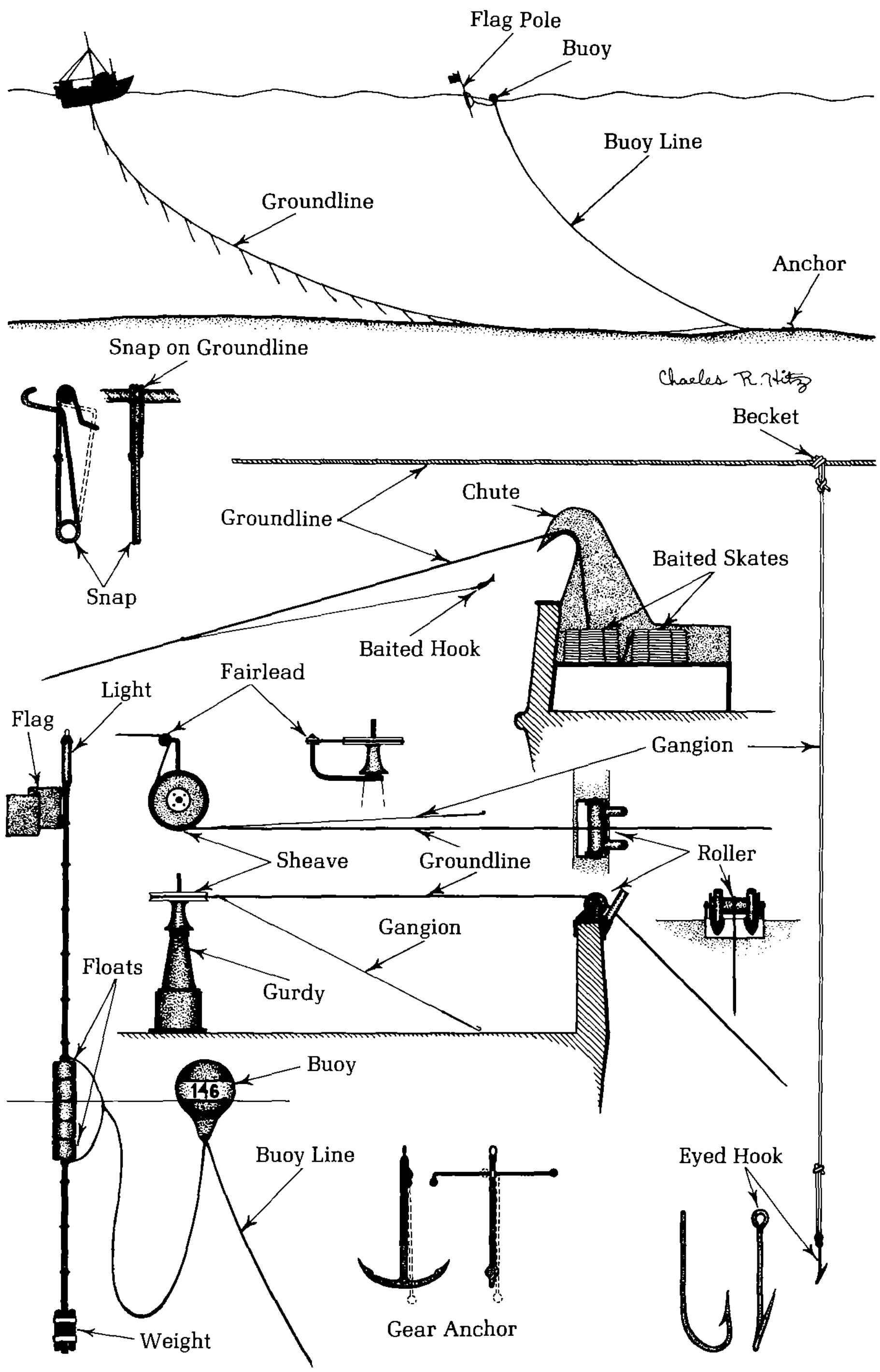

Figure 1. Halibut fishing gear and deck equipment. (Drawings by Charles H. Hitz)

Conventional halibut gear is standardized based on a vessel's fixed-hook spacing (Hamley and Skud 1978). Because snap gear hook spacing is not fixed, it is not clear how the hook spacing for snap gear can be standardized. IPHC has collected information on the number of hooks per skate reported by commercial vessels using snap gear since 1972, and has computed a provisional CPUE for snap gear vessels using their reported average hook spacing and the fixed-hook conversion factors. To minimize the effects of an individual vessel, daily CPUE observations of fixed-hook and snap gear were compiled for three regions between 1972 and 1982 where at least 10 vessels of each gear-type were fishing. The average of the ratios of CPUE across days of snap to fixed-hook gear is shown in Table 1 for each region and year. The ratio of snap to fixed-hook gear is less than one, with only one exception. The standard errors are quite low, suggesting little variability within year and region. The ratios are quite variable between years and between regions. Thus, a simple conversion of snap to fixed-hook gear is not possible without an understanding of the causes for the differences.

Table 1. Average ratio of snap to fixed-hook CPUE for three regions between 1972 and 1982, calculated from days where at least 10 vessels of each gear-type were fishing. Estimates are shown ± 1 standard error with number of daily observations in parentheses. For definition of regions, see Myhre et al. (1977).

Year	Charlotte-Inside (Canadian vessels)	S.E. Alaska-Inside (U.S. vessels)	Kodiak (U.S. vessels)
1972	0.88 ± 0.03 (33)	—	—
1973	0.81 ± 0.05 (21)	0.57 ± 0.05 (9)	—
1974	0.90 ± 0.05 (4)	0.72 ± 0.04 (12)	—
1975	1.07 ± 0.06 (13)	0.64 ± 0.09 (3)	—
1976	0.84 ± 0.03 (45)	0.77 ± 0.04 (33)	0.68 ± 0.04 (29)
1977	0.77 ± 0.03 (28)	0.71 ± 0.05 (26)	0.64 ± 0.02 (36)
1978	0.87 ± 0.04 (34)	0.77 ± 0.05 (12)	0.61 ± 0.02 (39)
1979	0.92 ± 0.03 (31)	0.76 ± 0.03 (20)	0.55 ± 0.02 (31)
1980	0.72 ± 0.03 (37)	0.87 ± 0.02 (9)	0.43 ± 0.02 (19)
1981	0.81 ± 0.04 (38)	0.75 ± 0.03 (6)	0.75 ± 0.04 (13)
1982	0.84 ± 0.04 (24)	0.50 ± 0.01 (4)	0.63 ± 0.03 (11)
Pooled	0.84 ± 0.01 (308)	0.73 ± 0.02 (134)	0.61 ± 0.05 (178)

Possible reasons for the differences have been suggested: (1) snap gear is under more tension when set off the drum, and on irregular bottom many hooks are suspended above the bottom where fish are less likely to encounter them, (2) snap gear boats are smaller and restricted to more sheltered water where halibut may be less concentrated, (3) new fishermen, who are inherently less experienced, are more likely to use smaller boats and snap gear, and (4) snap gear loses more fish due to detachment of snaps by struggling fish.

To further understand the fishing efficiency of snap gear, IPHC conducted an experiment in 1982 to fish snap and fixed-hook gear under identical conditions. The experiment was designed to test: (1) if unique properties of snap gear or the way it is fished could account for its lower catch compared with fixed-hook gear, and (2) if snap gear can be standardized for calculation of CPUE. The experiment showed an unexpected relationship between CPUE and hauling speed. In 1983, the experiment was repeated to further investigate the relationship between CPUE and hauling speed.

METHOD

The experiments were designed to minimize the effects of an individual vessel on the experimental results. The skipper and the crew of each vessel used in the experiments were experienced halibut fishermen. The locations of fishing were determined by the experimental design and the setting and hauling operations were closely monitored by scientific personnel on board.

During 1982, IPHC chartered two vessels to fish snap gear alongside two vessels using fixed-hook gear during its adult survey program. The M/V THOR, using fixed-hook gear, was chartered to operate with the M/V VALOROUS, using snap gear, in the western Gulf of Alaska (Figure 2). The M/V KRISTINE, using fixed-hook gear, fished alongside the M/V DAILY, using snap gear, in the outside waters of southeastern Alaska (Figure 3).

Fishing was done on a grid of stations represented by the black dots on Figures 2 and 3. The original plan was to fish each gear on each station, but weather and other conditions precluded this. In all, the THOR and VALOROUS fished 53 comparable stations and the KRISTINE and DAILY fished 29 comparable stations. The stations were spaced 6 nautical miles apart on lines that were 12 nautical miles apart. The paired vessels were to set and haul eight skates at each of four stations in their representative areas each day, weather and other conditions permitting. Actually, the KRISTINE/DAILY pair fished six skates per station after the first two days due to problems in maintaining the time schedule.

Baiting by each pair of vessels was the same, in that herring, salmon, and true cod were used in rotation throughout. The paired boats were to cut their baits to the same size and place them on the hooks in the same manner. Actually, the THOR cut baits somewhat larger than did the VALOROUS, while the KRISTINE and DAILY baits were of similar size. Because no quantitative data were collected on bait size, it was not possible to examine this factor in the analysis.

The snap vessels were to use the same hook spacing as the fixed-hook gear vessels. To achieve this, the hook spacing on the fixed-hook gear vessels was measured; the THOR used gear with 21 feet between hooks while the KRISTINE gear averaged 22 feet. Accordingly, when the VALOROUS set gear, the hooks were spaced as close to 21 feet as possible and the DAILY gear was set at 22 feet. These spacings were checked from time to time by counting the hooks on the snap gear when it was hauled.

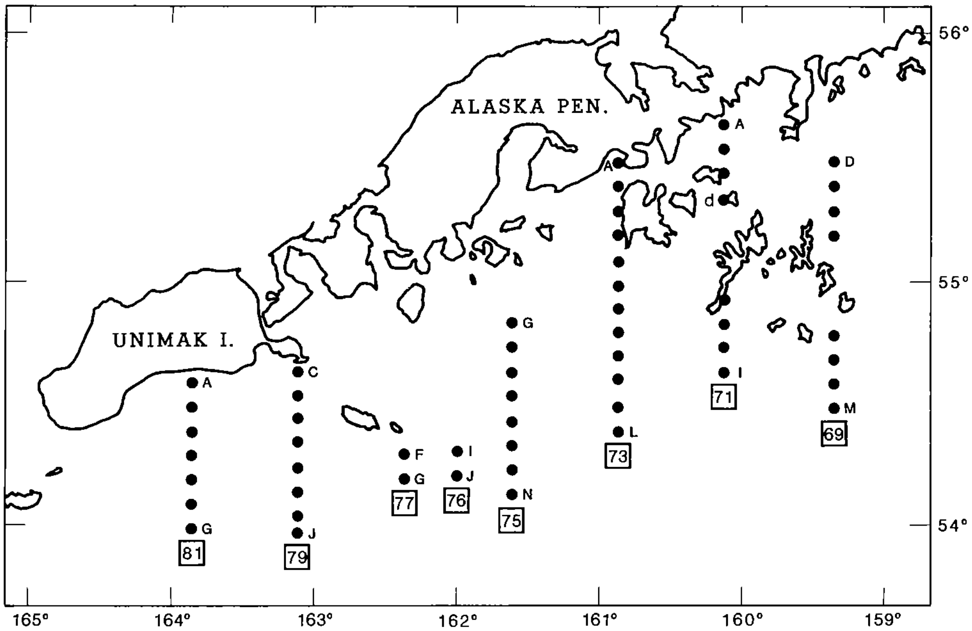

Figure 2. Map of the western Gulf of Alaska showing station locations.

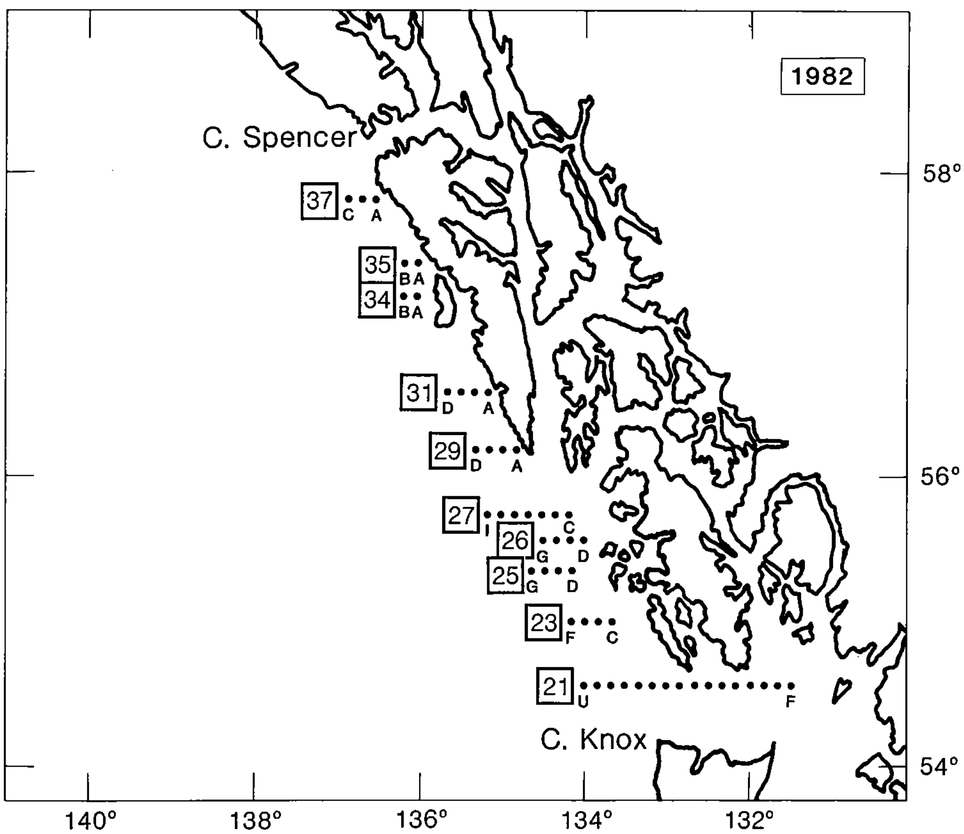

Figure 3. Map of southeastern Alaska showing station locations.

The vessels were to follow the same schedule of setting and hauling their gear, i.e., gear was to be set between 0500 and 0800 hours, and the gear was to be hauled between 1000 and 1900 hours, although the schedule was not always met. The snap vessel set gear alternately to the port and starboard sides of the fixed-hook vessel by station in the western Gulf of Alaska. Because this alternation created too much extra running time for the snap vessel, the alternation was made only daily in southeastern Alaska. To avoid gear competition and interference, the KRISTINE/DAILY gear was set 1.6 km apart and the THOR/VALOROUS gear was set 1.0 km apart.

All halibut caught by each vessel were measured, from which the weight was estimated using the IPHC length-weight relationship. Each vessel recorded the bottom contour and depth on sounder tapes when the gear was set on each station. These tapes were saved for comparison and for classifying bottom topography. Bottom composition at each station was determined from U.S. National Ocean Survey charts of the respective areas.

In 1983, the experiment was repeated in the Kodiak region; station locations are shown in Figure 4. The experimental design was the same as in 1982, except that bottom information was not collected. It was intended that the hauling speed on the snap vessel would be varied between slow, normal, and fast hauls consistently during the experiment, but poor weather and sea conditions prevented any control of hauling speed. IPHC chartered the MASONIC using fixed-hook gear and the VALOROUS using snap gear for the experiment. The two vessels fished 46 comparable stations side-by-side at a distance of about 1.25 km apart. Gear was lost by a vessel at two other stations that were fished, and these stations are not used in the analysis. The MASONIC used a hook-spacing of 26 feet and the VALOROUS used a hook-spacing of 25 feet. Effective effort is different as a result of hook-spacing differences. Thus, CPUE is used in the analysis of the data from the 1983 experiment. As in the 1982 experiments, the snap vessel set gear slower than the vessel with fixed-hook gear, which meant that the two vessels seldom started hauling at precisely the same time. This contributed to the difficulty in modifying hauling speed in the snap vessel in relation to the fixed-hook vessel.

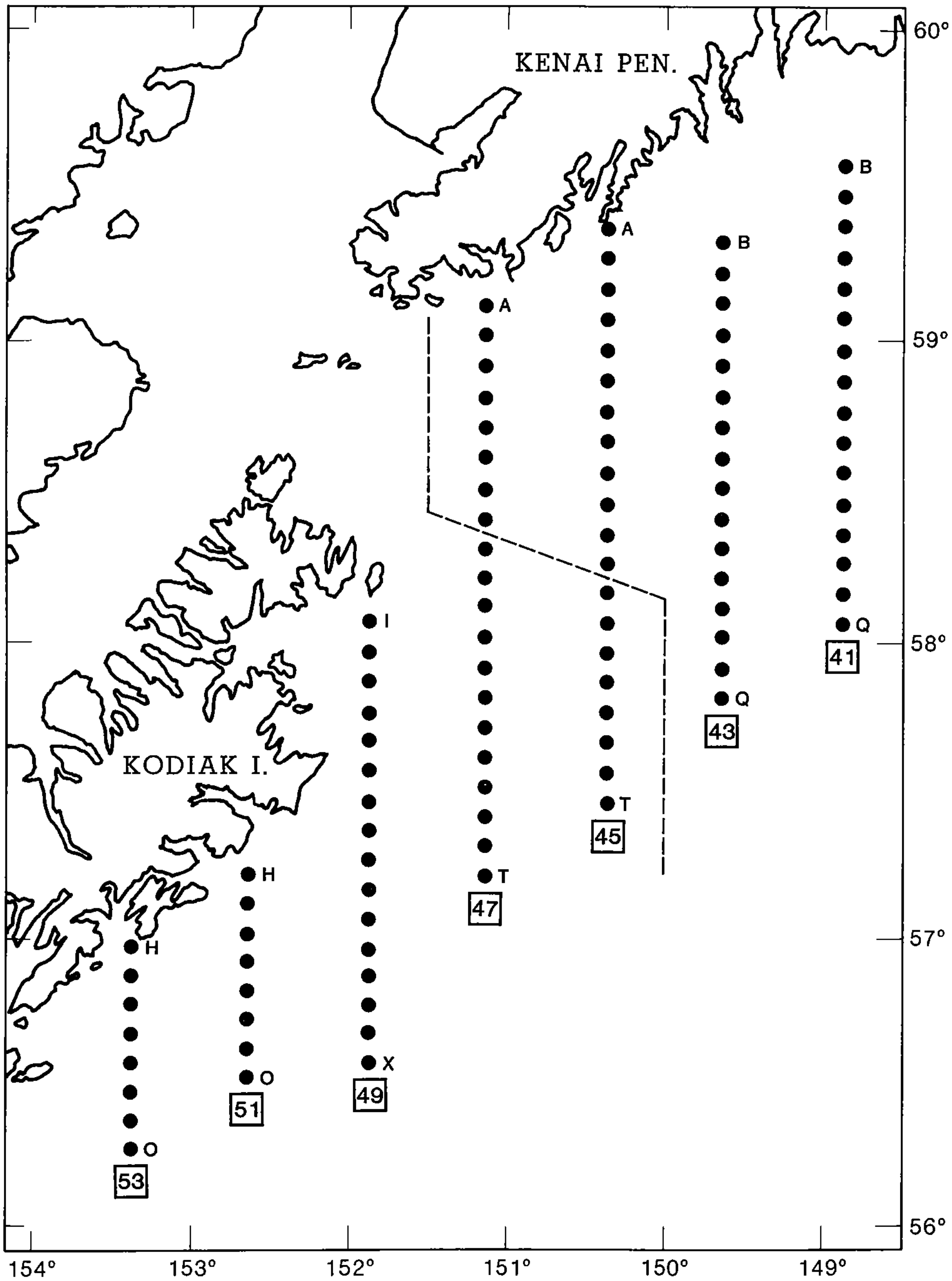

Figure 4. Map of the Kodiak region showing station locations.

RESULTS FROM THE 1982 EXPERIMENT

Station-by-station results of the catch are given for the western Gulf of Alaska (Appendix Table 1) and southeastern Alaska (Appendix Table 2). Auxiliary data on bottom type, bottom contour, depth, haul time, and soak time are given for the western Gulf of Alaska (Appendix Table 3) and southeastern Alaska (Appendix Table 4).

The summarized data across all stations shown in Tables 2 and 3 include number and total weight of sublegal (<82 cm), legal (≥ 82 cm), and total halibut. The ratio $\hat{R}$ of the average catch from the snap-on vessel ($\bar{y}$) and the conventional vessel ($\bar{x}$) is a measure of the relative gear efficiency (R) of snap-on gear to conventional gear. Because

$$\hat{R} = \bar{y}/\bar{x}$$

is a ratio estimator (Cochran 1963), its coefficient of variation may be written

$$cv(\hat{R}) = [cv^2(\bar{x})+cv^2(\bar{y}) - 2\hat{\rho}\, cv(\bar{x})cv(\bar{y})],$$

where $\hat{\rho}$ is the Pearson correlation coefficient between x and y. Under the assumption that $\hat{R}$ is normally distributed, a 95% confidence interval about R is calculated from the formula

$$\hat{R}[1 \pm t_{n-1,0.025}\, cv(\hat{R})],$$

where n is the number of stations and t is the critical value from a t-distribution. If the assumption of normality is not true, then inference from the data is only approximate. The large sample sizes in the western Gulf of Alaska experiment and Kodiak experiment make this a minor concern.

Western Gulf of Alaska

Depending on whether number or weight of fish is used, the snap gear vessel caught about 10-15% fewer sublegal size fish (<82 cm) and 17-23% fewer legal-size fish (≥82 cm) than the fixed-hook vessel (Table 2). Average fish weight was nearly the same for both vessels. The length frequencies of fish in the catch were similar for the two vessels (χ^2 = 42.5, 31df, .05 <P<.10) (Figure 5). The results were consistent across stations as evidenced by the high correlations between gears ($\hat{\rho}$) as shown in Table 2. Estimated relative gear efficiency ($\hat{R}$) of snap gear of about 80% was statistically different from unity for both the catch of legal fish and total fish, as indicated by the confidence intervals in Table 2. The 53 usable observations provided sufficient information to detect differences of 10% or greater between the vessels, due to the high correlation in catches.

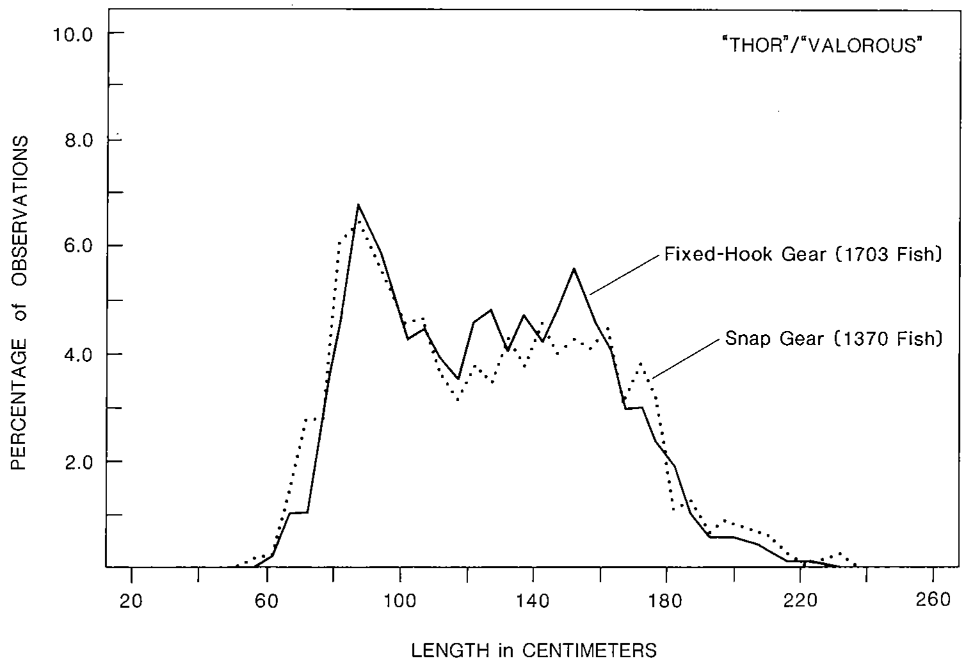

Figure 5. Relative length frequencies of halibut caught by each vessel in the western Gulf of Alaska, 1982.

Table 2. Western Gulf of Alaska experiment results, 1982.[1].

	$\bar{x}$	$\bar{y}$	cv($\bar{x}$)	cv($\bar{y}$)	n	$\hat{\rho}$	$\hat{R}$	cv($\hat{R}$)	95% Confidence Interval
ALL DATA	Number[3]								
Sublegal	9.4	8.4	0.12	0.13	53	0.73	0.90	0.092	(0.73,1.07)
Legal	22.7	17.4	0.11	0.11	53	0.89	0.77	0.052	(0.69,0.85)
TOTAL	32.1	25.8	0.07	0.07	53	0.78	0.81	0.046	(0.74,0.88)
	Weight[3]								
Sublegal	56.8	48.3	0.11	0.13	53	0.63	0.85	0.105	(0.67,1.03)
Legal	1073	887	0.15	0.15	53	0.93	0.83	0.056	(0.74,0.92)
TOTAL	1130	935	0.14	0.14	53	0.92	0.83	0.056	(0.74,0.92)
BOTTOM TYPE	Number								
Rock	30.1	22.2	0.13	0.14	26	0.88	0.74	0.067	(0.64,0.84)
Gravel	32.7	30.4	0.26	0.22	9	0.95	0.94	0.086	(0.75,1.13)
Sand	19.8	15.3	0.13	0.13	29	0.82	0.77	0.077	(0.65,0.89)
Mud	19.8	11.9	0.26	0.25	13	0.93	0.60	0.096	(0.47,0.73)
	Weight								
Rock	1530	1204	0.17	0.18	26	0.92	0.79	0.069	(0.68,0.90)
Gravel	1726	1643	0.37	0.30	9	0.98	0.96	0.097	(0.75,1.17)
Sand	828	687	0.18	0.17	29	0.87	0.83	0.089	(0.68,0.98)
Mud	964	644	0.32	0.33	13	0.92	0.67	0.130	(0.48,0.86)
BOTTOM CONTOUR	Number								
Rough	26.2	19.3	0.14	0.12	13	0.51	0.74	0.130	(0.53,0.95)
Uneven	22.1	17.9	0.15	0.16	17	0.86	0.81	0.083	(0.67,0.95)
Flat	20.6	16.9	0.19	0.20	27	0.94	0.82	0.068	(0.71,0.93)
	Weight								
Rough	1323	960	0.16	0.17	13	0.60	0.73	0.148	(0.49,0.97)
Uneven	987	866	0.20	0.21	17	0.94	0.88	0.073	(0.74,1.02)
Flat	960	853	0.28	0.26	27	0.97	0.89	0.069	(0.76,1.02)
DEPTH[2]	Number								
0-49	27.5	21.9	0.15	0.16	23	0.92	0.80	0.063	(0.70,0.90)
49-74	19.0	13.4	0.16	0.17	21	0.87	0.70	0.078	(0.59,0.81)
0-74	23.4	17.8	0.11	0.12	44	0.91	0.76	0.050	(0.68,0.84)
75+	19.1	15.4	0.32	0.22	9	0.84	0.81	0.180	(0.47,1.15)
	Weight								
0-49	1299	1130	0.22	0.21	23	0.94	0.87	0.069	(0.75,0.99)
49-74	873	658	0.21	0.22	21	0.89	0.75	0.101	(0.59,0.91)
0-74	1096	904	0.16	0.16	44	0.93	0.83	0.060	(0.73,0.93)
75+	960	799	0.37	0.32	9	0.89	0.83	0.169	(0.51,1.15
CATCH RATE[2]	Number								
0-14	8.2	8.2	0.12	0.18	20	0.62	1.00	0.142	(0.70,1.30)
15-29	19.0	14.2	0.05	0.07	16	0.31	0.75	0.072	(0.63,0.87)
30+	43.2	31.2	0.09	0.12	17	0.83	0.72	0.068	(0.62,0.82)
15+	31.5	23.0	0.09	0.11	33	0.88	0.73	0.053	(0.65,0.81)
	Weight								
0-14	244	311	0.18	0.23	20	0.69	1.27	0.168	(0.82,1.72)
15-29	840	624	0.12	0.13	16	0.75	0.74	0.089	(0.60,0.88)
30+	2267	1811	0.13	0.15	17	0.88	0.80	0.071	(0.68,0.92)
15+	1575	1236	0.13	0.14	33	0.92	0.79	0.055	(0.70,0.88)

[1] $\bar{x}$ average for fixed-hook gear
$\bar{y}$ average for snap gear
n number of stations
$\hat{\rho}$ correlation
R ratio
cv coefficient of variation

[2] Depth in fathoms. Catch rate in number per station.

[3] "Number" denotes average number per station. "Weight" denotes average weight per station in pounds.

Table 3. Southeastern Alaska experiment results, 1982.[1]

	$\bar{x}$	$\bar{y}$	cv($\bar{x}$)	cv($\bar{y}$)	n	$\hat{\rho}$	$\hat{R}$	cv($\hat{R}$)	95% Confidence Interval
ALL DATA	Number[3]								
Sublegal	4.5	6.6	0.23	0.26	29	0.75	1.47	0.18	(0.93,2.01)
Legal	23.3	23.7	0.16	0.11	29	0.70	1.02	0.11	(0.79,1.25)
TOTAL	27.8	30.3	0.13	0.11	29	0.55	1.09	0.12	(0.82,1.36)
	Weight[3]								
Sublegal	33.7	49.0	0.23	0.26	29	0.67	1.45	0.20	(0.85,2.05)
Legal	977	915	0.16	0.11	29	0.64	0.94	0.12	(0.71,1.17)
TOTAL	1011	964	0.16	0.10	29	0.60	0.95	0.13	(0.69,1.21)
BOTTOM TYPE	Number								
Hard	21.0	14.2	0.53	0.44	4	0.99	0.68	0.11	(0.44,0.92)
Rock	23.6	23.6	0.17	0.13	18	0.57	1.00	0.14	(0.70,1.30)
Gravel	25.1	27.8	0.27	0.15	13	0.73	1.11	0.19	(0.65,1.57)
Sand	19.9	21.4	0.18	0.14	19	0.65	1.08	0.14	(0.76,1.40)
	Weight								
Hard	567	428	0.35	0.32	4	0.81	0.76	0.21	(0.25,1.27)
Rock	945	899	0.12	0.11	18	0.19	0.95	0.15	(0.25,1.25)
Gravel	1048	1002	0.31	0.18	13	0.76	0.96	0.21	(0.52,1.40)
Sand	831	788	0.15	0.14	19	0.43	0.95	0.16	(0.63,1.27)
BOTTOM CONTOUR	Number								
Rough	21.2	19.4	0.18	0.13	10	0.71	0.92	0.13	(0.65,1.19)
Uneven	21.5	23.6	0.23	0.15	13	0.83	1.10	0.13	(0.79,1.41)
Flat	21.8	24.7	0.22	0.15	17	0.62	1.13	0.17	(0.72,1.54)
	Weight								
Rough	813	828	0.10	0.15	10	0.74	1.02	0.10	(0.79,1.25)
Uneven	921	922	0.16	0.14	13	0.67	1.00	0.12	(0.74,1.26)
Flat	976	963	0.26	0.16	17	0.64	0.99	0.20	(0.59,1.41)
DEPTH[2]	Number								
0-74	17.5	23.8	0.07	0.13	11	0.09	1.36	0.14	(0.94,1.78)
75+	26.9	23.6	0.22	0.16	18	0.81	0.88	0.11	(0.68,1.08)
	Weight								
0-74	740	961	0.14	0.13	11	0.34	1.30	0.16	(0.84,1.76)
75+	1122	877	0.22	0.16	18	0.74	0.79	0.14	(0.56,1.02)
CATCH RATE[2]	Number								
0-14	11.1	16.2	0.08	0.22	9	0.66	1.46	0.18	(0.85,2.07)
15+	28.8	27.0	0.17	0.11	20	0.70	0.94	0.12	(0.70,1.18)
	Weight								
0-14	467	576	0.13	0.21	9	0.39	1.23	0.20	(0.66,1.80)
15+	1206	1068	0.18	0.11	20	0.60	0.89	0.15	(0.61,1.17)

[1] $\bar{x}$ average for fixed-hook gear
$\bar{y}$ average for snap gear
n number of stations
$\hat{\rho}$ correlation
R ratio
cv coefficient of variation

[2] Depth in fathoms. Catch rate in number per station.

[3] "Number" denotes average number per station. "Weight" denotes average weight per station in pounds.

Southeastern Alaska

The snap gear vessel caught about 45-47% more sublegal-size fish and about the same amount of legal-size fish as compared to the fixed-hook vessel (Table 3). Average weight of legal-size fish was 3 pounds less on the snap gear vessel. The length frequencies of fish in the catch were statistically different ($\chi^2 = 44.2$, 25df, $P = .01$), due to fewer very large fish and more small fish in the catch of the snap gear vessel. However, the differences are not pronounced (Figure 6). Correlations between the two gears were not as high as in the western Gulf of Alaska experiments (Table 3), presumably because the vessels set their gear further apart and because of greater differences in bottom type. Estimated relative gear efficiency ($\hat{R}$) was not statistically different from unity for either the catch of sublegal, legal, or total fish (Table 3). The 29 usable observations provided sufficient information to detect differences of 25% or greater between the vessels, substantially less discrimination than in the western Gulf of Alaska experiment. The lower sensitivity of the southeastern Alaska comparisons is likely due to the smaller number of usable observations and the greater distance between vessels.

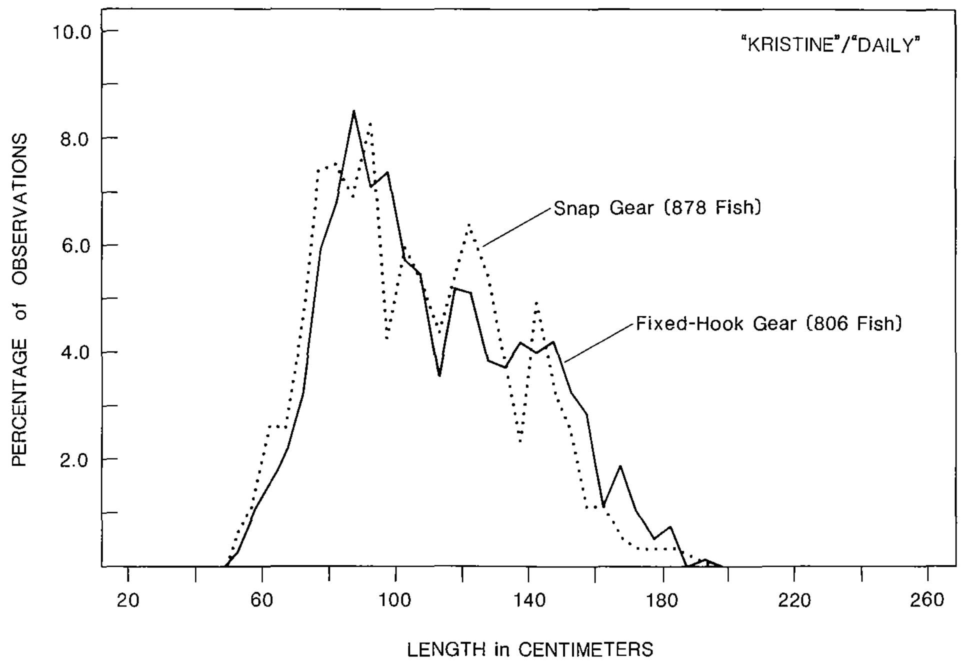

Figure 6. Relative length frequencies of halibut caught by each vessel in southeastern Alaska, 1982.

FACTORS AFFECTING CATCHABILITY AND GEAR EFFICIENCY

Further comparisons involve only the data on catch of legal-size fish, because any correction factors based on this study will apply to catches in the commercial fishery. The experimental design called for maintaining sufficient auxiliary information to examine catchability factors, including bottom type, topography, depth, fish density, soak time, and haul time. Only one-factor analyses were performed, because the sample sizes were too small to study interactions between factors.

Bottom Type

From nautical charts, the type of bottom at each station was classified into hard, rocky, gravel, sand, or mud substrates. Multiple bottom types occurred at stations; a station was included any time a bottom type was present. Thus, the bottom type results are not strictly independent, but sufficient sample sizes were not obtained to make a true stratification.

For both experiments, relative gear efficiency did not appear to be a function of bottom type. Most of the CPUE ratios for the southeastern Alaska experiment were near unity (Table 3), and most of the ratios for the western Gulf of Alaska experiment were near 80% (Table 2). Three notable exceptions to this generalization occurred. The ratios for four southeastern Alaska stations with hard, reef-like substrate were around 70%. The ratios for nine western Gulf of Alaska stations with mud substrate were near 60%. However, due to the small sample sizes, these results are not considered significant.

There were significant differences in the catch as a function of bottom type (Tables 2, 3). Larger catches occurred on stations with gravel or rock substrate than other substrates for both experiments. However, the increased catches occurred uniformly for both fixed-hook and snap gear. Thus, bottom type did not appear to affect the efficiency of snap gear compared to fixed-hook gear.

Bottom Contour

The topography of the bottom was broken into three classes (rough, uneven, flat) from examination of sounding tapes. Some stations could not be distinguished between two classes; such data appear in both breakdowns.

There were no significant differences in relative gear efficiency across these classes (Tables 2, 3) for both experiments. There were also no substantial differences in catch between classes, with the exception that the "rough" contour had slightly larger catches in the western Gulf of Alaska. Therefore, bottom contour did not appear to be a factor in the lower CPUE for snap gear in the western Gulf.

Depth

Stations in the western Gulf of Alaska were generally shallower than in southeastern Alaska. Generally, both vessels in an area fished a similar range of depths at each station. Stations were broken into two classes (0-74, 75+ fathoms) in southeastern Alaska and three classes (0-49, 50-74, 75+ fathoms) in the western Gulf of Alaska, based on the maximum depth fished by the fixed-hook gear vessel. The larger number of stations in the western Gulf permitted the finer breakdown of data. Maximum depth was used to isolate stations with fishing originating on the continental slope edge.

There were no essential differences in relative gear efficiency as a function of depth for both experiments (Tables 2, 3). The ratios in the western Gulf of Alaska were not significantly different from 80%, and the ratios in southeastern Alaska were not significantly different from unity. Catches in the shallowest stratum were largest in the western Gulf of Alaska, while catches in the deeper stratum in southeastern Alaska were larger, suggesting that there is no uniform pattern of abundance with depth and that depth was not a factor that affected the CPUE of snap gear.

Fish Density (Catch Rate)

To examine if gear efficiency changed with the density of fish on the gear, stations were post-stratified by catch rates in numbers per station into two classes (0-14, 15+ fish) in southeastern Alaska and three classes (0-14, 15-30, 30+ fish) in the western Gulf of Alaska based on the fixed-hook gear. For both experiments, relative gear efficiency is higher when few fish (0-14) are caught by the gear (Tables 2, 3). However, the ratios in southeastern Alaska are not significantly different from unity, and in only one case is the ratio in the western Gulf of Alaska significantly different from 80%. Therefore, fish density does not appear to be a cause of the lower relative efficiency for snap gear in the western Gulf of Alaska.

Soak Time and Haul Time

During the course of the western Gulf of Alaska experiment, it became apparent that the snap gear vessel set gear slower and hauled gear faster than the fixed-hook vessel. These differences reflected philosophical differences between the two skippers concerning fishing technique as well as characteristics of the gear. To test if haul time was a factor in the catch differences between the vessels, the haul time was kept the same for six stations near the end of the trip. For these stations, the fixed-hook vessel caught 174 fish weighing 6,981 pounds, while the snap gear vessel caught 173 fish weighing 7,652 pounds. The similarity of these catches with the same haul time, contrasted with 20% less catch when the snap vessel hauled faster, suggests that haul time may be a factor affecting gear efficiency. This suggestion is further supported from the southeastern Alaska experiment, where the average haul times for the two vessels and the average catches were similar.

To further explore the relationship of differences in vessel catch to differences in haul time, and also soak time, multiple linear regressions of the form

$$Y_i = \alpha + \beta_1 X_{1i} + \beta_2 X_{2i} + \varepsilon_i$$

were performed on the data where

$Y_i = \ln(x_i+1)-\ln(y_i+1)$ is the difference in the logarithms of CPUE in weight between fixed-hook and snap gear vessels for each station,

X_{1i} = difference in soak time,

X_{2i} = difference in haul time,

ε_i = normal random error,

α, β_1, β_2 = y-intercept, soak time parameter, haul time parameter (to be estimated).

CPUE values are given in Appendix Tables 3 and 4. The logarithmic transformation was used to stabilize the variance and to approximate normality. Models with subsets of the parameters were also fit and compared based on their sum of squares. Data from the two experiments were pooled, but tests were made to determine whether the parameters were the same for both experiments.

Results of the model fits are shown in Table 4. Neither the intercept parameter nor the soak time parameter was significant in any model fit. Although no model explained more than 15% of the variability in Y_i, the haul time parameter was significant for most models, reducing the sum of squares substantially. Plots of the data versus soak time (Figure 7) and haul time (Figure 8) illustrate these results. Incorporating separate parameters for each experiment did not lead to significant differences. The best model, therefore, consisted of a single parameter for haul time (Table 4). The lack of significance of the intercept term implies that there is no difference in relative gear efficiency between snap gear and fixed-hook vessels adjusted for haul time.

Table 4. Results of model fits and parameter estimates for the relationship of ℓn (CPUE) differences versus soak time and haul time differences for the 1982 experiments.

Model Parameters[1]	Residual Sum of Squares	Degrees of Freedom	$\alpha \pm 1$ s.e.	$\beta_1 \pm 1$ s.e.	$\beta_2 \pm 1$ s.e.
Data Pooled					
α	29.4	81	0.105 ± 0.067		
α,β_1	29.3	80	0.096 ± 0.071	0.043 ± 0.101	
α,β_2	26.8	80	0.008 ± 0.073		0.392* ± 0.141
α,β_1,β_2	26.7	79	-0.002 ± 0.076	0.041 ± 0.097	0.392* ± 0.142
β_1	30.0	81		0.086 ± 0.096	
β_2	26.8	81			0.400* ± 0.123
By Experiment					
β_2	26.7	80			[2]SE:0.535 ± 0.311
					GA:0.374* ± 0.135
α,β_1,β_2	26.0	76	[2]SE:0.113 ± 0.120	-0.332 ± 0.341	0.603 ± 0.335
			GA:0.057 ± 0.131	0.086 ± 0.103	0.424* ± 0.212
TOTAL (no parameters)	30.3	82			

[1]α — y-intercept; β_1 — soak time coefficient; β_2 — haul time coefficient (see text for further details).

[2]SE = Southeastern Alaska GA = Western Gulf of Alaska

* — significant at α = .05

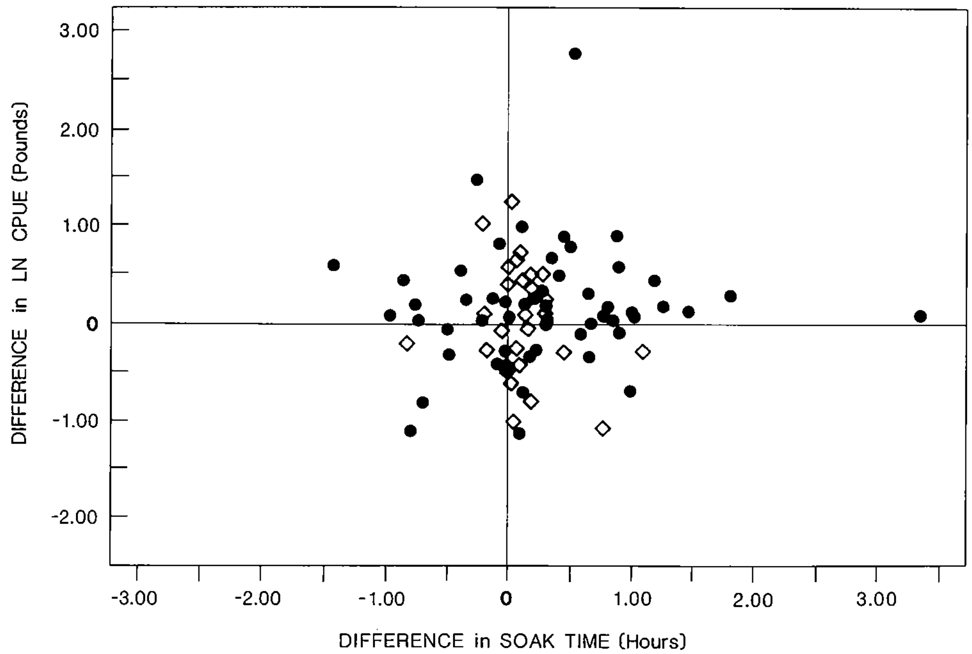

Figure 7. **Plot of ln(CPUE) differences versus soak time differences between vessels for stations of both 1982 experiments (● — western Gulf of Alaska; ◇ — southeastern Alaska).**

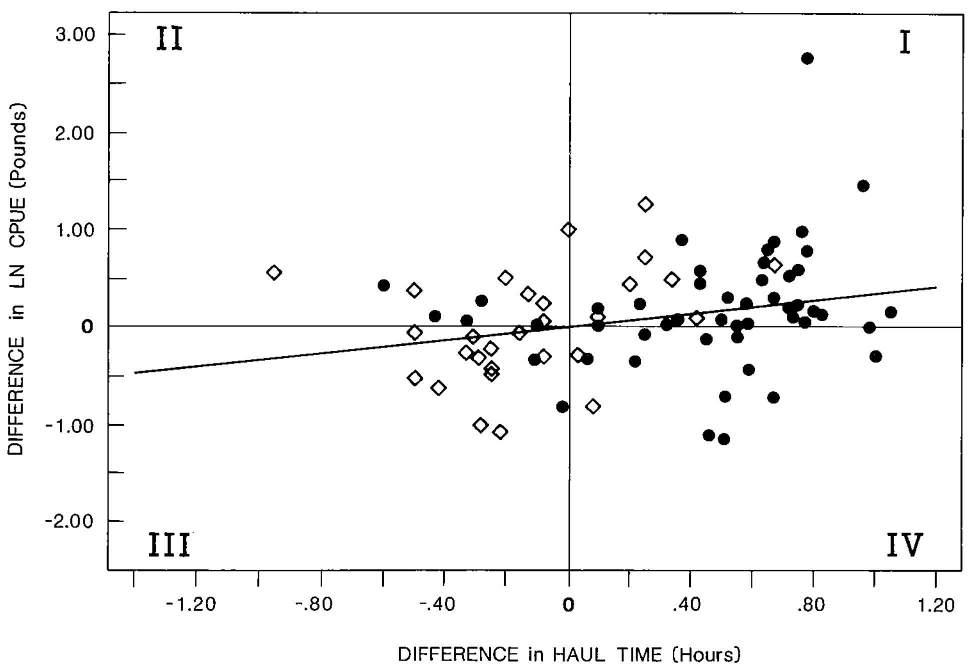

Figure 8. **Plot of ln(CPUE) differences versus haul time differences between vessels for stations of both 1982 experiments, and best fitting straight line (● — western Gulf of Alaska; ◇ — southeastern Alaska). Quadrants are denoted by Roman numerals.**

To ensure that the results were not influenced by outliers in the data (see Figure 8), the following robust analysis was performed. For each experiment, the number of stations with either negative or positive differences in both haul time and CPUE (i.e., the number of points in the first and third quadrants in Figure 8) was compared with the number of stations with a negative difference in one variable and a positive difference in the other (i.e., the second and fourth quadrants in Figure 8). With the reasonable assumption of independence of the data, a binomial test can be used to test the null hypothesis of no relationship between CPUE and haul speed. Under the null hypothesis, the expected proportion of stations in the first and third quadrants should be 50%. The observed proportion for the western Gulf was 35 out of 53 stations (66%), which is significantly different from 50% ($Z = 2.32$, $P = .020$). The observed proportion for southeastern Alaska was 21 out of 29 stations (72%), which is significantly different from 50% ($Z = 2.49$, $P = .012$). Overall, the observed proportion was 56 out of 82 (68%), which is significantly different from 50% ($Z = 3.44$, $P = .0006$). These results confirm the previous results which show a significant relationship between CPUE and haul time.

Relative gear efficiency as a function of haul time can be estimated from the best model as

$$R^* = e^{-\hat{Y}} = e^{-\hat{\beta}_2 X_2} \qquad (1)$$

where $\hat{\beta}_2 = 0.400 \pm 0.123$. For the western Gulf of Alaska experiment the average difference in haul time was 0.45 ±0.05 hour (±1 standard error) resulting in an estimated gear efficiency R^* of 0.84 ±0.05.

For the southeastern Alaska experiment, the average difference in haul time was -0.12 ±0.06 hour, resulting in R^* of 1.05 ±0.03. The similarity of these estimates to the observed gear efficiencies (Tables 2, 3) suggests that haul speed was the primary cause for the difference in the CPUE for snap gear in the western Gulf of Alaska experiment.

RESULTS FROM THE 1983 EXPERIMENT IN THE KODIAK REGION

Station-by-station results of CPUE are given in Appendix Table 5. Each vessel fished 8 skates at a station, but effort standardized for hook-spacing was 6.72 skates per station for the M/V MASONIC and 7.20 skates per station for the M/V VALOROUS. Because of this difference, CPUE is used for analysis of this experiment in contrast to using catch for the previous experiments where effort was the same for the two vessels. Auxiliary data on depth, soak time, and haul time are given in Appendix Table 6.

The summarized data for both vessels across all stations presented in Table 5 include number caught per unit of effort and weight caught per unit of effort of sublegal, legal, and total halibut. The estimated correlation coefficient between vessels, CPUE ratio $\hat{R}$ (relative gear efficiency), its coefficient of variation, and 95% confidence interval are also given. The results of stratifying the data by depth and catch rate are also shown in Table 5.

The snap gear vessel caught 13% more sublegal-size fish and about the same amount of legal size fish per unit of effort as compared to the vessel with fixed-hook gear. Average weight of legal-size fish was about 2 pounds greater on the snap vessel, resulting in a CPUE in weight of 6% more than the fixed-hook vessel. None of the ratios was significantly different from 1, indicating no statistical difference in relative efficiency. The relative length frequencies of fish in the catch for both vessels shown in Figure 9 were also not significantly different ($\chi^2 = 27.7$, 29df, $P > .50$). The results were consistent across stations as evidenced by the high correlations between vessels in Table 5. The 46 observations provided sufficient information to detect differences of at least 10-15% in CPUE of legal-size fish between the vessels, due to the high correlation in catches.

Table 5. Kodiak experiment results, 1983.[1]

	$\bar{x}$	$\bar{y}$	cv($\bar{x}$)	cv($\bar{y}$)	n	$\hat{\rho}$	$\hat{R}$	cv($\hat{R}$)	95% C.I.
ALL DATA	Number[3]								
Sublegal	0.58	0.72	0.13	0.13	46	0.52	1.24	0.13	(0.92, 1.56)
Legal	3.5	3.5	0.08	0.08	46	0.77	1.00	0.05	(0.89, 1.11)
Total	4.1	4.2	0.07	0.07	46	0.73	1.02	0.05	(0.92, 1.13)
	Weight[3]								
Sublegal	4	5	0.12	0.12	46	0.43	1.25	0.13	(0.93, 1.57)
Legal	153	162	0.10	0.09	46	0.76	1.06	0.07	(0.92, 1.20)
Total	157	167	0.09	0.08	46	0.76	1.06	0.06	(0.94, 1.19)
DEPTH[2]	Number								
0-74	2.7	3.4	0.15	0.14	11	0.43	1.26	0.16	(0.82, 1.69)
75-99	3.9	3.7	0.10	0.09	21	0.74	0.95	0.07	(0.81, 1.09)
100+	3.4	3.3	0.18	0.19	14	0.88	0.97	0.09	(0.78, 1.16)
75+	3.7	3.5	0.09	0.09	35	0.81	0.95	0.06	(0.84, 1.05)
	Weight								
0-74	112	158	0.19	0.16	11	0.61	1.41	0.16	(0.92, 1.90)
75-99	155	163	0.11	0.10	21	0.68	1.05	0.08	(0.87, 1.24)
100+	184	163	0.20	0.22	14	0.89	0.89	0.10	(0.69, 1.08)
75+	166	163	0.11	0.10	35	0.81	0.98	0.07	(0.85, 1.11)
CATCH RATE[2]	Number								
<2.0	1.3	1.9	0.12	0.23	10	0.59	1.46	0.19	(0.85, 2.08)
2-3.9	2.9	3.1	0.04	0.09	21	0.29	1.07	0.09	(0.87, 1.26)
4+	5.8	5.2	0.06	0.07	15	0.48	0.90	0.07	(0.77, 1.03)
	Weight								
<2	46	89	0.15	0.26	10	0.42	1.93	0.24	(0.89, 2.98)
2-3.9	126	137	0.06	0.10	21	0.14	1.09	0.11	(0.84, 1.33)
4+	262	244	0.09	0.10	15	0.79	0.93	0.06	(0.81, 1.06)

[1] $\bar{x}$ average for fixed-hook gear
$\bar{y}$ average for snap gear
n number of stations
$\hat{\rho}$ correlation
$\hat{R}$ ratio
cv coefficient of variation

[2] Depth in fathoms.
Catch rate in number per skate per station.

[3] "Number" denotes average number per skate per station.
"Weight" denotes average weight per skate per station.

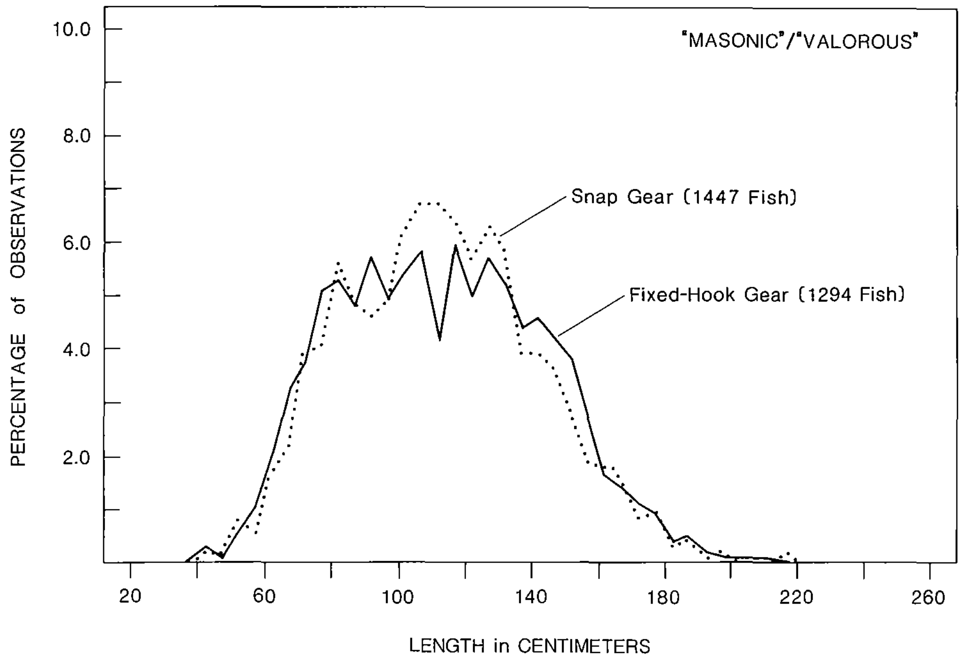

Figure 9. Relative length frequencies of halibut caught by each vessel in Kodiak, 1983.

The following comparisons involve only the data on CPUE of legal-size fish for applicability to the commercial fishery. Depth and fish density were examined as factors affecting the reliability of the results. The starting depth at each station for the fixed-hook vessel was used to stratify the data into 3 categories (0-74, 75-99, 100+ fathoms). The category (75+ fathoms) was also used for comparison with the 1982 experiment. The CPUE in numbers for snap gear was larger than for fixed-hook gear for the shallowest depth category, but smaller for the other three categories. The CPUE in weight for snap gear was larger for the 2 shallowest depth categories, but smaller for the other two categories. However, in no category was the relative gear efficiency significantly different from 1, indicating that depth was not a factor in the results.

Similarly, the data were stratified into 3 categories based on the catch in number per unit of effort of the fixed-hook vessel (0-1.9, 2-3.9, 4+). Both CPUE in number and CPUE in weight for snap gear were smaller than for fixed-hook gear for the two lowest catch rate categories, but larger for the highest catch rate category. However, in no category was the relative gear efficiency significantly different from 1, indicating that catch rate was not a factor in the results.

Soak time and haul time were also examined as factors affecting the results in a similar manner to the 1982 experiments. The difference in the logarithms of CPUE [actually ln(CPUE + 1), as before] in weight of the fixed-hook and snap vessels was plotted against soak time (Figure 10) and haul time (Figure 11). Both positive and negative differences in soak time and haul time occurred, which were fairly evenly distributed about 0. The range of soak time differences was -0.7 to 1.0 hour and the range of haul time differences was -0.8 to 0.4 hour. The range of haul time differences was smaller than in the 1982 western Gulf of Alaska experiment (-0.6 to 1.0 hour,

Figure 8). There appears to be no trend in the differences in ln (CPUE) with either soak time or haul time differences in the figures. Both positive and negative differences in ln (CPUE) occur consistently with positive and negative differences in soak time and haul time.

The multiple linear regression analysis of ln (CPUE) differences versus soak time and haul time differences was repeated with the 1983 experimental data. None of the parameters (α, β_1, β_2) were significantly different from 0 for any model (Table 6). Thus, the best model describing these data is the model with random variability about a mean of 0. This model implies there were no significant differences in ln (CPUE), soak time, or haul time between vessels nor any demonstrable relationship between ln (CPUE) and the two factors. This result is in accord with the lack of significant difference in gear efficiency between vessels presented earlier.

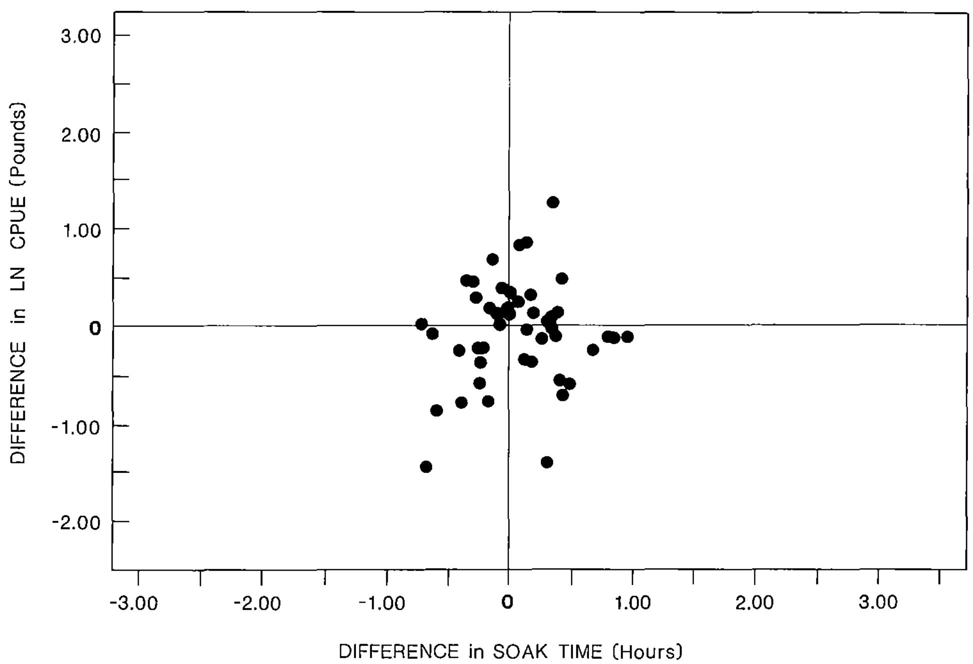

Figure 10. Plot of ln(CPUE) differences versus soak time differences between vessels for stations in the 1983 experiment.

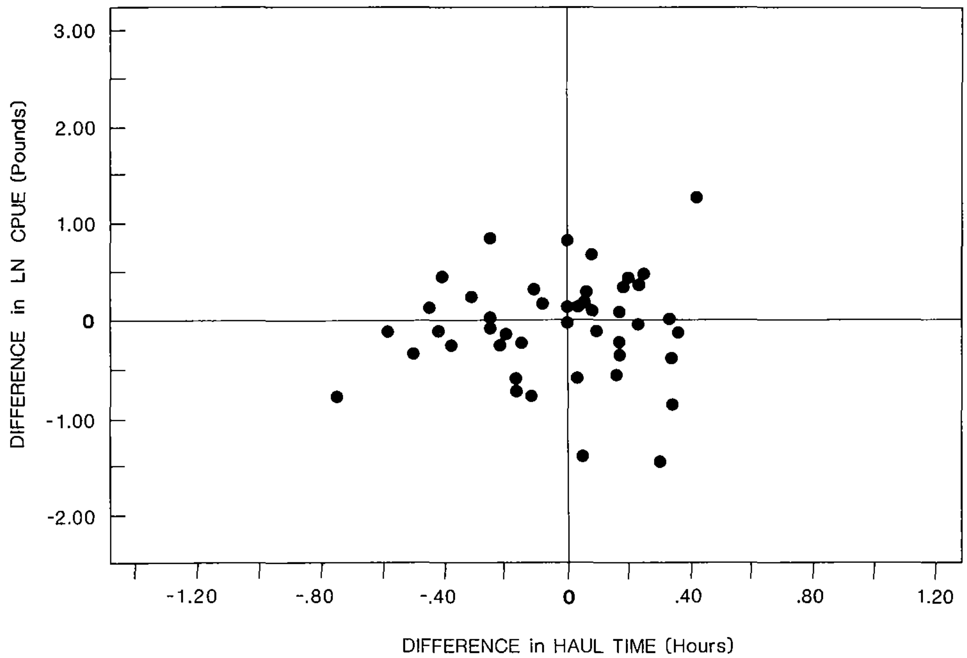

Figure 11. Plot of ln(CPUE) differences versus haul time differences between vessels for stations in the 1983 experiment.

Table 6. Results of model fits and parameter estimates for the relationship of ln(CPUE) differences versus soak time and haul time differences for the 1983 experiment.

Model Parameters[1]	Residual Sum of Squares	Degrees of Freedom	$\alpha \pm 1$ s.e.	$\beta_1 \pm 1$ s.e.	$\beta_2 \pm 1$ s.e.
α	12.88	45	-0.066±0.079		
α,β_1	12.69	44	-0.075±0.080	0.166±0.202	
α,β_2	12.80	44	-0.061±0.080		0.151±0.291
β_1	12.94	45		0.140±0.200	
β_2	12.97	45			0.180±0.287
α,β_1,β_2	12.58	43	-0.070±0.081	0.173±0.292	0.176±0.205
TOTAL (no parameters)	13.08	46			

[1]α — y-intercept; β_1 — soak time coefficient; β_2 — haul time coefficient

The lack of a demonstrable relationship with haul time in the 1983 experiment does not contradict the results of the 1982 experiment, because of the smaller range of haul time differences in the 1983 experiment. When the 1983 data were combined with the 1982 data, the haul time parameter in the multiple linear regression model was still significant ($t = 3.32$, $.001<P<.002$).

DISCUSSION AND CONCLUSIONS

In general, the experimental design for the fishing operations was satisfactory in that the vessels were able to conduct their fishing operations efficiently and the data required by the study were obtained. The sensitivity of the KRISTINE/DAILY comparison was reduced by the smaller number of usable observations, although useful results were obtained. If similar comparisons are conducted in the future, a minimum of 50 usable observations would be desirable. While several departures from the basic plan of operation did occur, such as the spacing for the two pairs of vessels, the size of bait used in the western Gulf of Alaska, the number of skates fished per station in southeastern Alaska, the hauling speed in the western Gulf of Alaska, and the poor weather and sea conditions in the Kodiak region, these departures did not appear to detract from the usefulness of the results. In fact, the difference in hauling speed in the western Gulf of Alaska was perhaps fortuitous in that it provided a rough test for the effect of hauling speed on the relative efficiency of the two gears.

The experimental results provide evidence that depth, fish density (measured by catch rate), bottom contour, and bottom type are not significant factors in determining the relative efficiency of snap gear and fixed-hook gear. Further, size composition was essentially the same for the two gear types for all three regions. While hauling speed was strongly suggested as an important factor in standardizing CPUE, the 1983 study indicated no effect when two vessels hauled 8 skates within one-half hour of each other.

At present, no information is available to test that the difference in the CPUE by snap gear and fixed-hook gear from the commercial fishery is due to differences in hauling speed. However, on the basis of the experimental results, it would be desirable to have port samplers collect information on the hauling speed by individual vessels when they copy log records. By solving equation (1) for haul time difference (X_2) in terms of the observed ratio (R^*) of snap to fixed CPUE and the coefficient β_2, it is possible to predict the haul time difference required to explain the observed ratio of CPUE. Using the pooled results from Table 1 and assuming each vessel fished 8 skates of gear, it would take a haul time difference of 0.44 hour to explain the CPUE ratio of 0.84 in Charlotte-Inside, 0.79 hour for the ratio of 0.73 in southeastern Alaska, and 1.23 hours for the ratio of 0.61 in Kodiak.

Other factors may affect the relative efficiency of snap gear. While the same average hook spacing was maintained between each pair of vessels, the variability of the spacing on snap gear may affect efficiency. Also, information about the number of fish lost at the rail or the number of gangions lost by the snap gear vessels could be useful in determining whether the loss of fish due to snap failure could be a factor in the relative efficiency of the two gears. Accurate information of this type is difficult to collect during research operations, but the collection of information on gangion replacement by individual vessels in the commercial fishery could provide a measure of this potentially important statistic.

The experimental results suggest no intrinsic difference in gear efficiency between snap and fixed-hook gear. Some of the possible reasons for lower CPUE of snap gear in the commercial fishery are not supported by these experiments. First, it is unlikely that snap gear "fishes" any differently on the bottom than fixed-hook gear. This is supported, in addition, by additional research using a submarine to observe both gears[1]. Secondly, it is unlikely that detachment of snaps from the groundline is a significant factor. Otherwise, the relative gear efficiency should have been significantly less than one.

There was evidence that hauling speed might have a bearing on the relative efficiency of halibut gear. However, if hauling speed is similar for both gear types in the commercial fishery, then the efficiency of both gear types should be the same. Then, the explanation of the lower CPUE of snap gear in the commercial fishery may rest in other causes. It appears that additional information from the commercial fishery is required if snap gear is to be incorporated into the calculation of CPUE statistics for halibut, including studies of fishing locations, skipper and crew experience, and vessel characteristics.

[1]These observations were made during joint IPHC/National Marine Fisheries Service (NMFS) studies in 1983 in which IPHC provided the chartered longliner and NMFS provided the chartered submarine.

ACKNOWLEDGMENTS

These experiments would not have been possible without the cooperation, skill, and intelligence of the skippers and crew of the chartered vessels. The skippers of the chartered vessels were Lloyd Larsen of the M/V VALOROUS (2 experiments), Helmut Opolka of the M/V DAILY, Jack Crowley of the M/V KRISTINE, Cal Falk of the M/V MASONIC, and Ralph Lund of the M/V THOR (1 experiment each). In addition to the authors, the following IPHC staff served as chief scientific personnel and we thank them for their help in carrying out the experiments: Steve Hoag, Gregg Williams, and Russell Price. We also thank other IPHC staff who participated in these experiments. We thank Dr. Ray Hilborn, Dr. Dan Kimura, Dr. Steinar Olsen, and Dr. Dan Ware for their reviews of this report. Finally, we thank Cynthia Doyer for typing the manuscript, Ken Exelby for preparing the figures, and Russell Price for classifying the bottom type and contour of the stations.

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APPENDIX

Appendix Table 1. Western Gulf of Alaska station details, 1982.

		#-S		W-S		#-L		W-L		
ST	DATE	THR	VAL	THR	VAL	THR	VAL	THR	VAL	CD
69D	0719	11	17	81	110	51	28	2685	1714	
69E	0719	4	14	31	113	14	14	714	736	
69F	0719	7	0	45	0	55	36	3125	2668	
69G	0719	0	2	0	8	41	39	2234	2443	S
69J	0718	4	5	28	36	39	46	2059	2345	
69K	0718	10	5	74	24	31	23	1853	1527	
69L	0718	0	3	0	24	97	78	6544	5232	
69M	0718	5	1	39	8	14	21	483	732	S
71A	0714	6	3	34	12	41	17	2270	859	
71B	0714	2	2	16	15	22	14	1006	758	
71C	0714	5	5	18	13	31	10	1533	348	
71D	0714	4	3	13	14	13	20	490	1165	S
71F	0717	4	1	32	2	43	34	1794	1456	
71G	0717	13	6	81	35	12	20	327	827	
71H	0717	4	7	32	49	31	32	1137	1530	S
71I	0717	6	4	36	23	36	25	1504	1344	
73A	0715	5	6	18	29	10	4	213	99	
73B	0715	3	2	13	8	4	4	79	140	
73C	0715	4	8	21	67	17	8	738	247	S
73D	0715	8	4	38	17	16	19	530	561	
73E	0716	5	2	27	9	36	30	1631	1395	S
73F	0716	9	6	50	32	6	3	142	79	
73G	0716	10	6	60	34	13	6	528	330	
73H	0716	7	5	53	26	12	0	457	0	
73I	0712	17	4	110	17	26	13	1580	685	
73J	0712	7	11	44	83	2	2	27	22	
73K	0712	9	8	62	63	3	4	34	262	
73L	0712	10	7	53	47	9	8	239	230	
75G	0711	4	0	19	0	45	27	2327	1537	
75H	0711	2	0	12	0	39	16	2343	1065	
75I	0711	4	12	32	56	18	9	1059	450	
75J	0711	10	10	34	26	15	17	909	865	
75K	0710	13	5	74	33	26	19	1598	1266	
75L	0710	2	3	12	20	0	1	0	12	
75M	0710	12	8	88	51	17	13	360	390	
75N	0710	7	0	52	0	38	2	1510	31	L
76I	0709	3	4	18	19	25	20	1362	1178	
76J	0709	0	4	0	23	52	45	3094	2912	
77F	0709	7	3	39	19	31	20	1546	1593	
77G	0709	7	5	58	28	18	19	914	939	
79C	0705	2	7	11	41	16	18	774	737	
79D	0705	13	11	67	66	20	16	773	748	
79E	0705	20	27	144	133	35	24	865	818	
79F	0705	24	9	127	27	11	6	223	291	
79G	0708	19	20	115	95	16	8	412	205	
79H	0708	30	27	179	146	9	8	164	151	
79I	0708	19	14	103	86	17	11	481	234	G
79J	0708	1	14	8	108	5	13	93	223	
81A	0707	10	9	75	51	19	12	413	352	
81B	0707	15	9	95	51	11	16	392	611	
81C	0707	28	25	153	136	16	10	714	315	
81D	0706	34	30	194	175	5	5	89	86	
81E	0706	24	7	137	41	6	5	101	137	
81F	0706	19	19	104	96	17	13	291	292	
81G	0706	18	32	109	203	6	5	87	80	

Codes:

ST — station
DATE — date
THR — Thor (fixed-hook gear vessel)
VAL — Valorous (snap gear vessel)
#-S — # of sublegal (<82 cm) halibut
#-L — # of legal (≥82 cm) halibut
W-S — weight of sublegal halibut
W-L — weight of legal halibut
CD — use code
S — hauled at same speed
L — lost gear or not fished (not used)
G — gear snarl (not used)

Appendix Table 2. Southeastern Alaska station details, 1982.

		#-S		W-S		#-L		W-L		
ST	DATE	KRI	DLY	KRI	DLY	KRI	DLY	KRI	DLY	CD
21F	0724	1	0	9.3	0	7	2	137.5	35.9	L
21G	0724	0	0	0	0	0	0	0	0	L
21H	0724	0	0	0	0	4	2	231.9	285.9	L
21I	0724	0	0	0	0	0	2	0	40.9	L
21J	0725	0	0	0	0	14	3	714.2	55.8	L
21K	0725	0	1	0	7.2	4	4	182.3	97.1	L
21L	0725	0		0		1		79.4		L
21M	0726	2	0	16.1	0	7	9	253.2	466.6	L
21N	0726	0	1	0	6.0	2	7	72.8	274.5	L
21O	0726	0	0	0	0	6	0	545.2	0	L
21P	0726	1	0	7.5	0	1	6	81.2	459.4	L
21Q	0727	0	1	0	10.1	6	0	331.4	0	L
21R	0727	1	0	5.7	0	1	0	48.9	0	L
23C	0728	14	25	99.4	136.5	12	19	535.5	721.4	
23D	0728	11	36	76.9	276.8	14	41	485.3	1378.7	
23E	0728	6	7	44.6	62.3	11	14	551.3	474.2	
25D	0729	8		59.4		14		692.2		L
25E	0729	1		4.9		1		68.1		L
25F	0729	1		9.7		8		342.3		L
25G	0729	4		34.6		14		429.5		L
26D	0730	19	30	118.5	232.7	11	22	220.1	536.6	
26E	0730	3	7	24.6	50.2	17	8	843.0	510.5	
26F	0730	5	3	37.1	22.5	12	10	240.4	280.3	
26G	0730	0	1	0	10.6	10	11	503.8	339.5	
27C	0731	17	5	147.9	39.1	54	32	1111.5	670.2	
27D	0731	1	6	4.4	34.3	22	27	1259.1	810.3	
27E	0731	4	0	30.9	0	13	12	601.5	651.9	
27F	0801	0	0	0	0	5	3	315.4	111.4	
27G	0801	1	1	6.9	9.3	23	17	1206.9	571.4	
27H	0801	2	4	19.0	34.9	15	22	661.4	1083.4	
27I	0801	1	4	9.3	27.8	36	13	1826.3	484.7	
29A	0802	2	0	10.7	0	12	14	752.7	691.4	
29B	0802	1	1	9.7	7.5	28	39	1386.0	1697.6	
29C	0802	1	1	4.7	9.0	19	41	912.3	1690.9	
29D	0802	1	1	10.6	9.0	95	59	4745.1	2440.7	
31A	0803	3	0	27.6	0	21	12	728.9	586.2	
31B	0803	2	7	13.5	43.3	21	27	1058.8	1289.8	
31C	0803	5	5	32.4	30.9	20	24	890.7	1162.0	
31D	0803	2	5	11.2	40.2	19	33	843.2	1321.1	
34A	0804	2	4	15.3	27.0	15	18	618.7	556.0	
34B	0804	1	0	9.7	0	21	22	945.9	1008.1	
35A	0804	2	0	13.5	0	17	10	692.2	421.6	
35B	0804	16	18	131.3	140.2	17	40	430.8	1414.8	
37A	0805	1	8	8.2	66.8	24	28	1234.5	1601.6	
37B	0805	5	10	42.5	89.7	15	17	437.1	649.5	
37C	0805	2	2	16.1	20.3	77	52	2288.1	1382.1	

Codes:

ST — station
DATE — date
KRI — Kristine (fixed-hook gear vessel)
DLY — Daily (snap gear vessel)
#-S — # of sublegal ($<$82 cm) halibut
#-L — # of legal ($\geq$82 cm) halibut
W-S — weight of sublegal halibut
W-L — weight of legal halibut
CD — use code
S — hauled at same speed
L — lost gear or not fished (not used)
G — gear snarl (not used)

Appendix Table 3. Western Gulf of Alaska auxiliary data by station, 1982.

			Depth(f)				CPUE (lbs./skate)		Soak time(hr)		Haul time(hr)	
			THR		VAL							
ST	BT	BC	Max	Min	Max	Min	THR	VAL	THR	VAL	THR	VAL
69D	SRM	F	71	56	69	53	373.32	243.24	12.47	11.28	2.60	2.17
69E	MSR	F	89	85	88	83	100.56	113.26	10.03	9.13	2.63	2.08
69F	RM	U	111	70	120	60	427.84	355.69	7.30	7.17	2.97	2.25
69G	RS	R	51	41	46	40	301.54	326.75	5.00	5.50	2.50	2.25
69J	RG	FU	36	27	35	22	281.59	317.54	13.00	12.42	2.53	2.08
69K	G	F	41	38	40	32	259.97	206.76	10.78	10.55	2.48	2.25
69L	RG	F	48	42	47	32	883.17	700.78	7..12	7.47	3.83	3.08
69M	GS	F	127	80	120	72	70.52	98.64	4.85	5.33	2.48	2.42
71A	RM	R	80	22	69	11	310.98	116.07	11.78	11.68	2.58	1.82
71B	RM	R	96	45	93	45	137.89	102.97	9.35	9.08	2.52	2.00
71C	R	R	35	24	30	22	209.31	48.07	7.08	7.35	2.38	1.42
71D	R	R	42	20	40	22	68.00	157.20	4.97	5.67	2.23	2.25
71F	RS	U	25	15	28	18	246.37	194.40	5.00	5.13	2.50	1.92
71G	SG	F	38	34	37	31	55.06	114.94	7.28	7.17	2.25	1.58
71H	SG	F	45	40	43	40	157.80	210.57	9.50	9.28	2.27	2.58
71I	SG	F	52	50	50	49	207.80	182.25	11.83	11.53	2.57	1.75
73A	RS	U	33	12	40	10	31.19	17.01	5.00	6.42	2.17	1.42
73B	RS	U	53	17	48	11	12.41	19.66	7.23	7.33	2.17	1.58
73C	RS	U	21	12	26	15	102.50	41.81	9.45	9.00	2.45	2.08
73D	RS	RU	37	16	34	17	76.65	77.13	11.67	11.00	2.13	1.58
73E	SR	R	58	44	45	35	223.78	187.16	5.15	5.92	2.43	2.33
73F	S	F	58	54	58	53	25.85	14.83	7.35	7.75	2.22	1.50
73G	S	U	56	39	49	37	79.42	48.57	9.40	9.00	2.38	1.75
73H	SM	F	54	47	54	40	68.88	3.44	11.62	11.08	2.28	1.50
73I	M	F	56	50	53	46	228.13	93.71	11.75	10.87	2.42	1.75
73J	M	F	73	64	70	65	9.52	14.06	9.48	8.83	2.30	2.08
73K	M	F	75	68	74	68	13.04	43.31	7.22	7.13	2.18	1.67
73L	M	F	60	59	59	59	39.38	36.94	4.95	5.92	2.18	1.83
75G	SR	R	46	27	65	23	316.60	204.92	4.97	5.83	2.48	3.08
75H	SR	R	66	30	43	26	317.87	141.94	7.25	7.33	2.48	1.83
75I	RS	RU	35	26	39	32	147.19	67.45	9.63	9.13	2.53	1.75
75J	R	F	45	40	44	39	127.22	118.81	12.02	11.25	2.25	1.75
75K			61	44	53	40	225.70	173.30	11.92	10.12	2.55	2.83
75L	M	F	81	78	80	77	1.59	4.25	9.92	8.93	2.18	1.67
75M		F	57	52	57	55	60.41	58.70	7.92	7.08	2.15	1.83
75N		U	135	60	120	57	210.82	16.78	4.97	5.67	3.18	1.58
76I	R	U	37	33	35	35	186.25	159.60	10.75	9.50	2.55	1.50
76J		F	45	41	43	40	417.50	391.33	13.93	10.58	2.00	2.33
77F	R	U	38	32	38	33	213.88	214.97	8.38	8.08	2.65	1.67
77G	SG	RU	186	42	180	40	131.20	128.97	5.13	5.87	2.65	2.55
79C	R	R	56	25	41	30	105.86	103.77	5.50	5.72	2.40	2.50
79D	R	U	51	35	30	30	113.35	108.55	7.70	7.70	2.47	1.70
79E	R	U	32	22	28	25	136.11	126.90	9.93	8.92	2.48	2.12
79F	S	F	29	28	25	25	47.26	42.48	12.20	10.75	2.32	2.75
79G	S	F	38	36	37	35	71.11	39.97	11.48	10.58	2.35	1.92
79H	SR	F	47	45	45	44	46.25	39.59	9.22	8.42	2.47	1.67
79I	SR	F	52	47	51	45	78.85	42.68	7.03	6.75	2.38	1.75
79J	S	RU	308	52	220	50	13.71	44.15	4.37	5.17	2.63	2.17
81A	S	F	45	34	47	35	65.89	53.73	4.77	4.80	2.30	1.58
81B	S	U	54	46	43	43	65.68	88.34	6.87	6.90	2.50	1.50
81C	G	U	62	44	52	52	116.93	60.09	9.35	9.00	2.47	1.83
81D	S	F	62	55	60	60	38.23	34.77	11.92	10.92	2.48	1.75
81E	M	F	60	55	53	53	32.18	23.75	9.53	8.88	2.42	1.75
81F	SM	F	45	42	40	40	53.36	51.83	7.73	7.42	2.33	1.75
81G	S	F	51	50	50	50	26.46	37.79	5.67	5.50	2.22	2.33

Codes:

BT—Bottom Type
- H — hard
- R — rocky
- G — gravel
- M — mud
- S — sand

BC— Bottom Contour
- R — rough
- U — uneven
- F — flat

THR—Thor (fixed-hook gear vessel)

VAL—Valorous (snap gear vessel)

Appendix Table 4. Southeastern Alaska auxiliary data by station, 1982.

			Depth(f)				CPUE					
			KRI		DLY		(lbs./skate)		Soak time(hr)		Haul time(hr)	
ST	BT	BC	Max	Min	Max	Min	KRI	DLY	KRI	DLY	KRI	DLY
21F	SM	UR	105	80	80	80	22.64	13.06	7.00	6.77	2.17	0.83
21G	S	UR	220	157	230	170	0.00	0.00	10.33	8.15	2.50	3.72
21H	R	F	190	185	190	186	31.30	39.06	13.50	11.30	3.58	2.75
21I	RM	U	194	136	180	110	0.00	5.58		5.60		3.18
21J	RS	F	88	77	100	90	86.74	7.62	7.00	8.22	1.67	2.28
21K	R	UR	103	84	140	110	32.79	14.25	8.75	10.63	1.42	2.32
21L	RG	R	135	115			14.29		12.25		1.42	
21M	RS	RF	97	61	160	150	48.44	85.01	6.17	7.10	1.50	2.75
21N	R	UF	187	109	120	90	13.11	51.10	7.33	9.98	2.42	2.12
21O	SR	F	215	208	212	210	98.05	0.00	22.40	11.93	3.27	1.50
21P	SG	F	229	222	230	230	15.95	83.66	12.00	13.32	2.33	2.17
21Q	SR	UF	170	145	185	185	46.51	1.85	5.00	4.88	2.00	2.12
21R	S	F	193	190	193	193	9.82	0.00	7.50	7.15	2.00	1.88
23C	GS	UF	61	53	56	56	114.17	156.27	5.83	4.73	1.33	1.62
23D	RG	F	68	64	65	65	101.10	301.57	7.50	6.73	1.58	1.80
23E	GS	F	89	80	82	75	107.17	97.72	9.17	8.88	1.67	1.58
25D	S	F	67	64			135.17		5.00		1.75	
25E	SG	F	100	100			13.14		6.75		1.50	
25F	HGS	F	106	103			63.30		8.50		1.75	
25G	GS	F	112	109			83.49		11.00		1.33	
26D	S	FU	55	47	54	40	60.91	140.13	5.83	5.65	1.58	1.50
26E	S	FU	87	79	80	65	156.05	102.15	7.17	7.07	1.67	1.47
26F	HGS	F	103	98	103	96	49.92	55.14	8.83	8.90	1.42	1.73
26G	SG	U	131	109	123	108	90.59	63.76	12.00	11.82	1.50	1.63
27C	HRG	R	95	48	115	35	226.51	129.20	4.75	4.75	1.67	2.62
27D	RSG	U	54	50	60	55	227.26	153.87	6.75	6.77	1.50	2.00
27E	HRS	RU	73	68	91	80	113.74	118.74	9.17	9.00	2.17	2.67
27F	HRS	F	102	98	110	91	56.72	20.29	5.00	5.22	1.50	1.50
27G	RS	F	106	105	105	105	218.31	105.74	6.83	6.75	1.75	1.50
27H	RS	F	110	103	113	112	122.37	203.69	9.00	9.02	1.50	2.00
27I	RS	F	110	106	115	106	330.19	93.38	11.33	11.32	1.75	1.50
29A	R	UR	81	77	96	80	137.29	125.94	5.25	5.45	2.00	1.58
29B	GS	UF	89	81	96	96	251.11	310.58	6.75	6.93	1.75	1.72
29C	GS	F	100	97	105	96	164.95	309.64	9.00	8.98	1.50	1.92
29D	G	F	104	100	110	105	855.34	446.20	11.33	11.30	2.75	2.08
31A	R	R	60	26	65	45	136.05	106.78	5.08	4.78	1.50	1.58
31B	R	R	64	44	46	45	192.88	242.84	6.25	7.08	1.67	1.92
31C	R	UR	74	50	75	60	165.96	217.27	9.50	9.45	1.50	1.83
31D	RG	FU	102	92	100	88	153.67	247.95	11.75	11.77	1.67	1.92
34A	RGS	UR	85	67	85	65	114.02	106.18	10.25	10.13	1.75	1.83
34B	S	F	115	103	115	97	171.88	183.62	8.00	7.85	1.67	1.83
35A	R	R	37	34	32	20	126.92	76.77	4.75	4.48	1.25	1.45
35B	RS	F	70	58	80	70	101.10	283.23	6.50	6.47	1.50	1.78
37A	R	RU	52	31	55	30	223.51	303.82	5.33	4.88	1.67	1.75
37B	GSM	RF	76	60	71	67	86.27	134.65	7.25	7.17	1.50	1.75
37C	RS	U	160	97	210	100	414.43	255.44	9.50	9.33	2.17	1.83

Codes:

BT —Bottom Type
- H — hard
- R — rocky
- G — gravel
- M — mud
- S — sand

BC — Bottom Contour
- R — rough
- U — uneven
- F — flat

KRI — Kristine(fixed-hook gear vessel)

DLY — Daily (snap gear vessel)

Appendix Table 5. Kodiak station details, 1983.

Appendix Table 5. Kodiak station details, 1983.

ST	DATE	#-S MAS	#-S VAL	W-S MAS	W-S VAL	#-L MAS	#-L VAL	W-L MAS	W-L VAL
41B	0523	1.0	0.0	7.9	0.0	1.6	0.8	60.1	25.1
41C	0523	0.4	0.0	3.4	0.0	1.2	1.0	44.4	43.9
41D	0523	0.3	0.8	1.9	5.4	2.5	3.8	111.1	163.9
41E	0523	0.6	0.8	4.2	6.6	4.3	3.6	171.9	169.9
41F	0522	0.6	0.1	5.5	1.1	2.8	1.7	107.8	66.8
41G	0522	0.1	0.3	1.2	2.0	2.7	3.3	114.5	117.6
41H	0522	0.0	0.3	0.0	2.4	2.8	1.8	201.8	102.1
41I	0522	0.1	0.6	0.8	4.7	0.9	1.7	30.8	135.9
41J	0521	0.1	0.4	1.0	2.6	3.0	3.6	188.3	172.9
41K	0521	0.1	1.0	1.2	6.4	2.4	2.4	80.7	78.2
41L	0521	0.7	1.0	4.2	6.0	3.7	2.9	118.9	169.0
41M	0521	0.4	1.8	3.1	10.7	3.3	2.8	132.3	99.1
43B	0524	1.0	1.4	4.7	7.7	2.2	1.9	89.3	65.0
43C	0524	0.4	1.7	3.2	12.9	2.7	4.4	118.2	244.3
43D	0524	0.4	0.1	3.1	1.2	2.7	1.3	153.0	42.7
43E	0524	0.1	0.3	1.2	2.5	3.1	4.6	143.2	184.2
43F	0525	0.4	0.0	3.3	0.0	7.7	5.6	473.2	371.4
43G	0525	0.6	0.1	4.4	1.2	1.3	1.5	69.4	61.2
43H	0525	0.6	0.0	4.2	0.0	7.6	8.8	374.1	431.1
43I	0525	1.0	0.4	7.7	2.2	2.7	4.0	122.1	215.5
43J	0526	0.4	1.3	3.4	8.6	1.8	2.9	72.0	157.7
43K	0526	0.7	0.8	4.9	5.7	4.9	4.9	202.3	167.3
43L	0526	1.0	1.1	8.3	6.9	6.7	3.9	222.1	141.7
43M	0526	0.7	1.1	4.3	6.4	5.5	6.3	264.0	286.1
43N	0528	0.1	0.1	1.2	1.4	3.4	1.9	164.3	71.3
43O	0528	0.9	1.4	4.5	10.7	3.1	5.0	101.3	184.6
43P	0528	2.1	1.1	16.7	8.7	5.4	5.7	155.9	177.2
43Q	0528	0.0	0.0	0.0	0.0	5.4	5.1	388.9	341.1
45A	0602	0.4	1.1	3.5	6.2	1.5	1.8	56.8	74.0
45B	0602	1.0	2.2	7.2	15.3	4.3	5.3	188.9	210.9
45C	0602	0.3	1.0	2.9	6.9	6.5	4.3	264.4	187.5
45D	0602	0.3	0.1	2.3	1.4	7.7	5.3	298.6	193.4
45E	0601	0.9	0.6	5.7	4.0	3.9	3.8	201.1	175.7
45F	0601	0.0	0.4	0.0	3.1	4.3	3.2	214.1	147.1
45H	0601	0.1	0.1	1.4	1.4	2.1	1.4	66.3	57.6
45I	0531	0.1	0.7	1.5	5.1	2.8	2.8	94.9	119.7
45J	0531	1.5	2.1	10.5	9.9	1.5	2.4	38.0	92.5
45K	0531	1.5	1.7	8.7	9.3	1.2	1.5	29.2	54.2
45M	0530	0.0	0.0	0.0	0.0	5.1	4.0	279.9	315.0
45N	0530	0.4	1.3	4.0	9.7	4.6	5.8	191.0	213.2
45O	0530	0.1	0.1	0.7	1.1	2.4	2.1	104.3	108.7
45P	0530	0.9	0.6	5.3	4.2	6.5	6.9	245.7	309.9
45Q	0529	1.3	0.8	9.9	5.5	2.7	5.3	119.0	265.0
45R	0529	1.8	1.4	7.8	8.3	1.6	5.1	59.8	246.1
45S	0529	1.5	1.0	11.0	6.8	3.4	3.6	120.4	173.5
45T	0529	0.0	0.0	0.0	0.0	0.1	0.1	3.8	3.0

Codes:

ST — station
DATE — date
MAS — Masonic (fixed-hook gear vessel)
VAL — Valorous (snap gear vessel)
#-S — # of sublegal (<82 cm) halibut/skate
#L — # of legal (≥82 cm) halibut/skate
W-S — weight of sublegal halibut/skate
W-L — weight of legal halibut/skate

Appendix Table 6. **Kodiak auxiliary data by station, 1983.**

ST	Depth(f) MAS Max	MAS Min	VAL Max	VAL Min	Soak time(hr) MAS	Soak time(hr) VAL	Haul time(hr) MAS	Haul time(hr) VAL
41B	98	97	99	95	11.55	11.42	2.00	2.25
41C	95	87	100	97	9.53	10.25	2.00	1.67
41D	96	92	94	93	7.58	7.83	2.17	1.83
41E	90	89	85	83	6.00	6.08	1.83	2.08
41F	100	99	95	93	11.75	11.33	2.00	1.75
41G	95	82	88	77	9.42	9.08	2.17	2.17
41H	143	123	138	116	7.28	7.42	2.25	2.17
41I	154	152	154	149	5.32	6.00	2.13	1.83
41J	140	133	140	130	11.58	11.25	2.25	2.08
41K	105	84	113	90	9.48	9.17	2.00	2.25
41L	69	64	62	60	7.20	7.08	2.00	2.50
41M	70	64	61	60	5.47	5.75	1.98	1.92
43B	68	66	80	65	5.92	5.75	1.97	2.08
43C	85	73	83	68	7.68	7.25	2.08	2.25
43D	121	108	120	101	9.60	9.25	2.50	2.08
43E	128	123	126	120	12.05	11.38	2.12	2.50
43F	131	131	127	124	5.23	5.17	2.27	2.58
43G	128	117	126	116	7.55	7.17	2.00	1.92
43H	106	93	106	88	9.50	9.25	2.13	2.33
43I	74	66	72	64	11.82	11.42	2.08	1.92
43J	84	65	76	63	5.58	5.75	2.05	2.17
43K	87	86	85	83	7.50	7.67	2.25	2.33
43L	80	50	70	47	27.82	28.17	1.92	2.33
43M	37	35	47	32	29.62	30.25	2.08	2.33
43N	130	86	130	105	5.58	5.50	2.17	2.17
43O	84	70	75	63	7.00	7.25	2.20	2.17
43P	80	66	102	63	10.17	9.33	2.03	1.67
43Q	195	147	200	142	11.97	12.00	2.22	2.67
45A	64	53	78	46	11.42	11.83	1.78	2.00
45B	82	80	79	77	9.70	9.33	2.25	2.67
45C	94	85	101	86	7.67	7.67	2.18	2.00
45D	97	85	100	89	5.62	5.92	2.28	2.08
45E	70	70	70	68	11.85	11.67	2.17	2.17
45F	88	87	85	82	9.60	9.67	2.23	2.00
45H	95	94	88	88	5.13	5.25	2.03	2.00
45I	89	64	90	67	11.10	11.33	1.93	2.08
45J	49	45	47	41	9.52	10.12	1.92	1.58
45K	38	30	33	26	8.15	7.67	1.83	2.00
45M	95	64	107	65	12.13	11.33	2.25	2.83
45N	108	100	102	100	10.20	9.25	2.17	2.08
45O	98	93	96	92	7.30	7.17	2.15	1.92
45P	85	67	87	60	5.08	5.33	2.25	2.08
45Q	60	57	56	56	11.35	11.75	2.17	2.92
45R	65	63	63	60	9.55	9.25	2.05	2.00
45S	84	72	86	67	7.75	7.58	2.17	2.00
45T	190	165	190	158	5.78	5.83	2.22	2.17

Codes:

MAS — Masonic (fixed-hook gear vessel)

VAL — Valorous (snap gear vessel)