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Factors Affecting Longline Catch and Effort:

I. General Review

by

Bernard E. Skud

II. Hook-Spacing

by

John M. Hamley and Bernard E. Skud

III. Bait Loss and Competition

by

Bernard E. Skud

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INTERNATIONAL PACIFIC HALIBUT COMMISSION

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Contents

ABSTRACT

In 1931, the International Pacific Halibut Commission defined a unit of fishing effort as 1,800 feet of longline gear. This definition assumed that catch was proportional to length of groundline regardless of the number of hooks. In 1940, the catch was assumed proportional to the number of hooks regardless of the length of groundline, and the unit of effort was redefined as a 6-line skate with 120 hooks. This proportionality also had been accepted in other longline fisheries and in theoretical studies.

In the early 1970's, 14 experiments were conducted to test the standards of CPUE used in the halibut fishery. Longlines with different hook-spacings were fished at the same time on the same grounds and the results showed that catch was dependent on the spacing and that effort was not proportional to the number of hooks. A new unit of effort, 100 hooks of 18-foot gear, was defined and effort by other longline gear was adjusted to this standard by an empirically determined curvilinear relation between catch per hook and hook-spacing.

During 6 of the cruises, special studies were conducted in which each hook was observed as it was retrieved to determine whether a fish had been caught or the bait retained. Over 170,000 hooks were examined and the data were compared with depth of fishing, soak-time and hook-spacing. Bait loss during a normal set was between 60 and 70% and differed with depth and soak-time. The distribution of halibut on the gear was not random, however, most of the halibut were not clustered on adjacent hooks. Halibut were more successful than other species in competing for the baited hooks. Apparently, halibut also were responsible for much of the bait loss, stealing the baits without being caught. The effects of bait loss and the catch of other species on the CPUE of halibut is discussed.

Comparisons made with results from the tuna longline fishery indicate that the effects of hook-spacing, bait loss, etc., are similar and suggest that the same basic phenomena occur in longline fisheries in general.

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INTRODUCTION

The relative simplicity of hook and line gear has contributed to the impression that the hook is an uncomplicated measure of fishing effort. This concept also is engendered by comparison with mobile gear such as trawls and purse seines; Allen (1963) and Gulland (1969) concluded that modifications in vessels or gear were more likely to change the fishing power of mobile gear than that of stationary gear such as traps and lines. A similar, but qualified, conclusion was echoed by Rothschild and Suda (1977): "The measurement of fishing effort in tuna fisheries involve the relatively simple (at least outwardly) problem of measuring fishing effort for a longline fishery and extremely complex problem of measuring fishing effort for a surface [purse seine] fishery". Intuitively, one accepts this difference between mobile and stationary gear and the significance of modifications in longline gear has often been neglected.

Most of the published works on longline gear concern pelagic fisheries, specifically the tunas (*Thunnus* spp.) in the Pacific, but the results of many of these papers are pertinent to demersal longline fisheries. These studies of pelagic gear, as well as theoretical papers on hook and line gear in general, will be reviewed along with the data from the fishery for Pacific halibut (*Hippoglossus stenolepis*).

In other demersal longline fisheries, most of the gear studies emphasized the relation of size selectivity to hook size or shape (Aasen 1965; Hamre 1968; McCracken 1963; Parrish 1963; Saetersdal 1963: and Forster 1973). Recognizing the need for experimental data on the size selectivity of hook and line gear, Clark (1960) and Pope (1966) suggested factors which should be considered in such research. Although not mutually exclusive, these factors fell into three categories: one concerned bait, its attractiveness and durability; a second, broadly classified as natural factors, included behavior and density of the target species, incidental catch of secondary species and environmental conditions; and the third category concerned fishing techniques and the gear itself: size, shape, and spacing of hooks, and the material and strength of the lines. These factors are as important to catch rates as they are to selectivity and my initial interest (Skud 1972) was directed toward the third classification, specifically the spacing of hooks as related to catch per unit of effort (CPUE), a subject that had received relatively little attention. In conjunction with the hook-spacing study, other factors affecting CPUE were considered, in particular, bait loss and competition between species for the baited hooks. The purpose in collecting these data was to learn more about the effectiveness of longline gear and its operation relative to the distribution of halibut, with the intent of evaluating and refining estimates of CPUE. The International Pacific Halibut Commission (IPHC), which is responsible for management of the fishery, has relied heavily on CPUE as an index of abundance.

The purposes of this introductory paper are (1) to discuss the general characteristics of longline gear using the halibut and tuna gear as examples of demersal and pelagic longline fisheries, and (2) to provide an historic review of papers pertinent to the estimation of CPUE in longline fisheries.

For convenience and to avoid unnecessary repetition, the Abstracts, Acknowledgements, Literature Cited, and the Appendices for all 3 of the papers in this report have been combined.

HALIBUT LONGLINE GEAR

The gear, setting and hauling equipment, and deck arrangement for conventional longline gear used in the halibut fishery are depicted in Figure 1. The functional unit of halibut longline gear is called a "skate" and consists of groundline, gangions, and hooks. In the early years, a number of lines (each 300 feet) were spliced end to end to form the groundline. The number of lines varied considerably, but the 6-line skate (1,800 feet) eventually was adopted by most of the fishermen. Now, groundline is sold in 1,800-foot coils. Loops of light twine (beckets) are attached at regular intervals to the groundline. Short branch lines (gangions) 4 to 5 feet long are attached to the beckets and a hook is attached to the end of each gangion. The interval between hooks or "rig" of the gear has varied from 9 feet to as much as 42 feet. The most common rigs have been 9, 13, 18, 21, 24, and 26 feet, as these intervals facilitate baiting the hooks and coiling the lines. Until the 1920's, fishermen consistently spaced their hooks at 9-foot intervals. By 1930, most of the gear was rigged at 13-foot intervals and, by the late 1950's, the predominant rig was 18-foot gear. More recently, 21-, 24-, and 26-foot gear has been introduced into the fishery.

Several skates (4 to 12) are usually tied together and each string of skates constitutes a set. The number of skates per string depends on factors such as the size of the fishing ground and the likelihood of snagging on the bottom. Each end of the string is attached to an anchor and buoy line and marked at the surface with a buoy, flagpole, and flag. When fishing at night or in heavy fog, lights or radar reflectors are used on each flagpole to aid in locating the gear.

Most of the fishing is conducted in depths between 15 and 150 fathoms. The skates with baited hooks are set over a chute at the stern of the vessel. Depending upon the grounds, time of year, and bait used, most of the gear is in the water for 4 to 48 hours, but the average "soak" for each skate is about 12 hours. The gear is hauled on a power-driven wheel, the gurdy, controlled by a fisherman who lands the fish, clears snarled lines, and stops the gurdy if the gear is snagged or if other problems occur. On traditional longline vessels, another man coils the line after it passes the gurdy. The gear is then inspected for necessary repairs, baited, and recoiled in preparation for the next set. Baits used in the halibut fishery are either fresh or frozen and include herring, octopus, salmon, and "shack" or "gurdy" bait such as grey cod, sablefish, or other species caught incidentally on the halibut gear.

Snap-on gear was introduced into the halibut fishery about 20 years ago; it differs from traditional setline gear in that the branch lines (gangions) are attached to the groundline with metal snaps rather than being tied or spliced to the groundline. Further, the groundline used for snap-on gear is one continuous line that is simply stored on a drum after the gangions are removed, instead of being coiled. The method of attaching the hooks to the gangions is the same for snap-on and traditional gear. When snap-on gear is set, the hooks are baited and the gangions are attached to the groundline with snaps as it unwinds from the

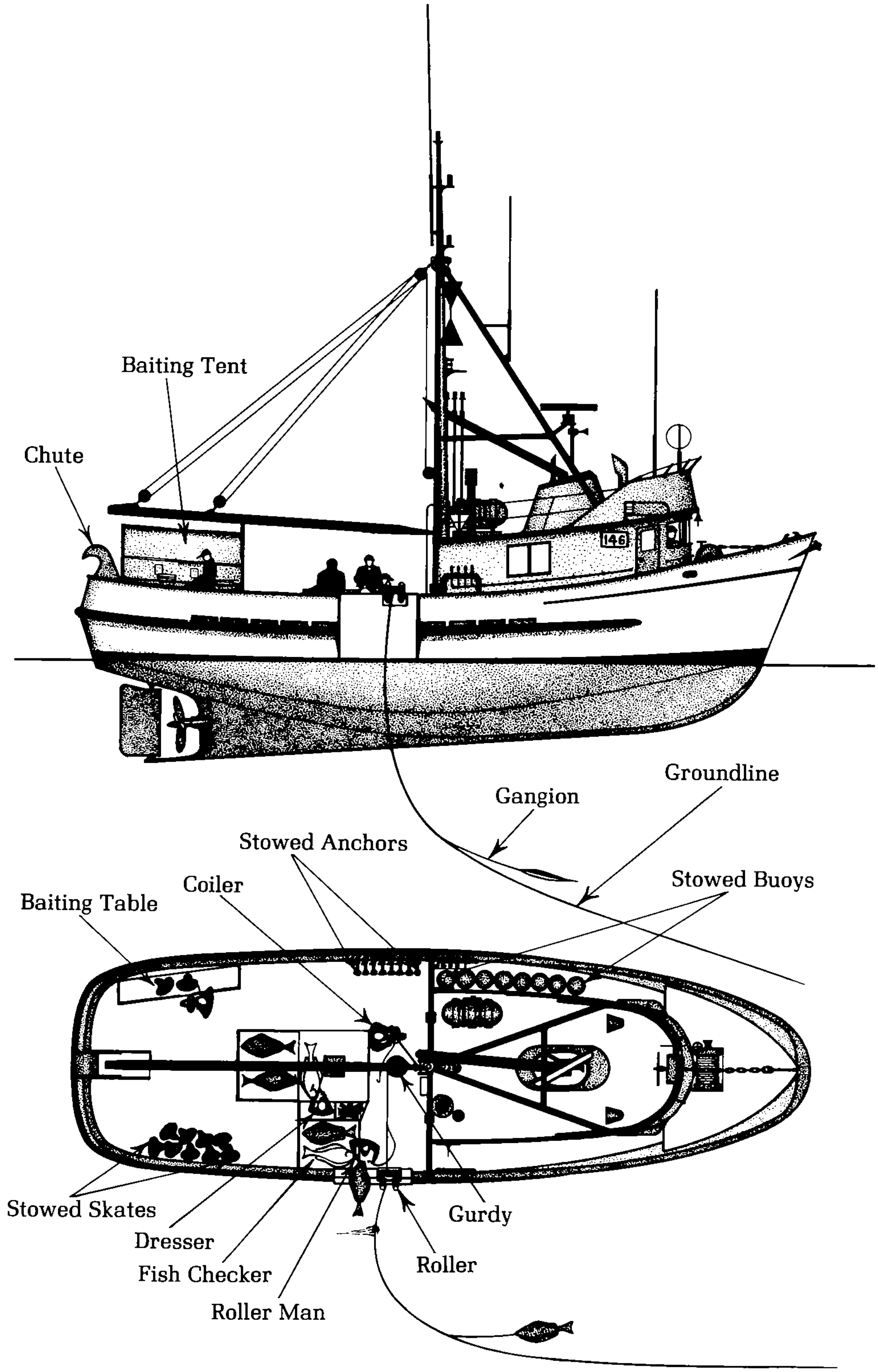

Figure 1. Deck layout and fishing arrangement. (Drawings by Charles R. Hitz)

drum. Hook intervals can be changed with each set. When the gear is retrieved, the hooks are unsnapped and stored on racks as the groundline is rewound on the drum. The snap-on gear is most prevalent on small boats.

More detailed information on the gear, vessels and fishing grounds has been described by IPHC (1978).

COMPARISON OF PELAGIC AND DEMERSAL GEAR

Demersal halibut gear and pelagic longline gear differ in several respects. Full details on the pelagic gear used in the tuna fishery have been described by Shapiro (1950), Mann (1955), and others. The major differences between the two types of gear are position in the water column and the number of hooks per unit of gear (basket vs. skate). These differences are depicted in Figure 2. The lines from the baskets and skates are tied together and fished in "strings". Whereas, the tuna line from each basket is buoyed, only the end of the halibut strings are buoyed. The tuna gear employs 4 to 6 hooks per basket, the halibut gear will use 75 to 150 hooks per skate. Tuna gear can be classified in two general types, shallow and deep. Recent descriptions of Japanese gear in the western equatorial Pacific Ocean are used as an example to compare with halibut gear (Suzuki and Warashina, MS[1]). However, the diversity of tuna gear is great and has changed substantially, for example, Maéda (1967) stated that as many as 11 hooks were used per basket in earlier years. Other dimensions such as length of line per basket and the length of the gangions have also changed.

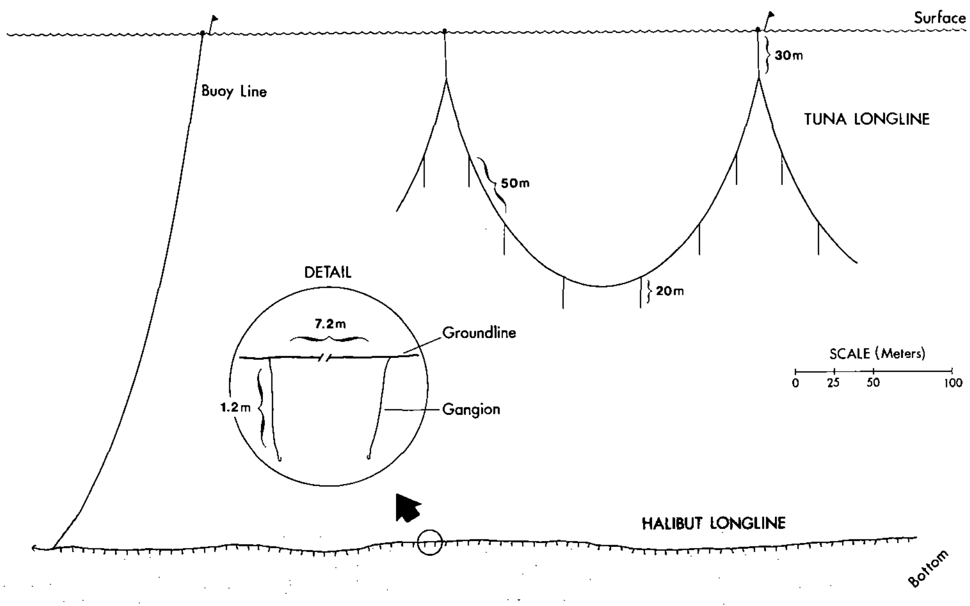

Figure 2. Comparison of pelagic and demersal longline gear in the tuna and halibut fisheries. (1 meter =3.28 feet)

[1] Suzuki, Ziro, and Yuio Warashina (MS). The comparison of catches made by regular and deep-fishing longline gear in the central and western equatorial Pacific Ocean. Translated by Tamio Otsu, Southwest Fisheries Center, Honolulu Laboratory, U.S. National Marine Fisheries Service.

The technique of fishing has for the most part been developed by trial and error by fishermen attempting to obtain a maximum catch with a minimum of effort. Undoubtedly, the differences in the gear relate to the behavior of the species; tuna are pelagic species which swim rapidly, whereas halibut are demersal and usually swim quite slowly and frequently rest on the bottom.

The depth of the halibut gear is dependent on the bottom contour. One end of a string of gear may be at 50 fathoms and the other end at 150 fathoms, but the gear can be set at a relatively uniform depth. In contrast, tuna gear hangs as a series of catenaries. The gear is buoyed at both ends so that the hooks in the middle are always deeper than those at either end. The mid-depth of the gear is often set in relation to the temperature stratum that is most usually frequented by tuna. Another difference in the two fisheries is the length of soak; tuna gear is usually hauled within 6 or 7 hours, a much shorter soak, as indicated earlier, than the halibut gear.

The variation in hook-spacing of longline gear is considerable. For pelagic species such as mackerel (*Scomber japonicus*) and salmon (*Oncorhynchus* spp.), which often are densely schooled, hook-spacing may be as close as 5 to 6 feet (Scofield 1947 and Shepard et al. 1975). However, in pelagic fisheries for tuna, which are faster-moving and less densely schooled, hook intervals may be as great as 600 feet (Fridman 1969), but usually are between 80 and 200 feet (Hirayama 1969a; Maéda 1967). Because pelagic longline gear hangs as a catenary, hook-spacing is also dependent on depth. If the surface buoys are relatively close, the catenary will be deeper and the spacing between hooks less than gear with widely-spaced buoys and a shallow catenary.

The hook-spacing of gear for slower-moving, demersal fish is much less than for tuna gear. McCracken (1963) and Nedelec (1975) reported the use of 6-foot spacings (50 hooks per 50 fathom line) for cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) in the Atlantic; whereas Alward (1932) reported 21-foot spacing for these species. Au (1972) reported variations from 4 to 54 feet for demersal fisheries in the South China Sea. In the North American halibut fishery, hook-spacing ranged from 5 to 15 feet in the Atlantic (McKenzie 1946) and, in the Pacific fishery, as previously mentioned, 18- to 24-foot spacings are now the most common. In Japan, the longline fishery for halibut prior to 1930 used hook-spacings of 7, 9, or 12 feet; most halibut are now taken with bottom trawls (Tsuji 1974).

Other differences between pelagic and demersal longline gear, such as hook size, material of lines, bait, etc., are not pertinent to this study, but are documented in the papers previously cited.

MEASURES OF LONGLINE EFFORT

Thompson (1916) and Thompson, Dunlop, and Bell (1931) compared different measures of fishing effort for the halibut fishery: number and length of trips, number of dories, number of men, and amount of gear. A 6-line skate of gear (1,800 feet) was adopted as the standard unit of effort.Thompson and Bell (1934) concluded that no adjustment was necessary either for the number of hooks per skate or the hook-spacing.

Later, Bell (unpublished circa 1940) analyzed the differences in catch between skates with 120 hooks (13-foot spacing) and those with approximately 80 hooks

(18-foot spacing). He concluded that effort was proportional to the number of hooks and the basic unit of effort was redefined in 1943 as a 6-line skate of 13-foot gear with 120 hooks. Although reported as catch per skate, this measure essentially was the catch per 120 hooks. Gear with fewer hooks were adjusted to this "standard skate", which was utilized until 1972. The subsequent revision, based on hook-spacing (Skud 1972), is discussed later in this section.

Tuna fisheries that utilize poles and nets, rather than longlines, usually rely on measures of effort such as catch per day, catch per set, etc. (Pella and Psaropulos 1975). Although similar measures such as catch per basket or per vessel-day have been used in the tuna longline fishery, the hook generally has been accepted as the preferred unit of effort. The earliest record I have located for CPUE in the tuna longline fishery was from the early 1930's (Nakamura 1952). He presented data on the catch per 100 hooks for the tuna fishery in the western Pacific. His measure of effort was in basic agreement with Bell's conclusion, as it implied that effort was proportional to the number of hooks. Apparently, the specific use of the hook as a measure of effort occurred earlier in the tuna fishery and in other demersal fisheries than it did in the halibut fishery.

With qualifications and refinements, this relation of number of hooks to effort was accepted in theoretical studies of hook and line gear. Gulland (1955) and Beverton and Holt (1957) assumed that fishing power of longline gear was proportional to the number of unoccupied hooks and presented catch equations to correct for gear saturation. Ricker (1958) emphasized that the efficiency of the gear was reduced, not only by those hooks that caught fish, but by the loss of bait. Murphy (1960) extended the treatment of saturation and incorporated factors in the catch equation for the loss of bait and loss of hooked fish. Ionas (1966), Fridman (1969), and Gulland (1969) concluded that longline effort was increased simply by adding hooks and that the amount of effort could be expressed as the number of hooks multiplied by fishing time. The catch equation of Shepard et al. (1975) was essentially the same as Murphy's (1960).

Because the theoretical definitions did not include explicit reference to hook-spacing or length of groundline, it is not possible to judge how the authors conceived the relationship of these factors to fishing effort. If the authors assumed a constant length of groundline (the practice in most longline fisheries), the definitions imply that catch per hook is independent of hook-spacing, because an increase in the number of hooks reduces the spacing between them. If hook-spacing was considered constant, then the length of groundline would increase as hooks were added, but once a hook was occupied or lost its bait, the effective spacing between baited hooks would change and also would imply that catch per hook is independent of spacing.

Until recently, few authors questioned this measure of longline effort, however, Shomura and Murphy (1955), Murphy (1960), and Hirayama (1969a) presented data from tuna longline fisheries that cast doubts about the proportionality of effort to the number of hooks. Although the importance in relation to estimates of abundance was not specifically discussed in these papers, their data showed that catch per hook increased with increases in hook-spacing.

Thompson, Dunlop, and Bell (1931) had considered hook-spacing in their review of measures of effort in the halibut fishery and had concluded that no correction was necessary. Skud (1972) reported on experimental fishing with 4 different spacings and showed that catch per hook increased with spacing, i.e., that effort was not proportional to the number of hooks. As a result, the standard unit of effort was redefined (IPHC 1972). Subsequent studies on hook-spacing by IPHC are reported in this volume. Because of the foresight of Thompson, Dunlop, and Bell, data on the number of hooks per skate had been recorded as part of the vessels' fishing logs; this enabled IPHC to recalculate effort and CPUE from 1929 to date in accordance with the new standard (Myhre et al. 1977).

In the longline fishery for tuna, many of the references to the effects of hook-spacing were indirect as the authors were concerned with the number of hooks per basket and, usually, their interest was directed towards improving the gear. Shomura and Murphy (1955) reported the results of a hook-spacing experiment in which the catch (number of tuna) was 0.262 per basket for 6-hook gear (wide spacing) and 0.316 for 11-hook gear (narrow spacing). They concluded that there was an advantage to adding hooks, although as previously indicated, the trend in the fishery had been towards reducing the number of hooks per basket. Murphy (1960) cited these results in reference to his modification of Gulland's (1955) catch equation. Murphy concluded that most of the increase on the 11-hook gear was the result of reducing localized saturation. He did not calculate the catch per hook and stated that if school size was constant, CPUE would not be distorted. I also reexamined Shomura and Murphy's (1955) data and calculated the catch per 100 hooks: 2.9 for the 11-hook gear and 4.4 for the 6-hook gear. Not only does this show an increase in the catch per hook with hook-spacing, but it also suggests that the gear probably was not saturated.

Maéda (1967) discussed the "thinning of hooks" and concluded that there were advantages in reducing the number of hooks per length of mainline. Hirayama (1969a) also was interested in improving the gear, but specifically examined the "hook rate" with intervals of spacing between approximately 100 and 200 feet. He noted the tendency for wider-spaced gear to catch more tuna per 100 hooks. But neither these authors, nor others, described the quantitative relation between spacing and CPUE. In most instances, I assume that detailed data on the number of hooks per basket were not available, however, authors attempting to assess the abundance of tuna usually did not mention the need for adjusting the data for differences in hook-spacing (Otsu and Sumida 1968; Wise and Fox 1969; Rothschild and Yong 1970; Shingu, Tomlinson and Peterson 1974; and others). Rothschild and Suda (1977) referred to factors affecting CPUE such as number of hooks per basket, but concluded that the long-term changes had not been great enough to warrant adjustments.

The interest in hook-spacing in other fisheries, particularly for groundfish, has also been relatively recent. Several of these papers have been presented as unpublished documents at the Annual Meeting of the International Council for the Exploration of the Sea (ICES). These include reports from Working Groups of the Gear and Behavior Committee that provide instructions for collecting and analyzing pertinent data. For example, Karlsen (1977) examined factors such as gangion length, bait size, hook type as well as hook-spacing in a Norwegian longline fishery. In one of his experiments, he compared CPUE with increases in hook-spacing of 35, 50 and 100%. The corresponding catch per line decreased 16.8, 18.6 and 29%; whereas the catch per hook increased 11, 22, and 42%. These results also indicate that effort is not proportional to the number of hooks. Karlsen also experimented with hook-spacing increases of 200 and 300% and concluded that at low catch rates, the gain in CPUE with hook-spacing is greater than at high catch rates.

Murphy and Elliot (1954) were among the first to express an interest in other factors influencing the catch, in particular, schooling and the resultant distribution of catch on the longline gear. Maéda (1960) also studied schooling and made an extensive analysis of the distribution pattern of the catches in relation to depth and soak-time. As previously mentioned, Ricker (1958) stated that the bait loss reduced the efficiency of longline gear and Murphy's (1960) catch equation specifically accounted for the loss of baits. Other authors also examined the effect of bait loss, for example Shepard et al. (1975) in an experimental longline fishery for salmon. This interest was followed by studies of the causes of bait loss and the relation to fish behavior. For example, Yamaguchi and Kobayashi (1973 and 1974) studied the "breaking-strength" of baits and the number of baits in the stomachs of hooked fish. Regarding bait loss and behavior, Fernø, Tilseth, and Solemdal (ICES Document)[1] described the activities of whiting (*Gadus merlangus*) that were observed with underwater TV. The fish often took the bait in their mouth without being hooked. Small hooks caught more fish than large hooks, but even with the small hooks only 10% of the attacks on the bait ("rushes and jerks") resulted in the capture of a fish.

Many other factors that affect CPUE have been studied and it is not practical to cite all the publications, but several are pertinent to IPHC's studies and merit attention. Kurogane (1968) compared the catch of bottomfish with hook size, bait type and size, as well as with hook-spacing. Hirayama's (1969a-d and 1972) extensive studies on the "fishing mechanism" included quantitative analyses of factors such as bait loss, soak-time, and methods of retrieving the gear. Sivasubramaniam (1961) also studied the relation of catch of tunas to soak-time. The results pertinent to our studies are discussed in the subsequent reports.

These attempts to refine estimates of CPUE of longline gear are basically related to adjustments for competition between species, because the fishing power for the target species is reduced by factors such as bait loss and the capture of other species. This general relationship was noted by Rothschild (1977). Gulland (1955) and Beverton and Holt (1957) made reference to the effects of competition in conjunction with general descriptions of trawl and longline fisheries. Ketchen (1964) specifically addressed the subject of competition in the British Columbia trawl fishery for petrale sole (*Eopsetta jordani*). Gulland (1964) also discussed the problem in the demersal fisheries in the Barents Sea. Specific attention to competition in pelagic longline fisheries was considered by Murphy (1960). Rothschild (1967) presented a model describing the effects of competition in a tuna longline fishery and his model was extended by Ricker (1975) to include baits that were removed (stolen) without the fish being captured.

An interesting correlative to the studies of longline gear occurred in the evaluation of other stationary gear such as traps and nets. Nearly 50 years ago, Hile and Duden (1933) began a study in the Great Lakes to determine the effectiveness of different types of gear, in particular gillnets and traps. They distinguished between "fishing effort" which measured the units of gear and "fishing intensity", the product of effort and time. Van Oosten (1935) used these data to show that the catch from lifts every 2 days were not double those lifted daily. Similarly, Kennedy (1951) showed that the catch in gillnets did not increase as expected with time. Ricker (1958) summarized these findings: "Thus the catch per unit time, for many kinds of gear, tends to decrease from the time they are set

[1] Fernø, A., S. Tilseth, and P. Solemdal. The behavior of whiting (*Gadus merlangus*) in relation to long lines. International Council for the Exploration of the Sea, Gear and Behavior Committee, Document C.N. 1977/B:44, 11 p.

to the time they are lifted, and the speed of this decrease is partly a function of the abundance".

Papers related to the gear efficiency of pots and nets appeared sporadically during the subsequent years, but as with the studies of longline gear, there has been far greater emphasis on the evaluation of these gears in the past 5 to 10 years. Hamley (1975) reviewed some of these studies concerning gillnets, and Skud (in press) reviewed the studies of pots, particularly in the lobster fishery.

Clearly, there is a renewed interest in reevaluating the effective effort of stationary fishing gears. Although IPHC's interest was in response to a specific problem in the halibut fishery and the initial research was conducted independently of the knowledge of studies of the tuna fishery, the subsequent review of the literature has stimulated and influenced the analyses presented in the following reports. We hope our experience and results also will be useful to those continuing similar studies on other species.

Factors Affecting Longline Catch and Effort:

II. Hook-Spacing

by

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and

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II. Hook-Spacing

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INTRODUCTION

The importance of hook-spacing to the definition of longline effort is critical to the International Pacific Halibut Commission (IPHC) because the fishery for Pacific halibut (*Hippoglossus stenolepis*) has been managed largely on the basis of stock abundance as estimated by catch per unit of effort (CPUE). Although IPHC's measure of effort changed with time, little was published, except in the early years of the Commission, on the estimation of CPUE of halibut longline gear (Thompson et al. 1931; Thompson and Bell 1934). Before 1940, IPHC's standard unit of effort was a specified length of groundline; after 1940, the 120-hook standard was introduced. Over the years, fishermen have increased the spacing between hooks. Skud (1972) showed that catch per hook increased with hook-spacing and that the 120-hook standard underestimated fishing effort and overestimated fish abundance. The importance of hook-spacing probably was not detected in the earlier analyses because the differences in hook-spacing (9-12 feet and 12-18 feet) were small compared to those in the present-day fishery (12-26 feet).

To test the standards, IPHC conducted 14 experimental cruises on which longlines rigged to different hook-spacings were fished side by side. The results proved immediately important to management of the halibut fishery, and the initial findings were reported by Skud (1972) and IPHC (1972 and 1973). Skud (1975) also used this information to revise estimates of abundance prior to 1930.

In the present paper we will (1) show the theoretical relation between the three standards of longline effort that have been used to assess the condition of halibut stocks, (2) quantitatively evaluate the three standards, and (3) present additional evidence on the effect of hook-spacing on CPUE.

STANDARDIZATION OF EFFORT

During the past 50 years, three different standards have been used to measure longline effort in the fishery for halibut. Thompson et al. (1931) compared the efficiencies of 9- and 13-foot gear and concluded that a unit of longline gear (skate) "...corrected for length, may be used as a unit of effort without any consideration as to whether the hooks were 9 or 13 feet apart...". Thus, regardless of the number of hooks or the hook-spacing, 1,800 feet of groundline was adopted as the standard unit of fishing effort. Obviously, their conclusion only applied to the two spacings, but, in theory, this "length-standard" implied that, for a given abundance of halibut, *catch per skate is the same* at any hook-spacing. As the number of hooks per skate is inversely proportional to hook-spacing, the standard also implied that *catch per hook increases* in proportion to hook-spacing (Figure 1).

Skud (1975) reexamined the original data used to establish the length-standard and found that the mean catch per skate of 9-foot gear was higher than that of 13-foot gear. Similarly, Bell (unpublished, circa 1940) found that the catch per skate of 13-foot gear (ca. 120 hooks) was more than that of 18-foot gear of the same length (ca. 80 hooks). Bell concluded that catch was proportional to the number of hooks and defined a new standard unit of effort based on the 13-foot gear. An 1,800-foot skate of 13-foot gear could hold 138 hooks (1,800 ÷ 13), but in practice the number was less and varied considerably because of differences in rigging and type of groundline. The modal number, 120 hooks, was chosen as the standard and from 1943 to 1972, gear of different lengths and hook-spacings were adjusted to this standard according to the number of hooks. We will refer to this as the "hooks-standard". Minor adjustments were made to account for differences in the effectiveness of bait and for differences in the type of groundline because certain fibers stretch more than others.

Bell's hooks-standard showed that *catch per skate decreases as hook-spacing increases,* thereby refuting Thompson's length-standard. The hooks-standard was applied only to gear with less than 21-foot spacings, but, theoretically, it implied that *catch per hook is the same for all hook-spacings* (Figure 1). However, Skud (1972) demonstrated that the catch per hook increased with hook-spacing from 12 to 24 feet, thereby refuting the hooks-standard. As a result of Skud's findings and the subsequent hook-spacing experiments detailed in this paper, the standard unit of effort was redefined in 1973 as 100 hooks at 18-foot spacing and will be referred to as the "spacing-standard", which is intermediate to the other two (Figure 1). Gear with other hook-spacings are adjusted to this new standard, considering spacing, the number of hooks, and the length of groundline.[1] The relation of the three standards and the data and analyses used to establish the new standard are described below.

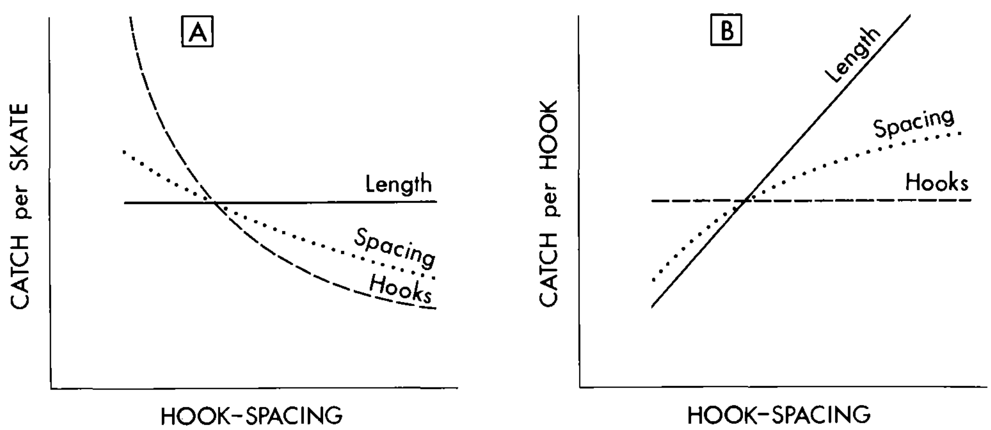

Figure 1. Relation of hook-spacing to (A) catch/skate and (B) catch/hook for (1) length-standard, catch proportional to length of groundline, (2) hooks-standard, catch proportional to number of hooks, and (3) spacing-standard, intermediate to the other standards.

[1] The factors used to convert setline gear with other hook-spacings to the 100-hook, 18-foot standard skate were developed from commercial fishing data, as well as from the research cruises. Records from the commercial fishery, including log books from 1954 to 1972, were analyzed by sections of the coast. The resulting correction factors, per skate, are 9-foot gear (1.26); 13 (1.14); 18 (1.00); 21 (0.93); 24 (0.87); 26 (0.83); 36 (0.67); and 42 (0.60).

EXPERIMENTAL FISHING

The hook-spacing studies of 1971 (Skud 1972) are reviewed here along with more recent data gathered in 1972 and 1973. To determine the relation between CPUE and hook-spacing, commercial halibut vessels were chartered to fish conventional longline gear with different hook-spacings from 9 to 42 feet. Data also were available from two vessels on which observers recorded the results of fishing activities. In all, 14 trips were made at various locations along the coast from Oregon to the Bering Sea (Table 1).

Two to four different hook-spacings were used on each cruise. Fishing was conducted as a regular commercial operation with several skates tied end to end, except that the gear was set on a prescribed rotation, e.g., 9-, 13-, and 18-foot gear on the first day, 13-, 18-, and 9-foot gear on the second day and so forth. This rotation minimized biases caused by factors such as soak-time and the position of a skate in a string. During most trips, skates of each hook-spacing were set in separate strings parallel to strings of other hook-spacing. On two trips, skates with different hook-spacings were used alternately in the same string.

Over 4,000 skates with nearly 400,000 hooks were set. The total catch was over 300,000 pounds, about 14,000 halibut. The catch varied from very poor (less than 50 pounds per 100 hooks) in the Bering Sea and Goose Island, British Columbia, to very good (over 400 pounds per 100 hooks) in Queen Charlotte Sound, B.C. The catch per skate and catch per hook were calculated for each hook-spacing. The results are summarized below and in Appendix I, Tables 1 to 6.

Table 1. Hook-spacing experiments.

Vessel	Location of Fishing	Date	Hook-spacing and Setting Pattern
		1971	
CHELSEA[1]	Albatross Bank, Shumagin Gully	5/5 to 27/5	13′ and 21′ skates, alternated in each string.
CHELSEA	Portlock Bank Seward Gully Portlock Bank	8/7 to 19/7 21/7 to 3/8 5/8 to 18/8	13′, 18′, 21′ and 24′ skates set in parallel strings.
AGNES-O[1]	Goose Island	24/8 to 30/8	13′ and 18′ skates mixed in each string.
		1972	
REPUBLIC	Bering Sea Shumagin Gully	9/3 to 28/3 28/3 to 4/4	13′, 21′ and 42′ skates set in parallel strings.
SEAPAK	Goose Island Bonilla Island	8/6 to 21/6 24/6 to 2/7	9′, 13′ and 18′ skates set in parallel strings.
CAPE BEALE	Masset Ramsay Island	15/8 to 26/8 28/8 to 5/9	9′, 13′ and 18′ skates set in parallel strings.
ALASKA QUEEN II	Washington-Oregon Coast	2/10 to 15/10	18′, 36′ and 42′ skates set in parallel strings.
		1973	
REPUBLIC	Queen Charlotte Sound	26/3 to 10/4 12/4 to 27/4	13′, 21′, 36′ and 42′ skates set in parallel strings.

[1] These two "observer" trips were regular commercial fishing trips, on which the captain controlled the operations and an IPHC employee recorded the results. All others were charter trips on which IPHC determined the hook-spacing and the manner of fishing.

As expected, the data were extremely variable but, in general, catch per hook increased with hook-spacing, confirming the previous results (Skud 1972 and IPHC 1973). The abundance and distribution of halibut varied from trip to trip and from day to day within each trip, but the experiment was designed so that this would not bias the result: within each trip all gear types were fished at similar depths and soak-times, and within each day, the same bait or combination of baits was used on all skates. Nonetheless, unusual circumstances apparently caused systematic variation on some trips. For example, when dogfish (*Squalus acanthias*) were caught on almost all hooks on Trip 1 of the *Cape Beale,* the catch per hook of halibut was no greater for 18-foot than for 13-foot gear. Such variations in the experimental catch serve to emphasize that many variables are encountered in the commercial fishery and that caution is needed in interpreting CPUE.

During six of the cruises, certain days were designated for a special study: each hook was examined as the gear was retrieved, to determine whether a fish was caught or the bait retained. These hook-by-hook observations are described in Part III of this report.

We also reexamined the results of a bait study conducted by the Commission in 1965 (unpublished). In this study, four trips were made using 13- and 18-foot gear. The catch per hook of 18-foot gear was higher than that of 13-foot gear, for all bait types (Table 2). Although the results agree with the findings used to establish the spacing-standard, the gear was not fished systematically and the data have not been incorporated in the present analysis. (Note the differences in effectiveness of the baits.)

Table 2. Halibut catch and catch per hook in pounds, by hook-spacing and bait, 1965.

Bait	13-Foot Gear Total Catch	13-Foot Gear Catch per Hook	18-Foot Gear Total Catch	18-Foot Gear Catch per Hook
Herring	12,632	0.53	11,320	0.60
Herring and Shack[1]	9,626	0.53	10,348	0.74
Shack[1]	7,094	0.65	6,623	0.70
Octopus	7,567	0.69	7,334	0.80
Octopus and Herring	12,220	0.72	11,040	0.87
Total	49,139		46,665	
Average		0.61		0.73

[1] Fresh fish caught on halibut gear, usually cod and sablefish.

TESTING THE STANDARDS

Effects of Saturation

We assume throughout that CPUE for a given hook-spacing is proportional to halibut abundance. This is based on the premise that the abundance is so low relative to the number of hooks that the capture of one halibut usually does not preclude capture of another. Obviously, if abundance were so high that all hooks were occupied, the gear would be saturated and CPUE at its maximum (Figure 2). Our catch rates were very low: they ranged from 0.01 to 0.15 fish and the average was 0.05 fish per hook (Appendix I, Table 6). Halibut were occasionally taken on adjacent hooks, suggesting that a section of the gear could have been at or near saturation but, overall, the gear was far from saturation.

In most other studies (Beverton and Holt 1957; Gulland 1955 and 1969), fishing power of longlines has been considered proportional to the number of hooks, with the qualification that, when approaching saturation, CPUE does not increase in proportion to abundance (Figure 2). Murphy (1960) and Ionas (1966) also commented on saturation. Murphy discussed tuna longlines and concluded that the effect of saturation would be less at shorter hook-spacings, because the density of hooks is greater. In contrast, Ionas thought that hooks next to a captured fish might be ineffective; if that were the case, saturation could be greater at shorter hook-spacings. In our experience with halibut, hooked fish do not appear to inhibit captures on adjacent hooks, and Murphy's view seems more realistic.

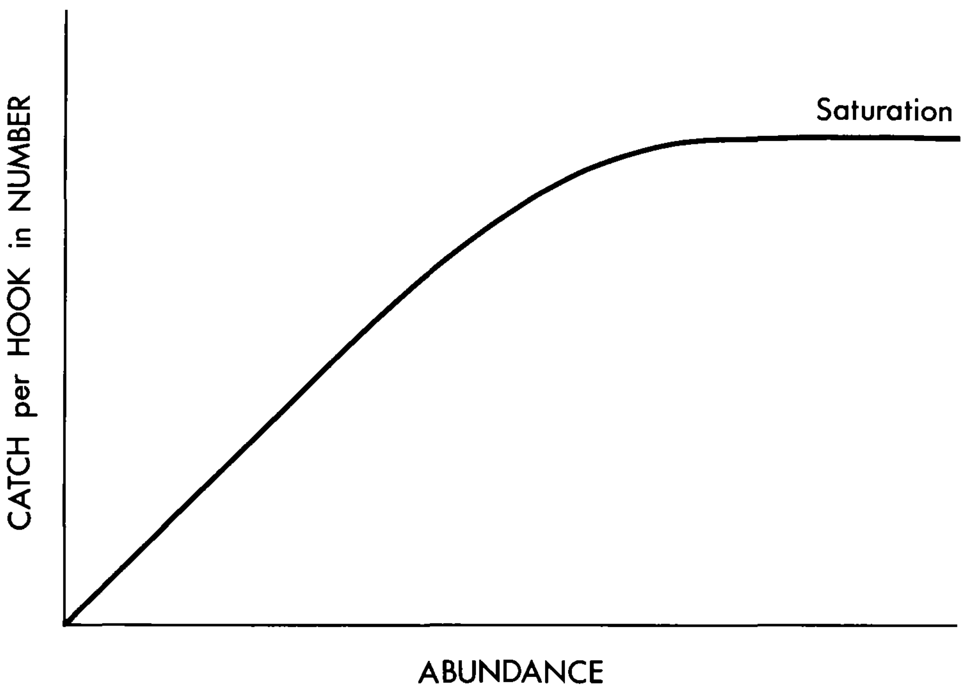

Figure 2. Relation of abundance to catch on longline gear.

CPUE Standards for Halibut

The difference in the catch per hook at different spacings is related to competition between hooks. If there is no "chumming" effect whereby a concentration of bait attracts halibut beyond their normal feeding ranges, the probability of any particular hook falling within the range of a halibut is not affected by the presence or absence of other hooks. If more than one hook falls within a halibut's range, these hooks "compete" for the capture of that fish, and the closer they are spaced, the lower is the catch per hook. On the other hand, if the hooks are so far apart that each halibut encounters no more than one hook, the hooks fish independently and their efficiency is at its maximum, so that the catch per hook no longer increases with hook-spacing.

The length-standard implies that the hooks compete; the hooks-standard, that the hooks fish independently. The spacing-standard allows for this whole range of possibilities (Figure 1). Hirayama (1969a), in a study of tuna longline gear, showed a similar relation that corresponds to our length- and hooks-standards, but he showed an abrupt transition between the two.

Both the length- and hooks-standards imply that, for a given abundance of halibut, the relation of catch per hook and hook-spacing can be represented by a straight line (Figure 1B). The length-standard specifies that this line goes through the origin (i.e., its intercept on the ordinate is zero); the hooks-standard specifies that this line is horizontal. The goodness of fit of the observations to each standard can be tested by calculating the ratio of the catch per 100 hooks of different hook-spacings to that of 18-foot gear on the same trip. The relation should approximate a straight line:

$$CPUE_h / CPUE_{18} = a + bh$$

where h is the distance between hooks. The intercept "a" equals zero if the length-standard is true, and the slope "b" equals zero if the hooks-standard is true. The catch per hook in pounds from the experimental fishing (Table 3) was fitted to a line by least squares, obtaining:

$$CPUE_h / CPUE_{18} = 0.693 + 0.0163h.$$

Table 3. Catch per hook in pounds of halibut.

	Hook-Spacing in Feet						
Trip	9	12-13	18	21	24	36	42
CHELSEA (Observer)	—	.782	—	.760	—	—	—
CHELSEA							
Trip 1	—	.726	.744	.938	1.014	—	—
Trip 2	—	.519	.742	.933	.909	—	—
Trip 3	—	.579	1.028	.791	1.042	—	—
AGNES-O (Observer)	—	1.440	1.631	—	—	—	—
REPUBLIC (1972)							
Trip 1	—	.241	—	.443	—	—	.635
Trip 2	—	1.501	—	2.415	—	—	3.017
SEAPAK							
Trip 1	.264	.329	.231	—	—	—	—
Trip 2	.577	.616	.916	—	—	—	—
CAPE BEALE							
Trip 1	.461	.643	.607	—	—	—	—
Trip 2	.256	.350	.352	—	—	—	—
ALASKA QUEEN II	—	—	.338	—	—	.258	.340
REPUBLIC (1973)							
Trip 1	—	2.135	—	3.773	—	4.056	4.760
Trip 2	—	2.049	—	2.301	—	3.488	2.508

The results from "t-tests" indicated that both the slope and intercept were significantly different from zero, therefore, neither the length- nor the hooks-standard gives a satisfactory description of the experimental fishing results. (We used the 18-foot gear as the standard because it was the hook-spacing most commonly used in the commercial fishery. In the calculations, we extrapolated the values for trips on which the 18-foot gear was not used.)

The spacing-standard states that catch per hook increases with hook-spacing, but at a rate less than proportional to the latter. This standard can be described as an asymptotic function:

$$CPUE_h / CPUE_{18} = C_\infty (1\text{-}e^{-kh})$$

where C_∞ is the maximum relative catch per hook and k is a constant (Figure 3). The estimated asymptote is approximately 1.50, only slightly larger than the relative catch per hook of 36- and 42-foot gear. This implies that the relative catch per hook is near the maximum at these wide spacings.

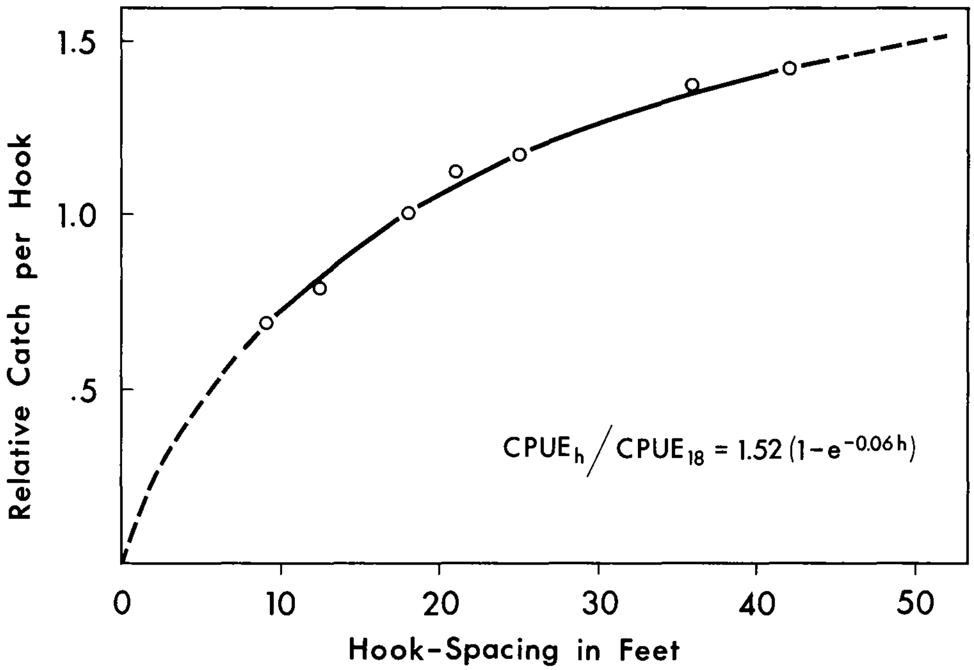

Figure 3. The relative catch per hook in pounds, $CPUE_h/CPUE_{18}$, of different hook-spacings.

SIZE SELECTIVITY

The first trips of the hook-spacing experiment with the *Chelsea* suggested that the mean weight of halibut increases with hook-spacing: fish from the 12-foot gear averaged 38 pounds; from 18- to 21-foot gear, 40 pounds; and from 24-foot gear, 43 pounds (Skud 1972). Subsequent trips also showed an increase in mean weight with an increase in hook-spacing or rig (Appendix I, Table 4). Analysis of covariance showed that this increase was significant:

Source of Variation	Degrees of Freedom	F-Statistic	Significance
Main effects: trips	13	35.20	0.1%
Covariate: hook-spacing	1	7.19	1.0%
Residual	30		

Figure 4 shows that the difference in mean weight of halibut increases as the difference in hook-spacing increases.

We can only speculate as to the reasons for the size selectivity of different hook-spacings, but it is associated with differences in behavior relative to the size of halibut. The most reasonable explanation is that smaller halibut have smaller feeding ranges and, when hooks are widely spaced, the probability of encountering a hook is reduced more for small fish. When these smaller fish are excluded, the mean size in catch is increased.

Size selectivity also can be important in the estimation of growth and mortality (Ricker 1969). Although beyond the scope of this paper, mention should be made of past findings on growth of Pacific halibut. Southward (1967) and Bell and St-Pierre (1970) showed that the growth rate has increased markedly since the early years of the fishery. This increase was assumed to be due to a combination of favorable environmental conditions and density-dependent factors (Southward 1967). Because of the long-term changes in hook-spacing, part of the assumed increase in growth may be an artifact of selectivity, but the reported increase in growth is much greater than can be accounted for by the differences credited to hook-spacing.

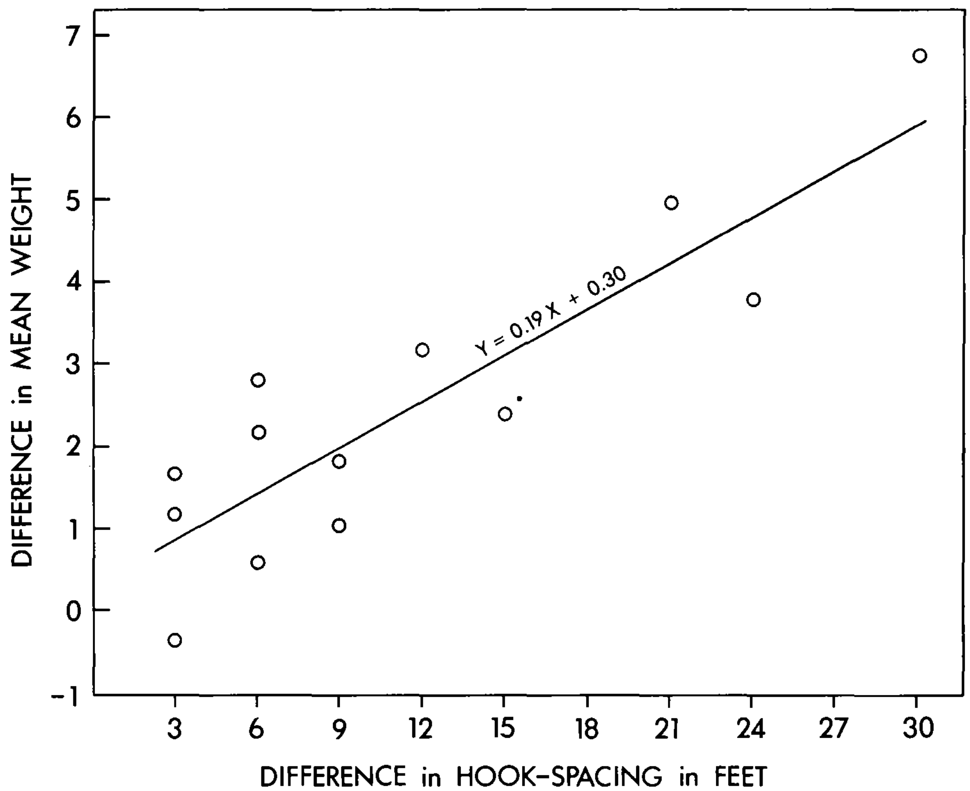

Figure 4. Relation of mean weight of halibut to differences in hook-spacing.

CONCLUSIONS

Before 1972, the Commission defined the fishing effort by longlines in terms of either the length of groundline or the number of hooks. Skud (1972) reexamined these old standards and concluded that the spacing of hooks also must be considered. The present paper supports this conclusion with data from fishing experiments that covered all seasons and spanned the coast from Oregon to the Bering Sea. The observed catch per hook increased with hook-spacing, but at a progressively decreasing rate. These findings agree with CPUE data from the commercial fishery and, since 1972, the Commission has used the relation derived from these experiments to standardize the fishing efforts by longlines of different hook-spacings.

Apparently, fishermen have realized the advantages of increasing hook-spacing on certain fishing grounds. Indeed, fishermen questioned the reliability of the hooks-standard at an IPHC annual meeting in 1967. This report may help fishermen attain the optimum spacing of their hooks, but other considerations such as soak-time, bait, etc., also will have to be evaluated. Skud (1972) showed that the baiting and hauling times per skate were reduced at the wider hook-spacings.

Factors Affecting Longline Catch and Effort:

III. Bait Loss and Competition

by

Bernard E. Skud

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INTRODUCTION

Although longline gear has been used extensively in fisheries throughout the world, relatively little information is available on the hook-by-hook catch, bait loss, and related data. Such knowledge is important to managment of longline fisheries as it is needed to assess changes in the fishery that affect estimates of abundance. Records of this type were collected in conjunction with a study of the effects of hook-spacing on the catch of Pacific halibut (*Hippoglossus stenolepis*) and have been analyzed in this paper.

As indicated in the General Review, most of the studies regarding competition, saturation, or bait loss apply to pelagic longline fisheries or are theoretical in nature, but they provide little data on the hook-by-hook results. Murphy and Shomura (1953), Murphy and Elliot (1954), and others did compare the catch of tuna on hooks at different depths. Murphy and Elliot (1954) and Maéda (1960 and 1967) considered the spatial distribution of the catch on longline gear to study the schooling behavior of tuna. Collectively, these papers showed the importance of hook-by-hook records to evaluate estimates of CPUE for longline gear. In addition, these detailed records can provide information on the behavior of the fish and the most effective fishing techniques.

The major objectives of this study were to examine the effects of bait loss, the distribution of halibut on the gear, and the catch of incidental species on the CPUE of longline gear in the halibut fishery. Unless otherwise noted, all references to CPUE are in terms of number of fish rather than weight as conventionally used by IPHC. Secondarily, the study provided information on competition between halibut and other species.

Throughout the paper comparisons are made with results from other longline fisheries, in particular that for Pacific tuna, to determine whether the observed phenomena are peculiar to the halibut fishery or have broader implications.

COLLECTION OF DATA

The data analyzed in this report were collected as an adjunct to hook-spacing studies during the early 1970's. The results of those studies and the description of the fishing methods were described in the previous reports, Part I and Part II. During 6 of the 14 cruises, special studies were conducted in which each hook was examined as the gear was retrieved to determine whether a fish was caught or the bait retained. The model in Figure 1 depicts four possible alternatives for each hook, i.e., at given time intervals, the bait may be retained or lost or a halibut or another species may be captured. The basic diagram was presented by Neyman (1950) and was adapted for the tuna fishery by Rothschild (1967). I have changed the symbols and added a category for empty hooks (lost bait).

In 2,214 sets of gear, over 170,000 hooks were examined. Depth of fishing was recorded for each set. Hook-spacing and soak-time were recorded for each skate. The hook-by-hook observations from all cruises were categorized as follows: empty hook (E), baited hook (B), halibut (H), and other fish (F). The other-fish category occasionally included species other than fish, such as crabs and starfish. Detailed information (location, date, and hook-spacing) for each cruise is listed in Tables 1 and 3 of Hamley and Skud. Cruises of each vessel have been designated by Roman numerals: I and II for *Chelsea* trips 1 and 2 in 1971; III for the *Republic* 1972; IV for the *Alaska Queen;* and V and VI for the two trips of the *Republic* 1973. The results of the observations from all cruises are summarized in Appendices II and III.

During all cruises, the gear was soaked (left on the bottom) for at least 5 hours. To obtain data on bait loss during shorter soaks, a one-day experiment was conducted in Puget Sound in March 1978. The soak-time of these sets varied from 10 minutes to 4 hours.

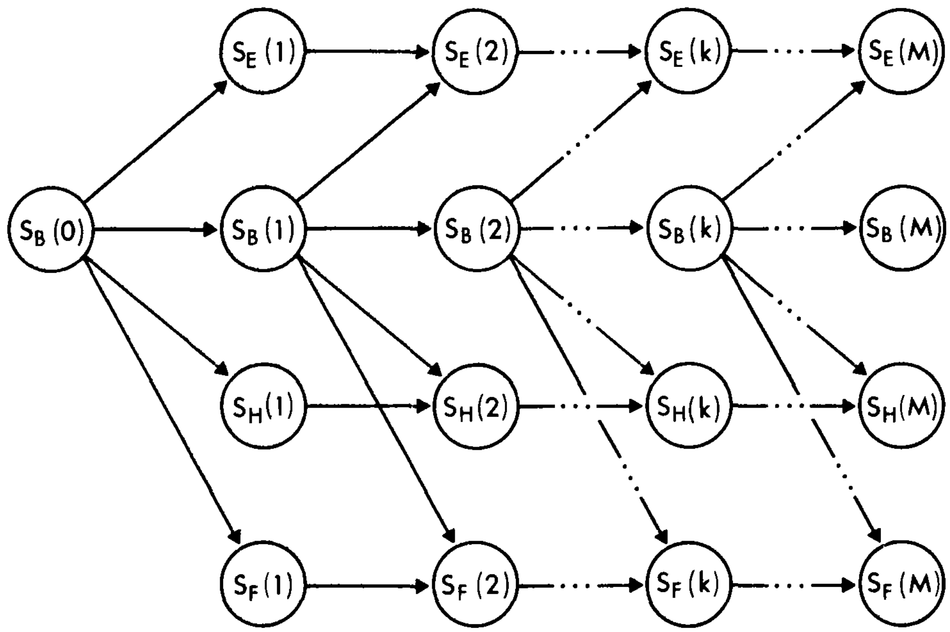

Figure 1. Model depicting baited hooks (S_B), empty hooks (S_E), hooks with halibut (S_H), and hooks with other species (S_F) for successive instants of time (k = 1,2, ..., M). Other alternatives exist, such as S_H to S_E and S_F to S_H, but are infrequent and were not depicted.

GENERAL OBSERVATIONS

Before discussing the results concerning bait loss and competition, general observations regarding saturation, catch with soak-time and depth, and mean size with depth are presented. As indicated below, these factors and the seasonal changes in the distribution of halibut can influence the estimates of CPUE.

Saturation

In the preceding report, Hamley and Skud showed that the catch rate of halibut was low, averaging 5 per 100 hooks, indicating that saturation was not a problem. However, this conclusion was reached without examining the actual distribution of halibut on the gear or the number of hooks occupied by other species. The hook-by-hook observations provide this detail. Obviously, once a bait was lost or a halibut or another fish was captured, that hook was no longer an effective unit of effort, except when the captured fish was small enough to be taken by a larger one or in the remote chance that a fish was snagged by a bare hook. This reduction in the number of effective hooks is fundamental in determining whether the gear is saturated.

Of the 170,016 hooks examined as the gear was retrieved, 106,375 were empty (no bait or catch), 42,593 still had a bait, 6,172 had caught halibut, and 14,876 had caught other species. The ratio of baited hooks retrieved (42,593) to hooks with a catch (21,048) indicates that saturation was not a problem. However, portions of the gear could have been saturated, but it is not possible to fully evaluate this possibility without knowing whether the bait was lost when the gear was being set, while it was soaking or when it was being retrieved. Whatever the cause, baitless hooks could bias conclusions about saturation. One means of determining how often fish were competing for bait is to examine the frequency of adjacent hooks that caught fish. The observations showed that 551 adjacent hooks (pairs) had halibut (HH), 869 pairs had a halibut and another species (HF or FH) and 2,093 pairs had other species (FF). The total number of pairs with a catch was 3,513. Thus, of the 21,048 fish caught only 7,026 were taken in pairs, and there were 8,920 pairs with a fish and a bait (HB, BH, FB or BF) and 13,828 baited pairs (BB) that were available. If all hooks had retained their bait, the number of adjacent hooks with a catch would have been greater, but these results indicate that the gear was not saturated.

Catch and Soak-Time

Skud (1975) presented data on the relation of catch per skate with soak-time. These data had been collected by IPHC in the 1960's and were analyzed by Myhre (unpublished). The results were based on a large number of observations (100 to 300 skates per year) on different fishing grounds and, although variability was high, the increase in CPUE (in pounds) with soak-time was clearly evident (Figure 2).

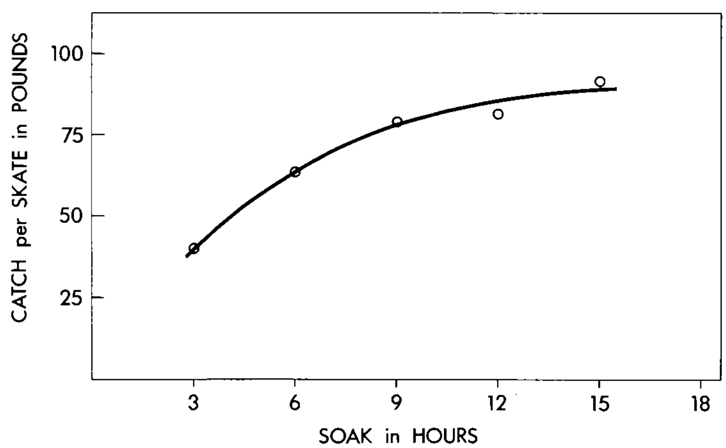

Figure 2. Relation of catch per skate to soak-time.

The hook-by-hook observations provided the opportunity of comparing soak-time with CPUE in numbers of halibut. The data corroborate the earlier findings on the relation of catch with soak-time, but, as before, showed a high degree of variability. Data from four cruises showed consecutive increases in CPUE of halibut at 5-hour intervals (0.0-5.0 to 15.1+), but data from II and III showed no trend (Table 1). The CPUE for other species was quite different than for halibut and only one cruise (I) showed a consecutive increase in CPUE with time. In fact, several of the cruises indicated that the catch of species other than halibut declined with soak-time.

Table 1. Comparison of soak-time and number of halibut per 100 hooks.

Soak-Time (hours)	Cruises I	II	III	IV	V	VI
			No. of halibut per 100 hooks			
0.0- 5	—	2.31	—	1.35	1.78	—
5.1-10	1.18	3.23	4.59	1.46	6.79	5.51
10.1-15	2.48	2.06	2.86	1.47	10.43	8.05
15.1+	2.70	2.17	3.45	—	17.75	16.34
Weighted Mean	2.33	2.43	3.37	1.44	8.17	6.68
			No. of other species per 100 hooks			
0.0- 5	—	3.23	—	13.06	10.18	26.67
5.1-10	5.16	4.01	6.97	9.56	8.69	8.90
10.1-15	8.38	5.83	7.11	9.52	5.21	7.80
15.1+	11.90	4.11	5.21	—	7.52	3.96
Weighted Mean	9.62	4.49	5.81	10.37	7.48	8.42

The catch rates for cruises V and VI were the highest for both halibut and other species and the amount of fishing effort at different soak-times was reasonably well distributed. This combination of events was conducive to examination of the results at shorter (3-hour) intervals (Table 2). The data show that the CPUE of halibut increased consecutively with time, whereas the CPUE of other species showed a continuous decline, each with one exception. It seems unlikely that the other species were escaping from the hooks, particularly when halibut, which are considerably larger and more powerful, were accumulating on the gear. This circumstance suggests that the other species, which generally are less than 10 pounds, are preyed upon by halibut or other large predators. Although halibut are sometimes captured on a hook already occupied by another fish, I assume that most halibut would be successful in capturing the other fish without being caught themselves. In any case, it is of interest to note, that the two cruises (II and III), which did not show an increase in the catch of halibut with time, not only had the lowest catch of other species but also that this catch showed no perceptible trend with time. Obviously, additional research is necessary to determine the relation between the catch of halibut and other species. However, I think that the observed decline in the catch of other species with time is peculiar to halibut gear, because Japanese blackcod gear catches a much higher proportion of the other species (see Table 7) which I assume increases with soak-time.

Table 2. Soak-time and the catch of halibut and other species, Cruises V and VI.

	Cruise V			Cruise VI			TOTAL	
Soak-time (hours)	Skates (No.)	Halibut (No./100 hooks)	Other (No./100 hooks)	Skates (No.)	Halibut (No./100 hooks)	Other (No./100 hooks)	Halibut (No./100 hooks)	Other (No./100 hooks)
0.0- 2.9	0	0.00	0.00	0	0.00	0.00	0.00	0.00
3.0- 5.9	33	2.46	9.24	39	3.77	10.46	3.11	9.85
6.0- 8.9	74	8.28	9.27	120	5.23	8.55	6.41	8.83
9.0-11.9	63	11.33	5.20	99	7.77	8.35	8.96	7.29
12.0-14.9	44	8.08	5.53	81	8.73	7.49	8.48	6.73
15.0-17.9	7	16.85	6.99	3	16.34	3.96	16.71	6.18

The relation of catch to soak-time also has been observed in other longline fisheries. Murphy (1960) showed a 2- to 3-fold increase in the catch of tuna from 5- to 8-hour soaks, but the catch declined slightly during the next 2 hours. Hirayama (1969b) also showed an increase in catch with soak-time but in one of his experiments the subsequent decline did not occur until after 12 hours. Maēda (1960) discussed the increase in catch of tuna with soak-time and pointed out that the rate of increase differed in accordance with the time of the set relative to the feeding behavior, e.g., the increase was greatest when the gear was set before the active feeding at dawn. Takagi (1971) also found that the time of the set affected the relation between the catch of salmon and the soak-time of longline gear. Sets made just before dawn or dusk were more productive than at other times and the catch increased with time, whereas the catch from sets made during the day often showed little or no change with time.

Factors such as tidal conditions and feeding behavior conceivably affect the catch of halibut, but these factors were not included as part of this analysis. Bait retention in halibut fishing obviously plays an important part in determining the catch rate with time. The fact that the catch appears to reach an asymptote and then may decline, suggests that the loss of bait from the hooks and perhaps deteriorating attractiveness of the bait, as well as local depletion, contribute to this relation of catch with time.

Catch With Depth

When all cruises were combined, CPUE increased with depth (Table 3): 0.017 in shallow depth (<75 fathoms), 0.039 in medium (75-125 f) and 0.043 in deep (>125 f). The variability of the results was high as shown in the comparison by cruises. Cruise IV was the only one in which the catch in shallow water was higher than in medium or deep water. Although the CPUE from other cruises did not always increase with depth, the CPUE of medium and deep waters always exceeded that in shallow waters. Cruise IV was conducted off Oregon and Washington in August and had the lowest mean weight of halibut (23.8 pounds). The average weight of fish from the other cruises, conducted in Alaska from March to July, ranged from 32 to 40 pounds. These differences may explain why the results from Cruise IV did not conform with the other cruises.

Table 3. Comparison of CPUE of halibut with depth.

Fathoms	< 75	75-125	>125
Total Hooks	26,904	100,507	42,605
Number of Halibut	449	3,875	1,848
CPUE	0.017	0.039	0.043
Cruise		CPUE	
I	0.008	0.024	0.036
II	0.018	0.025	—
III	0.001	0.068	0.013
IV	0.023	0.006	—
V	0.011	—	0.089
VI	0.012	0.072	0.071

Relatively little data on the catch with depth have been analyzed by IPHC, but unpublished data collected in 1976 during August showed that the best catches were taken at intermediate depths of 50 to 100 fathoms. In general, halibut move to shallow water as the temperature increases in the summer and early autumn. This change in seasonal distribution apparently contributed to the variability of the data in the experimental studies.

Mean Weight and Depth

Although CPUE of halibut generally increased with depth in the experiments, the increase in CPUE by number was not as great as that by weight, indicating that the mean weight of fish taken in deeper water is greater than that in shallower water. I examined the data from the several cruises in an attempt to confirm this interpretation. Although all the cruises included at least 2 depths, the number of fish taken at each depth was not always sufficient for comparison. The following table shows the mean weight (number of fish in parentheses) by three depth categories:

	Depth Category		
Cruise	Shallow	Medium	Deep
I	32.9 (196)	36.0 (736)	
II	27.4 (9)	41.2 (57)	
III	43.7 (47)		34.5 (327)
IV	24.0 (183)	22.9 (53)	
V	7.4 (18)	36.8 (1,275)	
VI	13.0 (26)	32.1 (1,382)	38.5 (227)
Mean	24.7	33.9	36.5

Although the average of these cruises does show an increase in mean weight with depth, not all of the cruises showed this trend and additional data are needed to confirm the relationship. As discussed in the previous section, the seasonal changes in the distribution of halibut also can influence the mean size with depth.

Thompson (1916) examined the relationship of mean weight to depth and although his data combined records from different fishing grounds and different seasons, the results are informative. Prior to 1910, his data only included depths of 15 to 75 fathoms, and the average weight of fish was greatest at the shallowest depths. The data collected after 1910 were more extensive and included depths to 135 fathoms. These data were in general agreement with the observations from the present study.

BAIT LOSS

Few hook-by-hook observations were available for soaks less than 5 hours, but the available data indicated that at least 50% of the hooks lost their bait within this time period. Some of this loss occurred when the gear was set. Baits were regularly seen flying off the hooks as the gear moved through the setting chute, seagulls occasionally stole the bait before the hooks were submerged, and I assume an additional loss occurred when the hooks hit the water and were lowered through the water column. Baits also may be lost when the gear is retrieved (hauled-in). Other causes of bait loss would include baits that are taken by fish or crustaceans without being hooked, baits that are lost as hooks are snagged on the bottom, and deterioration as baits softened with time.

Analysis of the hook-by-hook experiments showed that, in general, bait loss increased with soak-time (Table 4). Four of the cruises showed consecutive increases with time, and the results in the others, although variable, showed a higher proportion of empty hooks for soaks over 10 hours than those under 10

Table 4. Percentage of empty hooks with soak-time, depth and hook-spacing.

	Cruises					
	I	II	III	IV	V	VI
Soak-Time (hours)			Percent			
0.0- 5	—	57.3	—	68.1	53.7	66.7*
5.1-10	41.2	65.8	60.0	71.2	59.5	64.2
10.1-15	50.5	67.1	61.6	81.5	70.0	72.1
15.1+	52.4	73.9	67.9	—	67.0*	70.3*
Depth (fathoms)						
<75	53.6	63.3	50.2	63.2	48.9	43.7
75-125	49.1	66.8	66.0	80.1	—	61.1
>125	49.8	—	66.3	—	63.7	67.7
Hook-Spacing						
12-18 feet	46.6	65.0	59.9	69.4	60.2	55.5
21-24 feet	55.0	69.4	68.0	—	59.6	62.6
36-42 feet	—	—	71.0	74.6	68.0	65.1

*Based on less than 10 skates

hours. Obviously, the greatest loss of bait occurred during the first 5 hours and was lower and more gradual thereafter.

I also examined the bait loss with depth and hook-spacing (Table 4). With only one exception in each category, the percentage of empty hooks increased with depth and hook-spacing. For all cruises combined, the loss with depth increased from 60% at the shallow depth to 62% at medium depth and 66% at the greatest depth, and the loss with paired sets of spacings (12-18, 21-24, 36-42) was 59% for the narrow, 65% for the intermediate, and 70% for the widest-spaced gear.

I also examined the effects of these three variables on bait loss by holding the other two constant for each cruise. Because the spacing, depth, and soak-time were not the same on all cruises, different components of the variables had to be used for some cruises and components within variables were combined to obtain enough data for the comparison. For these reasons and because the number of variables was high and the number of replicates limited, I did not utilize analysis of variance or other multivariate techniques to test significance. I simply relied on probability of sequential events as evidence of significance. The results of the comparison with 2 variables held constant are shown in Table 5, confirming the relationship of bait loss with soak-time, depth, and hook-spacing, shown in the earlier comparison. The selected categories (e.g., hook-spacing) provided the greatest number of components for comparison. Other categories, which had more empty cells, showed similar trends but with exceptions, and, in a few instances, the opposite trend.

Table 5. Percentage of empty hooks with two variables held constant.

Soak-Time (hours)	Cruise I	II	III	IV	V	VI
00.0-10.0	38.73	64.76	59.09	78.89	54.27	59.98
10.1+	47.23	65.74	60.03	80.94	69.27	71.62
Comparisons are for 13-foot spacing except IV which was 18-foot. Comparisons are at mid-depth except V which was deep.						
Depth (fathoms)						
<75	33.23	53.53	50.19	54.77	47.89	39.04
75-125	38.73	65.36	60.84	80.33	—	59.98
>125	43.65	—	62.16	—	54.46	68.11
Comparisons are for 13-foot spacing except IV which was 18-foot. Comparisons are for 5- to 10-hour soaks except III which was 15+.						
Hook-Spacing (feet)						
12-18	38.73	64.66	59.09	80.33	54.46	59.58
21-24	44.17	67.17	—	—	61.21	69.16
36-42	—	—	67.59	80.93	65.85	73.44
Comparisons are for 5- to 10-hour soak-times. Comparisons are at mid-depth except V which was deep.						

Whereas one might expect a greater bait loss with time and depth because of bait deterioration or mechanical loss, the greater loss with hook-spacing cannot be explained on this basis. Apparently, baits are stolen and assuming a constant abundance of organisms that steal the bait, it would appear that a greater proportion of baits are stolen when the bait "abundance" is lower, i.e., the probability of a bait being stolen is greater at the wider hook-spacing, much the same as the probability of capturing a halibut.

As shown in Tables 1 and 3 and in Report II by Hamley and Skud, the CPUE of halibut also increased with soak-time, depth, and hook-spacing. The fact that CPUE and bait loss follow the same trend suggests that the bait loss is related, in part, to the abundance of halibut, but it is not possible to determine how much of the bait is stolen by halibut, by other species, or is otherwise lost. However, fishermen have reported that "whole baits" are frequently found in the stomachs of halibut. Fernø et al. (op. cit.) showed that only 10% of whiting attacks on the bait resulted in the capture of a fish. If the same applied to halibut and all attacks resulted in lost baits, halibut would be credited with 50% of the observed bait loss. If only half of the attacks resulted in a bait loss, the estimate would be 25%.

Bait loss also has been examined in the tuna fisheries. Shomura (1955) showed that the loss of bait increased with soak-time in the Pacific Ocean. He also demonstrated that the shallowest hooks, those most susceptible to agitation from surface swells, had a greater loss than the deeper hooks. Wathne (1959) confirmed these findings in experiments conducted in the Gulf of Mexico and the Caribbean Sea. These authors also reported that bait loss varied with the species used as bait and they recommended "double-hooking" to minimize the loss. Shepard et al. (1975) also examined bait loss in an experimental longline fishery for salmon. The rate of loss differed on the three research vessels, among gears, with sea condition, and with the amount of gear. The bait loss increased in rough seas and with soak-time, which increased when more gear was fished. The authors estimated the total expected bait loss and used "effective effort" in their calculation of CPUE.

Puget Sound Experiment

A special study was conducted in March 1978 to determine the loss of baits in sets of less than 5 hours duration. The M/V *Chelsea* was used in this experiment and the sets were made in Puget Sound. The fishing technique and method of recording data were similar to those described for the other experiments. The hooks were baited alternately with herring (*Clupea pallasii*) and blackcod (*Anoplopoma fimbria*). Captain A. Samuelsen reported that the bait was better (firmer) than is usually available during the commercial season. Only one bait came off the hook during setting, whereas the previous observations indicated that as many as 10 baits per skate may be lost during regular fishing operations. In this experiment, 4 sets of 4 skates each were made. On 2 of the sets, the gear was retrieved immediately after setting — in fact, all of the last skate may not have reached the bottom before hauling began. All of these skates were retrieved between 10 and 67 minutes. Skates in the other 2 sets were retrieved after soaking for 100 to 244 minutes. Halibut were not expected in this area and none was taken. Nearly all of the catch was dogfish (*Squalus acanthias*) and ratfish (*Hydrolagus colliei*), and the results show that the initial loss of bait from gear handling was minimal (Table 6).

Table 6. Number and percent of fish caught and baits lost during soaks of 4 hours or less on the M/V CHELSEA experiment, 1978.

Soak Per Skate (minutes)	Total[1] Hooks	Empty Hooks (No.)	Empty Hooks (%)	Fish on Hooks (No.)	Fish on Hooks (%)
10	80	2	2.5	1	1.3
11	62	0	—	1	1.6
24	58	1	1.7	—	—
29	69	9	13.0	3	4.3
40	59	8	13.6	2	3.4
52	70	22	31.4	13	18.6
53	81	29	35.8	8	9.9
67	74	32	43.2	17	23.0
100	75	38	50.7	24	32.0
117	80	34	42.5	24	30.0
134	71	29	40.8	23	32.4
152	71	27	38.0	27	38.0
185	76	45	59.2	15	19.7
205	55	35	63.6	10	18.2
220	60	25	41.7	18	30.0
244	75	39	52.0	23	30.7

[1] The hooks on each skate were spaced uniformly, but the lengths of skates differed, accounting for the wide range of the number of hooks per skate.

The loss of bait increased with time and reached the same levels (50 to 60%) observed during the main experiments after 5-hour soaks. Interestingly, the loss of bait was not constant with time during the first 4 hours of soak (Figure 4). Although conditions in this experiment were not entirely comparable to the other experiments, the results did indicate that the loss of bait was similar.

Regarding bait loss, fishermen generally consider herring to be the least durable type of bait, but many prefer to use herring along with other baits because it is effective and less expensive. The results of the short-soak experiment indicated that the loss of herring baits was higher than for blackcod baits but that the rate of catch with herring was higher during the first hour. For longer soaks, the catch was about the same for both types of bait. Although fish may steal much of the bait, additional study is necessary to determine whether the higher loss of herring bait is due to its attractiveness or to its relatively low durability.

DISTRIBUTION OF THE CATCH ON THE GEAR

Because some of the baits are lost before the gear begins to fish and an additional loss occurs with soak-time, all of the baits are not available to halibut during the entire set. The results indicate that at least 50-60% of the baits are lost during the first 5 hours; however, some of these are actually lost when the gear is being retrieved. Although bait loss is high and will affect the apparent distribution of the catch on the longline gear, I used the following approximation to determine whether the halibut were randomly distributed on the gear. I calculated the probability of catching halibut on adjacent hooks in "runs"

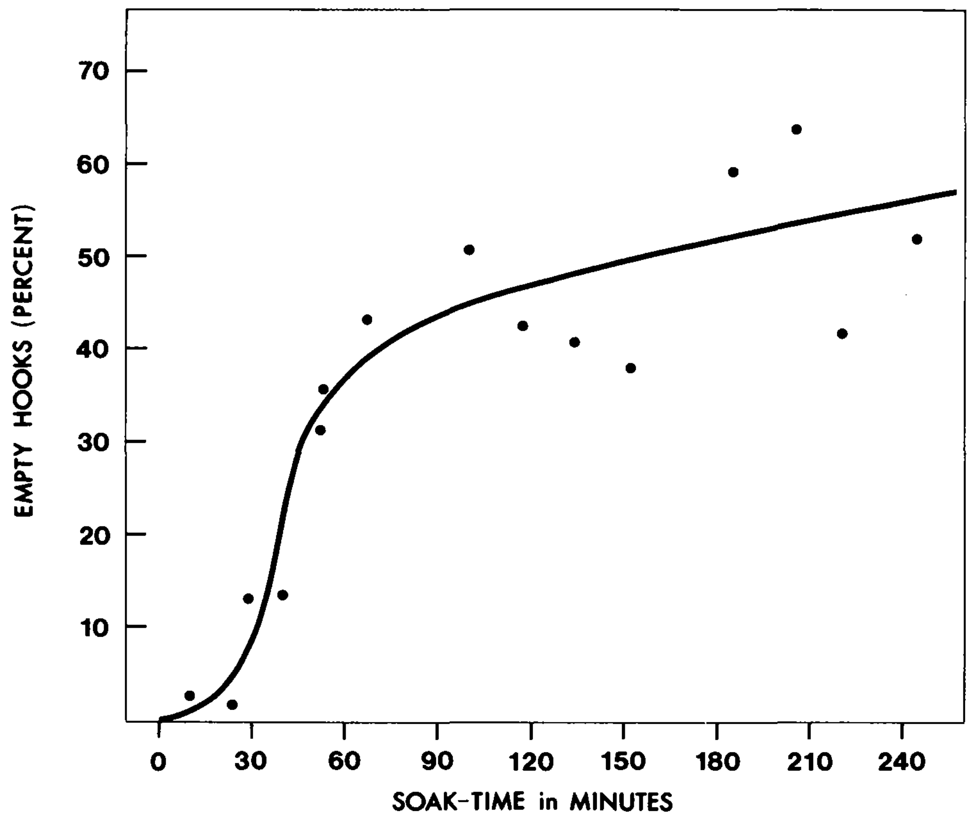

Figure 4. Bait loss and soak-time in the Puget Sound experiment (curve fitted by eye).

from 1 to 5, using the data from each cruise (number of halibut ÷ number of hooks = p) to calculate the expected frequency and combining the results to obtain the expected frequency for all cruises. Assuming a random distribution of halibut along the groundline, the expected frequency of the runs approximates a geometric distribution. The expected frequency of a run of 1 = $(1\text{-}p)^2$ and the ratio of frequencies for runs of 2 halibut (HH) to runs of 1 halibut (H) is equal to p. Similarly, the ratio of other runs, HHH/HH, etc., are equal to p. Based on this premise, I calculated the expected frequencies of the runs as indicated below:

Length of Run	Expected Frequency	Observed[1] Frequency
H	5,591	5,152
HH	262	403
HHH	15	57
HHHH	1	5
HHHHH	0	3

The observed frequencies of runs greater than H exceeded the expected and the difference was highly significant (chi square test), indicating that the halibut and/or the available baits were not randomly distributed. The results

[1] Frequencies of runs for each cruise are tabulated in Appendix III. There also were two runs of 8 halibut.

of this comparison suggest that there is a tendency for halibut to be clustered, however, most of the fish were not taken on adjacent hooks even though there were many adjacent baits available. Obviously, more halibut would have been taken on adjacent hooks if none of the baits had been lost or if other species had not been captured. Other factors such as fish size and abundance undoubtedly affect the degree of clustering.

I also calculated the expected frequency of catching halibut on adjacent hooks for different hook-spacings (12-18 foot, 21-24 foot, and 36-42 foot) and found less deviation between expected and observed values at the wider hook-spacings. This result suggests that halibut maintain broad territories relative to the spacing of hooks. That is, at the wider spacings, there may only be one hook per territory and the likelihood of capturing halibut on adjacent hooks is increased. Further, fewer small halibut are taken on the widely-spaced gear, suggesting that the size of the territories may be related to fish size. This may explain why larger fish are more successful in capturing the bait as suggested by Allen (1963) and Myhre (1969).

COMPETITION

As mentioned previously, the other species of fish caught were not recorded separately and were combined with invertebrates as well. I compared the catch of other species (F) with the catch of halibut (H). The ratio (H/F) increased with wider hook-spacing as shown in the following table:

	Hook-spacing in feet					
	12	18	21	24	36	42
	Catch in number of fish					
Halibut (H)	1,819	196	1,295	260	531	483
Other Species (F)	4,690	485	2,653	519	626	691
H/F	0.37	0.40	0.49	0.50	0.85	0.70

Because the number of hooks per skate decreases with wider spacing, this trend indicates that halibut are more successful than other species in competing for the available bait and can be classed as the "dominant predator". At the narrower hook-spacings, the number of baited hooks is relatively greater than the abundance of halibut and apparently, more of the bait is available to other species. This conclusion is similar to that reached by Hamley and Skud regarding large and small halibut. A larger feeding range, "territory", was suggested as a possible explanation. The same may hold for the relation between halibut and the other species, but other factors such as halibut preying on smaller fish may also be important.

Several experiments comparing Japanese and North American longline gear were reported at annual meetings of the International North Pacific Fisheries Commission (INPFC) and provide information about competition among species. In one experiment (INPFC Document, 1964)[1], the hooks of the Japanese gear were spaced at approximately 30 inches apart, whereas the hook-

[1] Results of a test comparing the catching efficiency of Japanese and North American longline gear. Tokai Regional Fisheries Research Laboratory, October 1964.

spacing of the North American longline gear was approximately 18 feet. The size and material of the hooks and lines also differed, but fishing was conducted on the same grounds at the same time. The catch of halibut and the catch of other species were compared in four parallel sets. The catch of halibut for the two types of gear was nearly the same, whereas the catch of Pacific cod (*Gadus macrocephalus*) on the Japanese gear was 10 times greater than on the North American gear (Table 7). The Japanese gear also caught substantially more turbot (*Atheresthes stomias*), blackcod (*Anoplopoma fimbria*), and other species (pollock, *Theragra chalcogramma*, and several species of sculpins). The fact that the catch of halibut was nearly the same for both gears even though the number of hooks on the Japanese gear was far greater than the North American gear suggests that the abundance of halibut was comparable and confirms the findings of the IPHC study that indicated halibut were more successful in competing for baited hooks than the other species of fish. It is worthy of note, that the catch of halibut per 100 hooks for the gear spaced at 30 inches was 0.3 and for the 18-foot gear was 0.9. Because spacing was not the only difference between the two types of gear, it was surprising that the relative CPUE of the two gears ($0.3 \div 0.9 = 0.33$) was at the expected point on the curve presented in Figure 3 of the Hamley and Skud paper.

Table 7. Catch of halibut and other species on Japanese and North American longline gear (from INPFC Document 709, 1964).

Groundline in meters	No. of hooks	Spacing in meters	Halibut	Pacific cod	Turbot	Black-cod	Other
Japanese							
2,500	1,900	0.76	3	56	3	0	30
2,500	1,900	0.76	2	155	52	41	10
2,500	1,900	0.76	18	292	31	0	2
2,500	1,900	0.76	3	137	1	0	1
TOTAL							
10,006	7,600		26	640	87	41	43
North American							
4,200	800	5.25	4	6	0	0	1
2,100	400	5.25	5	30	2	2	2
4,200	800	5.25	11	20	2	0	0
3,360	640	5.25	3	11	0	0	1
TOTAL							
13,860	2,640		23	67	4	2	4

Kurogane (1968) reported on another hook-spacing study in which halibut were included in the catch and concluded that the traditional Japanese longline gear with narrow spacing and small hooks was superior for catching blackcod and that North American gear with wide spacings and larger hooks was superior for halibut.

The fact that halibut are more competitive and that proportionately more halibut are taken on the widely-spaced gear is an important consideration in the evaluation of CPUE. If other species were equally competitive and increased in abundance when the abundance of halibut declined, the CPUE of halibut could be biased. Because the other species are not as competitive, the results suggest that changes in abundance of halibut relative to the abundance of other species may not seriously distort the estimates of CPUE for halibut. However, the CPUE of the other species would not increase in proportion to actual abundance and the distortion would increase with wider hook-spacings.

ESTIMATES OF CPUE

Prior to 1950, investigators assumed that longline effort was proportional to the number of hooks (see General Review). This basic premise was maintained in later studies in which CPUE was refined to account for saturation and occupied hooks (Gulland 1955 and Beverton and Holt 1957). It also was basic in Murphy's (1960) comprehensive catch equation, which apparently was the first to account for the loss of bait. The proportionality of effort to hooks is inherent in other studies, most recently, that of Rothschild (1967) and Shepard et al. (1975). Rothschild's model was based on the theory of competing risks (Neyman 1950 and Chiang 1968), but his basic approach is similar to Murphy's. Although Murphy did not emphasize the fact that his equation adjusted for competition among species (Rothschild's major objective), the equation did account for hooks occupied by "undesirable species" as well as for hooks without bait. Because of its relative simplicity, Rothschild's equation is described here. A unit of time was divided into M intervals, each of duration 1/M and the transitional probabilities were assumed proportional to the time lapse 1/M, that is, the probabilities of each interval were constant. The instantaneous rate of capture of species i was estimated by:

$$\lambda_i = \frac{-n_i \left[\log_e (n_o/N)\right]}{N-n_o}$$

where:

n_o = the number of hooks without a catch
n_i = the number of hooks that caught species i
N = the total number of hooks

The probability of species 1 being caught, when species 2 was absent is:

$$P_{o1} = 1-e^{-\lambda}$$

This expression is analogous to the conditional rate of fishing mortality and can be used when 3 or more species are caught, by letting n_1 represent species 1 and n_2 all other species. Rothschild assumed that all hooks without a catch, whether baited or empty, were effectively fishing. He did not incorporate a factor for bait loss, but cautioned that an overestimate of the hooks actually fishing (n_o) would result in an underestimate of the effect of competition.

Ricker (1975) considered Rothschild's model unrealistic because it assumed that no baits were lost to fish that were not caught. Ricker extended the model to account for n_1a_1 baits eaten by species 1 without being captured and for n_2a_2 baits eaten by species 2 to estimate the hooks without bait (n_e):

$$n_1 a_1 + n_2 a_2 = n_e$$

As an example, he assumed $a_1 = a_2 = a$, which was calculated from:

$$a = \frac{n_e}{n_1 + n_2}$$

He substituted n_1 (1+a) for n_1 and $n_o - n_e$ for n_o to obtain the conditional probability of removal of baits $1\text{-}e^{-\lambda_{1a}}$ and the conditional rate of capture becomes:

$$P_{ola} = \frac{1 - e^{-\lambda_{1a}}}{1 + a}$$

I considered using this competing-risk model for the halibut data collected during the hook-by-hook experiments even though the loss of bait did not occur at a constant rate (Figure 4) as specified in the model. In my examination of the data, it became apparent that the model implicitly assumes that fishing effort is proportional to the number of hooks, whereas our studies, and the data from other fisheries clearly show otherwise. This suggested that the model could be used if the data were all from gear of the same hook-spacing. However, I eventually realized that if the number of hooks occupied by other species differed substantially from one set to another, the effect would be similar to the effects of different hook-spacing and also would fail to meet the basic assumption of the model. This and other reasons for not applying this model or modifications of Murphy's (1960) catch equation are discussed below.

Paloheimo and Dickie (1964), Rothschild (1967), and others have pointed out that CPUE not only represents the fraction of the population captured by a unit of effort but also, more simply represents the probability of capture. Skud (1972) showed that the catch per hook increased with hook-spacing, i.e., the probability of capture was greater when the distance between hooks increased on a given length of groundline. The present study showed that bait loss also increased with hook-spacing. In effect, the loss of baits widens the distance between baited hooks, thereby increasing the "effective hook-spacing". Therefore, the difference between the wide- and narrow-spaced gear is compounded. If this greater reduction in effort on widely-spaced gear is applicable to the commercial fleet, the actual probability of capture indicated by CPUE is even greater than that shown by Skud (1972).

At this time, and until a more comprehensive model is formulated, it does not seem practical to apply a modification of Murphy's (1960) catch equation or the competing-risk model of Rothschild (1967) and Ricker (1975) to the annual estimates of CPUE in the halibut fishery. The variation in fishing techniques from vessel to vessel, the amount and kind of gear fished, the bait, soak-time, etc., is great. Also, the detailed information on the catch from each commercial operation is not sufficient. For these reasons, standard adjustments are apt to be seriously biased.

Because of the bait loss and the catch of other species, it is obvious that the fishing effort is less and the actual CPUE of halibut is higher than the values reported annually for each regulatory area. However, this does not mean that the calculated annual changes or short-term trends are not representative of the actual CPUE. Because it is impractical to obtain enough detailed data from a large enough sample of vessels in the commercial fleet, it is necessary to assume that the bait loss and the catch of other species is essentially the same from one year to the next. Based on past experience, this assumption has been rational when considering year to year changes; however, there probably have been and can be long-term changes that would adversely affect this assumption. One example is a change in bait. Unpublished data on bait types suggests that octopus bait stays on the hooks longer than other bait. If, as has happened in the past, there is a gradual increase in the use of octopus bait, the bait loss could be reduced or at least the time that bait remains on the hook could be increased and these factors would increase the effective effort of a skate of gear. In the past, when IPHC has been aware of such a change, adjustments have been made in the CPUE. There is the possibility, however, that more subtle changes have not been realized. If the changes in bait, or other changes are made gradually, the year to year changes in CPUE as a measure of abundance are not likely to be serious. Long-term changes, however, could be significant and I do not consider present-day CPUE values comparable with those in the early years of the fishery.

OPTIMIZATION OF FISHING TECHNIQUES

Examination of the logs of the commercial fleet revealed that the fishing success differs widely from vessel to vessel and from year to year. Rothschild (1972) attributed much of the variability in fishing power among vessels to the skill of the skipper. My findings support this conclusion, and suggest that particular techniques of fishing as well as the ability to locate fish might provide the advantages. A skipper fishing at favorable depths, using long-lasting bait and employing optimum soak-times will have a better catch rate than a skipper whose technique is not so refined, even though the latter's vessel is better equipped. Adaptation of techniques to particular grounds and to seasonal changes in the distribution of halibut also contribute to the skipper's success.

Other factors, such as the performance of the crew, can contribute to the efficiency. Skud (1972) showed that baiting-time and retrieval-time aboard the *Chelsea* in 1971 were substantially reduced with wider-spaced gear. More skates could be fished per day and more ground covered with hooks spaced at 21 and 24 feet than at 13 or 18 feet. These findings were confirmed on the other cruises conducted in 1972 and 1973. The average time required to bait a hook did not differ greatly, so, baiting-time per skate decreased with hook-spacing. The average baiting-time for 12-foot gear (about 120 hooks) was approximately 20 minutes, whereas baiting-time for 36- and 42-foot gear was 10 minutes or less. Although the wider-spaced gear usually required less time to retrieve, on the average the difference was less than 2 minutes between the wider-spaced and the narrow-spaced gear.

Long-lasting bait has obvious advantages, but the more fragile baits (such as herring) may be more attractive to the halibut and there are highly successful fishermen that consistently use herring and others that seldom use herring. The more successful fishermen are undoubtedly aware of the advantages offered by different baits and other fishing techniques. They also are aware that baits are lost and stolen and presumably try to minimize their bait loss, however, prior to this study, no quantitative information had been available from the commercial fishery.

DISCUSSION

As evident from this study and others, the experimental design for gear studies is extremely important because many factors influence the catch rate of longline gear and must be considered. Although our design provided meaningful results, certain questions could not be answered because, for example, we did not identify the other species caught. Unfortunately, some factors (such as the availability of bait) are difficult to control. We could have gained more information on the effects of bait had we been able to use only one type or, when mixed, had alternated the types on every other hook. While most designs will be wanting in some respect, the shortcomings of past experiments will serve to alert others conducting similar studies. The analyses of the data also must be considered in the experimental design and, as Blalock (1960) points out, the assumptions required by analysis of covariance severely restrict its utility as a general procedure for handling simultaneously large numbers of variables. He discusses limitations of other multivariate techniques of analysis and mentions that it is possible to control simultaneously for several variables, but cautions that a very large number of cases are required.

Our studies clearly indicate the complexity of measuring effort in the halibut fishery and, along with the excellent studies by Murphy (1960), Maéda (1960), and Hirayama (1969c), show that estimates of CPUE of longline gear must be carefully analyzed. These papers indicate the need for constant review and evaluation of changes in fishing techniques to assure meaningful assessments of stock abundance. Further, the results from the studies of the halibut fishery and those of the tuna fishery show that the effects of hook-spacing, bait loss, etc., are similar and suggest that the same basic phenomena occur in longline fisheries in general.

As indicated, additional research can provide not only valuable information for assessment but also for optimizing fishing techniques. In any case, I see the estimation of CPUE as a continual process of evaluating changes in the fishery and, when possible, conducting experiments to confirm conclusions based on theoretical analyses. I fully expect other studies to enhance the interpretations of this report and the understanding of past and future events in the halibut fishery.

CONCLUSIONS

This study shows that bait loss in the halibut fishery is high and is related to depth, time, and hook-spacing. Although the rate of loss differs with the kind of bait, the evidence indicates that the loss of all types of bait is relatively high. The data are not sufficient to indicate with certainty how the baits are lost. Although losses occur from bait deterioration and handling of the gear, fish also "steal" bait without being captured and apparently, halibut steal a proportionately larger quantity of the baits than other species.

Bait loss is not constant with time and is very rapid during the first 30 to 60 minutes of soak. Thereafter, the loss rate appears to be more or less constant at a relatively low rate depending, in part, on the density of fish on the grounds, hook-spacing, and other factors.

Although Hamley and Skud showed that catch per hook of halibut increased with hook-spacing, there was evidence in this study that the relationship did not hold for the CPUE of other species. The results from certain cruises indicated that CPUE of the non-target species actually decreased with hook-spacing, i.e., was highest when the number of hooks is high relative to the density of halibut. This suggests that halibut is the dominant species and more successful than other species in competing for the available bait. Further, it suggests that CPUE of halibut may not be seriously distorted by a change in relative abundance of the other species; whereas the CPUE of other species will be underestimated at wider hook-spacings. This conclusion applies only to the gear presently in use in the fishery which is selective for halibut. Longlines with lighter lines, smaller hooks, and shorter spacings are more selective for groundfish other than halibut.

Bait loss does affect the estimate of CPUE but, with so many vessels in the fleet, it is not possible to make a useful correction. One can only assume that the annual rate of bait loss is relatively constant, and that the actual and observed CPUE are proportional. For the most part, past data suggest that this assumption is valid, but exceptions are to be expected depending on the availability and quality of the bait.

The results also confirmed that the catch of halibut increases with soak-time but is asymptotic, as is the catch of tuna on longline gear. The data utilized in this report also showed that the catch and mean weight of halibut increased with depth, but these relationships apparently change seasonally.

Models published by other authors (to adjust estimates of CPUE for bait loss and competition between species) all assume that the catch is proportional to the number of unoccupied hooks. Experiments on halibut and tuna longline gear show that this assumption is not valid and that a more comprehensive model is needed.

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LITERATURE CITED

Aasen, Olav
1965 Angelseleksjon ved pigghåfiske (Hook selection by spiny dogfish). Saertrykk av "Fiskets Gang", Volume 31, pp. 31-33.

Allen, K. Radway
1963 The influence of behavior on the capture of fish with baits. International Commission for the Northwest Atlantic Fisheries, Special Publication No. 5, pp. 5-7.

Alward, George Lowe
1932 The sea fisheries of Great Britain and Ireland. Albert Gait, Grimsby, 473 p.

Au, Lai-Shing
1972 An inventory of demersal fisheries in Hong Kong. Food and Agriculture Organization of the United Nations, Proceedings of the Indo-Pacific Fisheries Council, Section III, Symposium on Demersal Fisheries, pp. 270-297.

Bell, F. Heward and Gilbert St-Pierre
1970 The Pacific halibut. International Pacific Halibut Commission, Technical Report No. 6, 24 p.

Beverton, R. J. H. and S. J. Holt
1957 On the dynamics of exploited fish populations. U.K. Ministry of Agriculture, Fisheries, and Food, Fishery Investigations, Series II, Volume XIX, 533 p.

Blalock, Hubert M.
1960 Social statistics. McGraw-Hill Book Company, Inc., New York, 465 p.

Chiang, Chin Long
1968 Introduction to stochastic processes in biostatistics. John Wiley and Sons, Inc., New York, 313 p.

Clark, J. R. (Convener)
1960 Report on selectivity of fishing gear. [In] Fishing effort, the effect of fishing on resources and the selectivity of fishing gear. International Commission for the Northwest Atlantic Fisheries, Special Publication No. 2, pp. 27-36.

Forster, G. R.
1973 Line fishing on the continental slope. The selective effect of different hook patterns. Journal of the Marine Biological Association, United Kingdom, Volume 53, pp. 749-751.

Fridman, A. L.
1969 Theory and design of commercial fishing gear. (Translated by IPST, 1973) Pishchevaya Promyshlennost, Moscow, 568 p.

Gulland, J. A.
1955 Estimation of growth and mortality in commercial fish populations. U.K. Ministry of Agriculture and Fisheries, Fishery Investigations, Series II, Volume XVIII, No. 9, 46 p.

1964 The abundance of fish stocks in the Barents Sea. Conseil Permanent International pour l'Exploration de la Mer, Rapports et Procés-Verbaux des Rèunions, Volume 155, pp. 126-137.

1969 Manual of methods for fish stock assessment. Part 1. Fish population analysis. Food and Agriculture Organization of the United Nations, FAO Manuals in Fisheries Science, No. 4, 154 p.

Hamley, John M.

1975 Review of gillnet selectivity. Journal of the Fisheries Research Board of Canada, Volume 32, No. 11, pp. 1943-1969.

Hamre, Johs

1968 Relative catching capability of a new fish hook for spiny dogfish. Saertrykk av "Fiskets Gang", Volume 46, pp. 793-796.

Hile, Ralph and William R. Duden

1933 Methods for the investigation of the statistics of the commercial fisheries of the Great Lakes. Transactions of the American Fisheries Society, Volume 63, pp. 292-305.

Hirayama, Nobuo

1969a Studies on the fishing mechanism of tuna longline - I. Relation between catch and size of the gear. Bulletin of the Japanese Society of Scientific Fisheries, Volume 35, No. 6, pp. 546-549.

1969b Studies on the fishing mechanism of tuna longline - III. The difference of catch by retrieving methods. Bulletin of the Japanese Society of Scientific Fisheries, Volume 35, No. 7, pp. 629-634.

1969c Studies on the fishing mechanism of tuna longline - IV. Theoretical analysis of fishing effectiveness of the gear. (Translation by Rae R. Mitsuoka.) Bulletin of the Japanese Society of Scientific Fisheries, Volume 35, No. 7, pp. 635-640.

1969d Mechanical behavior of tuna longline - I. Form of main line and hook depth in water. Journal of the Tokyo University of Fisheries, Volume 55, No. 2, pp. 125-130.

1972 Estimation of "swept area" of the unit gear and tuna population size according to catch distribution of tuna longline. Journal of Tokyo University of Fisheries, Volume 59, pp. 9-19.

International Pacific Halibut Commission

1972 Annual Report 1971. International Pacific Halibut Commission, 36 p.

1973 Annual Report 1972. International Pacific Halibut Commission, 36 p.

1978 The Pacific halibut: biology, fishery, and management. International Pacific Halibut Commission, Technical Report No. 16, 56 p.

Ionas, V. A.

1966 Fishing efficiency of the longline. (Translated by Tanya Bevan.) Ryb. Khoz., Volume 42, No. 5, pp. 41-43.

Karlsen, Ludvig
1977 A study of different parameters of longline gear and their effect on catch efficiency. (Partial translation by Carleen Ormbrek.) Norwegian Institute of Fishery Technology Research, No. 661, 72 p.

Kennedy, W. A.
1951 The relationship of fishing effort by gillnets to the interval between lifts. Journal of the Fisheries Research Board of Canada, Volume 8, No. 4, pp. 264-274.

Ketchen, K. S.
1964 Measures of abundance from fisheries for more than one species. Conseil Permanent International pour l'Exploration de la Mer, Rapports et Procès-Verbaux des Réunions, Volume 155, pp. 113-116.

Kurogane, Kenji
1968 Experimental comparison of fishing power of longline for bottom-fishes in the North Pacific. Tokai Regional Fisheries Research Laboratory, Bulletin, No. 55, pp. 115-128.

Maéda, Hiroshi
1960 A tentative analysis of the distribution pattern of tuna projected on the longline. Journal of the Shimonoseki College of Fisheries, Volume 9, No. 2, pp. 89-308.

1967 Distribution pattern of fish in relation to fishing method, with special reference to that of tuna along longline. Symposium on Scombroid Fishes, Part III, pp. 1025-1041.

Mann, Herbert J.
1955 Construction details of improved tuna longline gear used by Pacific Oceanic Fishery Investigations. Commercial Fisheries Review, Volume 17, No. 12, pp. 79-88.

McCracken, F. D.
1963 Selection by codend meshes and hooks on cod, haddock, flatfish, and redfish. International Commission for the Northwest Atlantic Fisheries, Special Publication No. 5, pp. 131-155.

McKenzie, R. A.
1946 The Canadian Atlantic halibut fishery. Fisheries Research Board of Canada, Bulletin No. LXXI, 29 p.

Murphy, Garth I.
1960 Estimating abundance from longline catches. Journal of the Fisheries Research Board of Canada, Volume 17, No. 1, pp. 33-40.

Murphy, Garth I., and K. C. Elliott
1954 Variability of longline catches of yellowfin tuna. U.S. Fish and Wildlife Service, Special Scientific Report: Fisheries No. 119, 30 p.

Murphy, Garth I., and R. S. Shomura
1953 Longline fishing for deep-swimming tunas in the central Pacific, 1950-51. U.S. Department of the Interior, Fish and Wildlife Service, Special Scientific Report: Fisheries No. 98, 47 p.

Myhre, Richard J.
1969 Gear selection and Pacific halibut. International Pacific Halibut Commission, Scientific Report No. 51, 35 p.

Myhre, Richard J., Gordon J. Peltonen, Gilbert St-Pierre, Bernard E. Skud, and Raymond E. Walden
1977 The Pacific halibut fishery: catch, effort, and CPUE, 1929-1975. International Pacific Halibut Commission, Technical Report No. 14, 94 p.

Nakamura, Hiroshi
1952 The tunas and their fisheries (Translated by W. G. Van Campen. Originally published by Takeuchi Shobo, Tokyo, 1949). U.S. Fish and Wildlife Service, Special Scientific Report: Fisheries, No. 82, 115 p.

Nédélec, C.
1975 Catalogue of small-scale fishing gear. Food and Agriculture Organization of the United Nations, Fishing News (Books) Ltd., 191 p.

Neyman, J.
1950 First course in probability and statistics. Henry Holt and Co., N.Y., 350 p.

Otsu, Tamio and Ray F. Sumida
1968 Distribution, apparent abundance and size composition of albacore (*Thunnus alalunga*) taken in the longline fishery based in American Samoa, 1954-65. U.S. Bureau of Commercial Fisheries, Fishery Bulletin, Volume 67, pp. 47-69.

Paloheimo, J. E. and L. M. Dickie
1964 Abundance and fishing success. Conseil Permanent International pour l'Exploration de la Mer, Rapports et Procès-Verbaux des Réunions, Volume 155, pp. 152-163.

Parrish, B. B.
1963 Some remarks on selection processes in fishing operations. International Commission for the Northwest Atlantic Fisheries, Special Publication No. 5, pp. 166-170.

Pella, Jerome J. and Christopher Psaropulos
1975 Measures of tuna abundance from purse-seine operations in the eastern Pacific Ocean adjusted for fleet-wide evaluation of increased fishing power, 1960-1971. Inter-American Tropical Tuna Commission Bulletin, Volume 16, No. 4, pp. 283-400.

Pope, J. A.
1966 Manual of methods for fish stock assessment. Part III. Selectivity of fishing gear. Food and Agriculture Organization of the United Nations, Fisheries Technical Paper 41, 50 p.

Ricker, W. E.
1958 Handbook of computations for biological statistics of fish populations. Fisheries Research Board of Canada, Bulletin No. 119, 300 p.

1969 Effects of size-selective mortality and sampling bias on estimates of growth, mortality, production, and yield. Journal of the Fisheries Research Board of Canada, Volume 26, No. 3, pp. 479-541.

1975 Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada, Bulletin No. 191, 382 p.

Rothschild, Brian J.

1967 Competition for gear in a multiple-species fishery. Journal du Conseil International pour l'Exploration de la Mer, Volume 31, No. 1, pp. 102-110.

1972 An exposition on the definition of fishing effort. U.S. Department of Commerce, National Marine Fisheries Service, Fishery Bulletin, Volume 70, No. 3, pp. 671-679.

1977 Fishing effort. [In] Fish population dynamics. Edited by J. A. Gulland. John Wiley and Sons, pp. 96-115.

Rothschild, B. J. and A. Suda

1977 Population dynamics of tuna. [In] Fish population dynamics. Edited by J. A. Gulland. John Wiley and Sons, pp. 309-334.

Rothschild, Brian J., and Marian Y. Y. Yong

1970 Apparent abundance, distribution, and migrations of albacore, (*Thunnus alalunga*), on the North Pacific longline grounds. U.S. Bureau of Commercial Fisheries, Special Scientific Report—Fisheries No. 623, 37 p.

Saetersdal, Gunnar

1963 Selectivity of longlines. International Commission for the Northwest Atlantic Fisheries, Special Publication No. 5, pp. 189-192.

Scofield, W. L.

1947 Drift and set line fishing gear in California. California Division of Fish and Game, Fish Bulletin No. 66, 38 p.

Shapiro, Sidney

1950 The Japanese longline fishery for tunas. U.S. Fish and Wildlife Service, Commercial Fisheries Review, Volume 12, No. 4, pp. 1-26.

Shepard, M. P., R. F. A. Roberts, K. V. Aro, and C. E. Turner

1975 Effect of bait loss on catching power of floating longline gear. International North Pacific Fisheries Commission, Bulletin No. 32, pp. 71-75.

Shingu, Chiomi, Patrick K. Tomlinson, and Clifford L. Peterson

1974 A review of the Japanese longline fishery for tunas and billfishes in the eastern Pacific Ocean, 1967-1970. Inter-American Tropical Tuna Commission, Bulletin, Volume 16, No. 2, pp. 65-230.

Shomura, Richard S.

1955 A comparative study of longline baits. U.S. Fish and Wildlife Service, Special Scientific Report — Fisheries, No. 151, 34 p.

Shomura, Richard S. and Garth I. Murphy

1955 Longline fishing for deep-swimming tunas in the Central Pacific, 1953. U.S. Department of the Interior, Fish and Wildlife Service, Special Scientific Report: Fisheries, No. 157, 70 p.

Sivasubramaniam, K.
1961 Relation between soaking time and catch of tunas, in longline fisheries. Bulletin of the Japanese Society of Scientific Fisheries, Volume 17, No. 9, pp. 835-845.

Skud, Bernard Einar
1972 A reassessment of effort in the halibut fishery. International Pacific Halibut Commission, Scientific Report No. 54, 11 p.

1975 Revised estimates of halibut abundance and the Thompson-Burkenroad debate. International Pacific Halibut Commission, Scientific Report No. 56, 36 p.

In Press Soak-time and the catch per pot in an offshore fishery for lobsters *(Homarus americanus)*. Journal du Conseil International pour l'Exploration de la Mer, Volume 175.

Southward, G. Morris
1967 Growth of Pacific halibut. International Pacific Halibut Commission, Scientific Report No. 43, 40 p.

Takagi, Kenji
1971 Information on the catchable time period for Pacific salmon obtained through simultaneous fishing by longlines and gillnets. Far Seas Fisheries Research Laboratory, Shimizu, Japan. Bulletin No. 5, pp. 177-194.

Thompson, William F.
1916 Statistics of the halibut fishery in the Pacific: their bearing on the biology of the species and the condition of the banks. [In] Report of the British Columbia Commissioner of Fisheries, 1915, pp. 65-126.

Thompson, William F., Harry A. Dunlop and F. Heward Bell
1931 Biological statistics of the Pacific halibut fishery (1) Changes in yield of a standardized unit of gear. International Fisheries Commission, Report No. 6, 121 p.

Thompson, William F. and F. Heward Bell
1934 Biological statistics of the Pacific halibut fishery (2) Effect of change in intensity upon total yield and yield per unit of gear. International Fisheries Commission, Report No. 8, 49 p.

Tsuji, Satoshi
1974 A historical review of the halibut fishery in Japan, with some notes on the biological information of the fish. (Translated by Rae R. Mitsuoka). Far Seas Research Laboratory, Bulletin No. 11, pp. 77-109.

Van Oosten, John
1935 Logically justified deductions concerning the Great Lakes fisheries exploded by scientific research. Transactions of the American Fisheries Society, Volume 65, pp. 71-75.

Wathne, Frederick
1959 Summary report of exploratory longline fishing for tuna in Gulf of Mexico and Caribbean Sea, 1954-1957. U.S. Bureau of Commerical Fisheries, Commercial Fisheries Review, Volume 21, No. 4, pp. 1-26.

Wise, John P. and William W. Fox, Jr.
1969 The Japanese Atlantic longline fishery, 1965, and the status of yellowfin tuna and albacore stocks. U.S Bureau of Commercial Fisheries, Special Scientific Report: Fisheries No. 582, 7 p.

Yamaguchi, Yuichiro and Hiroshi Kobayashi
1973 Studies on the appearance of empty hooks. II. The change of breaking strength of baits with different sticking methods. Japanese Society of Scientific Fisheries, Bulletin, Volume 39, No. 6, pp. 605-609.

1974 Studies on the appearance of empty hooks. IV. Number of baits in the stomach of hooked fish. Japanese Society of Scientific Fisheries, Bulletin, Volume 40, No. 2, pp. 129-134.

APPENDICES

[1] The data in these tables represent all possible combinations of each hook category. For example, 4 halibut on adjacent hooks were counted as 3 HH's and as 2 HHH's. This tabulation contrasts with data in Appendix III in which runs are independent, hence runs of 2 and 3 halibut were not counted when they occurred in a run of HHHH.

Table 1. Number of skates fished.

Trip	Hook-Spacing in Feet 9	12-13	18	21	24	36	42	Total
CHELSEA (Observer)	—	162	—	157	—	—	—	319
CHELSEA								
Trip 1	—	108	108	95	109	—	—	420
Trip 2	—	135	135	135	135	—	—	540
Trip 3	—	142	139	141	144	—	—	566
AGNES-O (Observer)	—	150	80	—	—	—	—	230
REPUBLIC (1972)								
Trip 1	—	96	—	54	—	—	85	235
Trip 2	—	55	—	43	—	—	47	145
SEAPAK								
Trip 1	95	88	96	—	—	—	—	279
Trip 2	79	80	80	—	—	—	—	239
CAPE BEALE								
Trip 1	50	50	50	—	—	—	—	150
Trip 2	45	45	45	—	—	—	—	135
ALASKA QUEEN II	—	—	114	—	—	114	111	339
REPUBLIC (1973)								
Trip 1	—	51	—	51	—	50	51	203
Trip 2	—	80	—	80	—	75	79	314
Total	269	1,242	847	756	388	239	373	4,114

Table 2. Number of hooks fished.

Trip	Hook-Spacing in Feet 9	12-13	18	21	24	36	42	Total
CHELSEA (Observer)	—	19,792	—	11,305	—	—	—	31,097
CHELSEA								
Trip 1	—	13,083	8,840	6,851	6,628	—	—	35,402
Trip 2	—	16,347	11,063	9,733	8,207	—	—	45,350
Trip 3	—	17,202	11,387	10,163	8,755	—	—	47,507
AGNES-O (Observer)	—	16,527	7,113	—	—	—	—	23,640
REPUBLIC								
Trip 1	—	11,905	—	4,429	—	—	3,564	19,898
Trip 2	—	6,808	—	3,531	—	—	1,970	12,309
SEAPAK								
Trip 1	16,761	11,310	9,139	—	—	—	—	37,210
Trip 2	12,674	10,031	7,509	—	—	—	—	30,214
CAPE BEALE								
Trip 1	9,794	6,247	5,117	—	—	—	—	21,158
Trip 2	8,816	5,364	4,531	—	—	—	—	18,711
ALASKA QUEEN II	—	—	9,225	—	—	4,589	3,859	17,673
REPUBLIC (1973)								
Trip 1	—	6,081	—	4,141	—	2,040	2,101	14,363
Trip 2	—	9,528	—	6,377	—	3,052	3,280	22,237
Total	48,045	150,225	73,924	56,530	23,590	9,681	14,774	376,769

Table 3. Weight of fish caught, in pounds.

	Hook-Spacing in Feet							
Trip	9	12-13	18	21	24	36	42	Total
CHELSEA (Observer)	—	15,477	—	8,592	—	—	—	24,069
CHELSEA								
Trip 1	—	9,498	6,577	6,426	6,721	—	—	29,222
Trip 2	—	8,484	8,209	9,081	7,460	—	—	33,234
Trip 3	—	9,960	11,706	8,039	9,123	—	—	38,828
AGNES-O (Observer)	—	23,799	11,601	—	—	—	—	35,400
REPUBLIC (1972)								
Trip 1	—	2,869	—	1,962	—	—	2,263	7,094
Trip 2	—	10,219	—	8,527	—	—	5,942	24,688
SEAPAK								
Trip 1	4,425	3,721	2,111	—	—	—	—	10,257
Trip 2	7,313	6,179	6,878	—	—	—	—	20,370
CAPE BEALE								
Trip 1	4,515	4,017	3,106	—	—	—	—	11,638
Trip 2	2,257	1,972	1,595	—	—	—	—	5,824
ALASKA QUEEN II	—	—	3,118	—	—	1,184	1,312	5,614
REPUBLIC (1973)								
Trip 1	—	12,982	—	15,624	—	8,274	10,001	46,881
Trip 2	—	19,523	—	14,673	—	10,646	8,222	53,064
Total	18,510	128,700	54,901	72,924	23,304	20,104	27,740	346,183

Table 4. Average weight of fish, in pounds.

	Hook-Spacing in Feet						
Trip	9	12-13	18	21	24	36	42
CHELSEA (Observer)	—	33.87	—	33.83	—	—	—
CHELSEA							
Trip 1	—	35.84	36.95	42.84	35.94	—	—
Trip 2	—	28.66	34.78	38.16	38.65	—	—
Trip 3	—	52.98	46.82	42.53	52.43	—	—
AGNES-O (Observer)	—	11.51	11.21	—	—	—	—
REPUBLIC (1972)							
Trip 1	—	28.69	—	32.70	—	—	36.50
Trip 2	—	31.83	—	33.57	—	—	39.61
SEAPAK							
Trip 1	36.27	38.36	28.92	—	—	—	—
Trip 2	18.61	17.26	21.56	—	—	—	—
CAPE BEALE							
Trip 1	6.25	6.47	7.11	—	—	—	—
Trip 2	33.69	31.30	39.88	—	—	—	—
ALASKA QUEEN II	—	—	25.77	—	—	20.41	23.02
REPUBLIC (1973)							
Trip 1	—	33.81	—	36.94	—	40.36	38.03
Trip 2	—	31.95	—	31.62	—	32.96	39.15

Table 5. Number of fish caught.

Trip	Hook-Spacing in Feet 9	12-13	18	21	24	36	42	Total
CHELSEA (Observer)	—	457	—	254	—	—	—	711
CHELSEA								
Trip 1	—	265	178	150	187	—	—	780
Trip 2	—	296	236	238	193	—	—	963
Trip 3	—	188	250	189	174	—	—	801
AGNES-O (Observer)	—	2,067	1,035	—	—	—	—	3,102
REPUBLIC (1972)								
Trip 1	—	100	—	60	—	—	62	222
Trip 2	—	321	—	254	—	—	150	725
SEAPAK								
Trip 1	122	97	73	—	—	—	—	292
Trip 2	393	358	319	—	—	—	—	1,070
CAPE BEALE								
Trip 1	722	621	437	—	—	—	—	1,780
Trip 2	67	63	40	—	—	—	—	170
ALASKA QUEEN II	—	—	121	—	—	58	57	236
REPUBLIC (1973)								
Trip 1	—	384	—	423	—	205	263	1,275
Trip 2	—	611	—	464	—	323	210	1,608
Total	1,304	5,828	2,689	2,032	554	586	742	13,735

Table 6. Catch per hook in number of halibut.

Trip	Hook-Spacing in Feet 9	12-13	18	21	24	36	42
CHELSEA (Observer)	—	.023	—	.022	—	—	—
CHELSEA							
Trip 1	—	.020	.020	.022	.028	—	—
Trip 2	—	.018	.021	.024	.024	—	—
Trip 3	—	.011	.022	.019	.020	—	—
AGNES-O (Observer)	—	.125	.146	—	—	—	—
REPUBLIC (1972)							
Trip 1	—	.008	—	.014	—	—	.017
Trip 2	—	.047	—	.072	—	—	.076
SEAPAK							
Trip 1	.007	.009	.008	—	—	—	—
Trip 2	.031	.036	.042	—	—	—	—
CAPE BEALE							
Trip 1	.074	.099	.085	—	—	—	—
Trip 2	.008	.012	.009	—	—	—	—
ALASKA QUEEN II	—	—	.013	—	—	.013	.015
REPUBLIC (1973)							
Trip 1	—	.063	—	.102	—	.100	.125
Trip 2	—	.064	—	.073	—	.106	.064

APPENDIX II. HOOK OBSERVATIONS BY DEPTH AND HOOK SPACING (B=BAITED, E=EMPTY, H=HALIBUT, F=OTHER FISH)
TABLE ONE. ALL CRUISES COMBINED

HOOK	DEPTH IN FATHOMS				HOOK SPACING IN FEET						
COMB	< 75	75-125	> 125	TOTAL	12	18	21	24	36	42	TOTAL
BB	2819	8228	2781	13828	7667	1140	3883	426	421	291	13828
BE	3797	14659	5425	23881	11178	2045	7313	1403	839	1103	23881
BF	624	2057	753	3434	1836	229	936	132	143	158	3434
BH	86	805	191	1082	482	55	410	48	37	50	1082
EB	3823	14913	5373	24109	11267	2093	7380	1436	830	1103	24109
EE	10317	39439	18144	67900	20937	9116	22614	3705	4495	7033	67900
EF	1579	4788	2439	8806	3135	998	2477	313	789	1094	8806
EH	293	2470	1242	4005	1218	220	1479	183	420	485	4005
FB	629	1951	785	3365	1832	202	915	122	132	162	3365
FE	1552	4794	2413	8759	3099	1013	2454	313	800	1080	8759
FF	516	1035	542	2093	814	248	502	57	204	268	2093
FH	44	275	140	459	168	31	143	14	58	45	459
HB	93	737	209	1039	433	60	394	44	54	54	1039
HE	300	2588	1193	4081	1286	218	1509	190	405	473	4081
HF	30	218	162	410	141	25	130	14	54	46	410
HH	16	288	247	551	176	10	223	10	64	68	551
*TOTAL	26518	99245	42039	167802	65669	17703	52762	8410	9745	13513	167802
BBB	1457	3245	1168	5870	3355	552	1555	124	204	80	5870
BBE	1088	4030	1341	6459	3480	477	1902	261	174	165	6459
BBF	219	694	206	1119	647	77	308	25	28	34	1119
BBH	28	198	48	274	140	19	90	11	6	8	274
BEB	1517	5423	1851	8791	4546	681	2515	517	253	279	8791
BEE	1829	7522	2758	12109	5301	1180	3845	770	397	616	12109
BEF	321	1037	547	1905	929	117	568	68	96	127	1905
BEH	75	495	173	743	309	43	259	26	57	49	743
BFB	229	798	242	1269	778	67	311	44	32	37	1269
BFE	263	959	375	1597	768	121	472	70	83	83	1597
BFF	117	209	103	429	234	32	106	13	19	25	429
BFH	9	61	23	93	41	7	35	1	5	4	93
BHB	30	226	46	302	148	21	102	13	9	9	302
BHE	46	475	99	620	267	28	247	28	24	26	620
BHF	4	38	28	70	29	1	32	3	2	3	70
BHH	5	55	15	75	30	5	27	4	2	7	75
EBB	1113	4116	1347	6576	3522	493	1945	278	170	168	6576
EBE	2322	9064	3432	14818	6492	1420	4583	1013	540	770	14818
EBF	297	1113	439	1849	919	126	525	93	82	104	1849
EBH	51	488	115	654	276	33	254	31	23	37	654
EEB	1866	7651	2763	12280	5373	1211	3875	768	420	633	12280
EEE	7138	26641	12909	46688	12917	6910	15957	2515	3217	5172	46688
EEF	954	2996	1462	5412	1704	729	1542	210	497	730	5412
EEH	184	1560	752	2496	720	146	926	145	243	316	2496
EFB	268	863	409	1540	768	96	449	62	70	95	1540
EFE	992	3078	1603	5673	1845	710	1611	197	540	770	5673
EFF	265	618	318	1201	403	163	296	36	126	177	1201
EFH	32	158	84	274	94	16	83	11	41	29	274
EHB	47	418	116	581	233	31	219	28	34	36	581
EHE	211	1702	855	2768	794	164	1021	140	291	358	2768
EHF	19	140	95	254	77	18	77	8	39	35	254
EHH	9	188	158	355	106	4	148	5	46	46	355
FBB	198	617	206	1021	614	71	254	19	33	30	1021
FBE	319	1055	469	1843	932	107	542	85	69	108	1843
FBF	97	193	90	380	232	19	79	12	23	15	380
FBH	5	65	15	85	42	1	32	3	3	4	85
FEB	322	1082	482	1886	919	124	553	80	97	113	1886
FEE	927	2942	1500	5369	1685	723	1512	201	512	736	5369
FEF	247	544	290	1081	382	130	256	20	134	159	1081
FEH	27	160	102	289	83	20	100	6	41	39	289
FFB	120	226	112	458	250	33	123	15	17	20	458
FFE	265	590	310	1165	383	159	275	34	133	181	1165
FFF	124	172	96	392	155	47	83	6	45	56	392
FFH	1	33	14	48	20	6	14	1	4	3	48
FHB	10	36	21	67	27	3	27	2	4	4	67
FHE	25	193	80	298	105	19	93	11	37	33	298
FHF	6	23	21	50	21	6	12	1	8	2	50
FHH	1	14	15	30	12	1	7	0	7	3	30
HBB	35	203	44	282	146	18	102	3	6	7	282
HBE	45	434	134	613	230	32	240	35	36	40	613
HBF	7	46	17	70	31	5	20	2	8	4	70
HBH	2	47	11	60	21	2	30	3	3	1	60
HEB	70	568	196	834	342	43	317	43	39	50	834
HEE	200	1597	680	2477	738	151	921	131	241	295	2477
HEF	24	159	107	290	94	14	81	10	42	49	290
HEH	4	224	188	416	97	8	167	5	69	70	416

APPENDIX II. HOOK OBSERVATIONS BY DEPTH AND HOOK SPACING (B=BAITED, E=EMPTY, H=HALIBUT, F=OTHER FISH)
TABLE ONE. ALL CRUISES COMBINED

HOOK COMB	DEPTH IN FATHOMS < 75	75-125	> 125	TOTAL	HOOK SPACING IN FEET 12	18	21	24	36	42	TOTAL
HFB	9	45	18	72	32	5	22	1	7	5	72
HFE	13	121	105	239	78	14	83	10	29	25	239
HFF	7	27	19	53	17	5	13	1	10	7	53
HFH	1	22	17	40	13	1	10	1	7	8	40
HHB	5	49	23	77	23	5	38	0	7	4	77
HHE	9	191	145	345	110	5	132	7	45	46	345
HHF	1	16	15	32	14	0	7	2	3	6	32
HHH	1	30	51	82	27	0	37	1	8	9	82
*TOTAL	26132	97983	41473	165588	65120	17475	52067	8269	9497	13160	165588
BBBB	890	1507	593	2990	1702	334	748	51	130	25	2990
EEEE	5290	18957	9537	33784	8521	5412	11806	1820	2373	3852	33784
FFFF	40	38	21	99	47	10	18	0	15	9	99
HHHH	0	3	13	16	5	0	6	0	2	3	16
*TOTAL	6220	20505	10164	36889	10275	5756	12578	1871	2520	3889	36889
#SKATES	386	1262	566	2214	549	228	695	141	248	353	2214
#HOOKS	26904	100507	42605	170016	66218	17931	53457	8551	9993	13866	170016
#B	7407	25970	9216	42593	21283	3512	12653	2039	1469	1637	42593
#E	16273	62489	27613	106375	36918	12589	34446	5733	6718	9971	106375
#F	2775	8173	3928	14876	5960	1512	4073	519	1216	1596	14876
#H	449	3875	1848	6172	2057	318	2285	260	590	662	6172
HHX	15	256	183	454	147	10	177	9	55	56	454
XHH	15	257	188	460	148	10	182	9	55	56	460
HXH	7	293	216	516	131	11	207	9	79	79	516
XHFX	58	394	286	738	254	49	239	24	95	77	738
XFHX	83	504	243	830	308	57	264	27	99	75	830
XHBX	174	1363	378	1915	815	110	710	83	97	100	1915
XBHX	164	1490	351	2005	902	103	757	89	67	87	2005
XHEX	576	4694	2017	7287	2340	419	2680	363	674	811	7287
XEHX	563	4475	2093	7131	2216	422	2602	353	705	833	7131
XFEX	3016	9195	4560	16771	5982	1967	4679	602	1499	2042	16771
XEFX	3047	9136	4629	16812	6031	1945	4722	593	1463	2058	16812
XFBX	1231	3752	1528	6511	3574	393	1758	237	244	305	6511
XBFX	1222	3966	1455	6643	3578	442	1801	257	267	298	6643
B,E,H	334	2878	833	4045	1657	210	1536	191	213	238	4045
B,E,F	1790	6109	2721	10620	5235	691	3109	458	497	630	10620

APPENDIX II. HOOK OBSERVATIONS BY DEPTH AND HOOK SPACING (B=BAITED, E=EMPTY, H=HALIBUT, F=OTHER FISH)
TABLE TWO. CRUISE I (CHELSEA)

HOOK COMB	DEPTH IN FATHOMS < 75	75-125	> 125	TOTAL	HOOK SPACING IN FEET 12	18	21	24	36	42	TOTAL
BB	683	3721	193	4597	3222	0	1375	0	0	0	4597
BE	497	4521	299	5317	3386	0	1931	0	0	0	5317
BF	49	1088	93	1230	907	0	323	0	0	0	1230
BH	12	193	14	219	150	0	69	0	0	0	219
EB	510	4598	308	5416	3460	0	1956	0	0	0	5416
EE	1003	6292	464	7759	4347	0	3412	0	0	0	7759
EF	53	1432	133	1618	1046	0	572	0	0	0	1618
EH	11	329	42	382	240	0	142	0	0	0	382
FB	41	1074	90	1205	885	0	320	0	0	0	1205
FE	62	1411	140	1613	1054	0	559	0	0	0	1613
FF	7	446	47	500	360	0	140	0	0	0	500
FH	0	87	11	98	65	0	33	0	0	0	98
HB	7	153	12	172	107	0	65	0	0	0	172
HE	14	399	39	452	292	0	160	0	0	0	452
HF	1	58	16	75	53	0	22	0	0	0	75
HH	0	12	2	14	10	0	4	0	0	0	14
*TOTAL	2950	25814	1903	30667	19584	0	11083	0	0	0	30667
BBB	443	1519	52	2014	1464	0	550	0	0	0	2014
BBE	212	1685	110	2007	1340	0	667	0	0	0	2007
BBF	22	430	26	478	352	0	126	0	0	0	478
BBH	2	62	4	68	50	0	18	0	0	0	68
BEB	220	2000	115	2335	1513	0	822	0	0	0	2335
BEE	249	1850	124	2223	1369	0	854	0	0	0	2223
BEF	21	492	41	554	378	0	176	0	0	0	554
BEH	1	126	19	146	100	0	46	0	0	0	146
BFB	25	480	37	542	417	0	125	0	0	0	542
BFE	20	432	39	491	344	0	147	0	0	0	491
BFF	4	134	14	152	120	0	32	0	0	0	152
BFH	0	31	3	34	21	0	13	0	0	0	34
BHB	3	61	3	67	45	0	22	0	0	0	67
BHE	8	113	9	130	91	0	39	0	0	0	130
BHF	1	12	2	15	10	0	5	0	0	0	15
BHH	0	5	0	5	3	0	2	0	0	0	5
EBB	218	1722	109	2049	1365	0	684	0	0	0	2049
EBE	259	2228	143	2630	1587	0	1043	0	0	0	2630
EBF	22	521	43	586	419	0	167	0	0	0	586
EBH	8	97	8	113	72	0	41	0	0	0	113

APPENDIX II. HOOK OBSERVATIONS BY DEPTH AND HOOK SPACING (B=BAITED, E=EMPTY, H=HALIBUT, F=OTHER FISH)
TABLE TWO. CRUISE I (CHELSEA)

HOOK COMB	DEPTH IN FATHOMS < 75	75-125	> 125	TOTAL	HOOK SPACING IN FEET 12	18	21	24	36	42	TOTAL
EEB	267	1911	136	2314	1426	0	888	0	0	0	2314
EEE	684	3454	241	4379	2289	0	2090	0	0	0	4379
EEF	27	684	61	772	470	0	302	0	0	0	772
EEH	9	158	18	185	107	0	78	0	0	0	185
EFB	13	422	34	469	326	0	143	0	0	0	469
EFE	38	740	69	847	516	0	331	0	0	0	847
EFF	2	216	22	240	164	0	76	0	0	0	240
EFH	0	38	7	45	31	0	14	0	0	0	45
EHB	4	68	8	80	50	0	30	0	0	0	80
EHE	6	211	25	242	149	0	93	0	0	0	242
EHF	0	37	8	45	31	0	14	0	0	0	45
EHH	0	7	1	8	6	0	2	0	0	0	8
FBB	16	407	28	451	336	0	115	0	0	0	451
FBE	18	516	39	573	405	0	168	0	0	0	573
FBF	5	115	20	140	116	0	24	0	0	0	140
FBH	2	25	2	29	21	0	8	0	0	0	29
FEB	16	495	36	547	383	0	164	0	0	0	547
FEE	41	652	74	767	472	0	295	0	0	0	767
FEF	4	207	26	237	159	0	78	0	0	0	237
FEH	1	37	3	41	28	0	13	0	0	0	41
FFB	2	149	14	165	123	0	42	0	0	0	165
FFE	4	198	21	223	159	0	64	0	0	0	223
FFF	1	84	9	94	65	0	29	0	0	0	94
FFH	0	13	1	14	10	0	4	0	0	0	14
FHB	0	17	1	18	8	0	10	0	0	0	18
FHE	0	62	4	66	45	0	21	0	0	0	66
FHF	0	8	5	13	11	0	2	0	0	0	13
FHH	0	0	1	1	1	0	0	0	0	0	1
HBB	2	54	4	60	43	0	17	0	0	0	60
HBE	4	74	5	83	41	0	42	0	0	0	83
HBF	0	18	3	21	17	0	4	0	0	0	21
HBH	0	6	0	6	5	0	1	0	0	0	6
HEB	4	143	16	163	107	0	56	0	0	0	163
HEE	10	205	18	233	146	0	87	0	0	0	233
HEF	0	39	4	43	30	0	13	0	0	0	43
HEH	0	7	0	7	3	0	4	0	0	0	7
HFB	1	18	5	24	16	0	8	0	0	0	24
HFE	0	27	9	36	25	0	11	0	0	0	36
HFF	0	8	2	10	9	0	1	0	0	0	10
HFH	0	5	0	5	3	0	2	0	0	0	5
HHB	0	4	0	4	4	0	0	0	0	0	4
HHE	0	8	1	9	5	0	4	0	0	0	9
HHF	0	0	1	1	1	0	0	0	0	0	1
HHH	0	0	0	0	0	0	0	0	0	0	0
*TOTAL	2919	25547	1883	30349	19422	0	10927	0	0	0	30349
BBBB	316	685	15	1016	770	0	246	0	0	0	1016
EEEE	501	2062	128	2691	1309	0	1382	0	0	0	2691
FFFF	0	23	2	25	17	0	8	0	0	0	25
HHHH	0	0	0	0	0	0	0	0	0	0	0
*TOTAL	817	2770	145	3732	2096	0	1636	0	0	0	3732
#SKATES	31	267	20	318	162	0	156	0	0	0	318
#HOOKS	2981	26081	1923	30985	19746	0	11239	0	0	0	30985
#B	1249	9590	606	11445	7706	0	3739	0	0	0	11445
#E	1599	12814	957	15370	9192	0	6178	0	0	0	15370
#F	110	3047	291	3448	2381	0	1067	0	0	0	3448
#H	23	630	69	722	467	0	255	0	0	0	722
HHX	0	12	2	14	10	0	4	0	0	0	14
XHH	0	12	2	14	10	0	4	0	0	0	14
HXH	0	18	0	18	11	0	7	0	0	0	18
XHFX	2	110	31	143	102	0	41	0	0	0	143
XFHX	0	169	21	190	126	0	64	0	0	0	190
XHBX	13	292	24	329	204	0	125	0	0	0	329
XBHX	24	370	28	422	289	0	133	0	0	0	422
XHEX	28	773	76	877	568	0	309	0	0	0	877
XEHX	21	637	81	739	465	0	274	0	0	0	739
XFEX	123	2724	265	3112	2033	0	1079	0	0	0	3112
XEFX	105	2761	253	3119	2013	0	1106	0	0	0	3119
XFBX	79	2089	172	2340	1723	0	617	0	0	0	2340
XBFX	98	2112	179	2389	1768	0	621	0	0	0	2389
B,E,H	29	621	65	715	461	0	254	0	0	0	715
B,E,F	110	2878	232	3220	2255	0	965	0	0	0	3220

APPENDIX II. HOOK OBSERVATIONS BY DEPTH AND HOOK SPACING (B=BAITED, E=EMPTY, H=HALIBUT, F=OTHER FISH)
TABLE THREE. CRUISE II (CHELSEA)

HOOK COMB	DEPTH IN FATHOMS < 75	75-125	> 125	TOTAL	HOOK SPACING IN FEET 12	18	21	24	36	42	TOTAL
BB	702	2082	0	2784	1581	497	280	426	0	0	2784
BE	1868	5261	0	7129	3283	1394	1049	1403	0	0	7129
BF	139	422	0	561	250	84	95	132	0	0	561
BH	33	153	0	186	89	27	22	48	0	0	186
EB	1853	5345	0	7198	3291	1409	1062	1436	0	0	7198
EE	4735	13969	0	18704	6729	4373	3897	3705	0	0	18704
EF	493	1208	0	1701	677	345	366	313	0	0	1701
EH	146	551	0	697	250	146	118	183	0	0	697
FB	165	376	0	541	256	77	86	122	0	0	541
FE	460	1208	0	1668	653	344	358	313	0	0	1668
FF	101	147	0	248	102	39	50	57	0	0	248
FH	10	59	0	69	21	18	16	14	0	0	69
HB	36	168	0	204	98	34	28	44	0	0	204
HE	141	560	0	701	248	141	122	190	0	0	701
HF	10	37	0	47	12	14	7	14	0	0	47
HH	7	28	0	35	15	5	5	10	0	0	35
*TOTAL	10899	31574	0	42473	17555	8947	7561	8410	0	0	42473
BBB	270	784	0	1054	636	215	79	124	0	0	1054
BBE	398	1158	0	1556	859	261	175	261	0	0	1556
BBF	20	93	0	113	54	12	22	25	0	0	113
BBH	8	33	0	41	22	4	4	11	0	0	41
BEB	726	1861	0	2587	1286	479	305	517	0	0	2587
BEE	979	3017	0	3996	1748	818	660	770	0	0	3996
BEF	98	224	0	322	148	60	46	68	0	0	322
BEH	40	104	0	144	77	20	21	26	0	0	144
BFB	47	143	0	190	90	29	27	44	0	0	190
BFE	68	238	0	306	131	48	57	70	0	0	306
BFF	19	25	0	44	20	3	8	13	0	0	44
BFH	2	10	0	12	5	3	3	1	0	0	12
BHB	10	57	0	67	38	9	7	13	0	0	67
BHE	20	79	0	99	43	15	13	28	0	0	99
BHF	0	7	0	7	2	0	2	3	0	0	7
BHH	2	10	0	12	5	3	0	4	0	0	12
EBB	401	1169	0	1570	854	258	180	278	0	0	1570
EBE	1315	3730	0	5045	2194	1050	788	1013	0	0	5045
EBF	99	289	0	388	164	66	65	93	0	0	388
EBH	23	103	0	126	58	22	15	31	0	0	126
EEB	987	3049	0	4036	1771	836	661	768	0	0	4036
EEE	3282	9469	0	12751	4293	3122	2821	2515	0	0	12751
EEF	320	865	0	1185	448	250	277	210	0	0	1185
EEH	93	397	0	490	154	108	83	145	0	0	490
EFB	91	198	0	289	136	41	50	62	0	0	289
EFE	325	846	0	1171	454	259	261	197	0	0	1171
EFF	64	99	0	163	64	30	33	36	0	0	163
EFH	6	42	0	48	14	11	12	11	0	0	48
EHB	22	98	0	120	52	22	18	28	0	0	120
EHE	110	410	0	520	182	110	88	140	0	0	520
EHF	8	22	0	30	6	11	5	8	0	0	30
EHH	4	17	0	21	9	2	5	5	0	0	21
FBB	21	77	0	98	50	15	14	19	0	0	98
FBE	120	253	0	373	170	55	63	85	0	0	373
FBF	19	31	0	50	27	4	7	12	0	0	50
FBH	1	8	0	9	5	0	1	3	0	0	9
FEB	82	243	0	325	142	47	56	80	0	0	325
FEE	300	846	0	1146	428	257	260	201	0	0	1146
FEF	61	79	0	140	65	27	28	20	0	0	140
FEH	10	31	0	41	13	9	13	6	0	0	41
FFB	25	28	0	53	27	6	5	15	0	0	53
FFE	57	93	0	150	56	25	35	34	0	0	150
FFF	18	16	0	34	18	3	7	6	0	0	34
FFH	1	5	0	6	1	3	1	1	0	0	6
FHB	2	5	0	7	3	1	1	2	0	0	7
FHE	6	47	0	53	14	13	15	11	0	0	53
FHF	1	5	0	6	2	3	0	1	0	0	6
FHH	0	1	0	1	1	0	0	0	0	0	1
HBB	7	46	0	53	39	6	5	3	0	0	53
HBE	26	102	0	128	49	24	20	35	0	0	128
HBF	1	9	0	10	5	2	1	2	0	0	10
HBH	1	9	0	10	4	1	2	3	0	0	10
HEB	40	123	0	163	72	26	22	43	0	0	163
HEE	90	382	0	472	156	101	84	131	0	0	472
HEF	7	30	0	37	12	5	10	10	0	0	37
HEH	2	17	0	19	6	7	1	5	0	0	19

APPENDIX II. HOOK OBSERVATIONS BY DEPTH AND HOOK SPACING (B=BAITED, E=EMPTY, H=HALIBUT, F=OTHER FISH)
TABLE THREE. CRUISE II (CHELSEA)

HOOK COMB	DEPTH IN FATHOMS < 75	75-125	> 125	TOTAL	HOOK SPACING IN FEET 12	18	21	24	36	42	TOTAL
HFB	2	5	0	7	3	1	2	1	0	0	7
HFE	7	23	0	30	8	9	3	10	0	0	30
HFF	0	6	0	6	0	3	2	1	0	0	6
HFH	1	2	0	3	1	1	0	1	0	0	3
HHB	2	7	0	9	5	2	2	0	0	0	9
HHE	3	18	0	21	8	3	3	7	0	0	21
HHF	1	3	0	4	2	0	0	2	0	0	4
HHH	1	0	0	1	0	0	0	1	0	0	1
*TOTAL	10772	31196	0	41968	17409	8836	7454	8269	0	0	41968
BBBB	141	388	0	529	314	131	33	51	0	0	529
EEEE	2476	6772	0	9248	2972	2293	2163	1820	0	0	9248
FFFF	6	1	0	7	6	0	1	0	0	0	7
HHHH	0	0	0	0	0	0	0	0	0	0	0
*TOTAL	2623	7161	0	9784	3292	2424	2197	1871	0	0	9784
#SKATES	127	378	0	505	146	111	107	141	0	0	505
#HOOKS	11026	31952	0	42978	17701	9058	7668	8551	0	0	42978
#B	2768	7995	0	10763	5239	2024	1461	2039	0	0	10763
#E	7314	21334	0	28648	11041	6353	5521	5733	0	0	28648
#F	746	1825	0	2571	1045	485	522	519	0	0	2571
#H	198	798	0	996	376	196	164	260	0	0	996
HHX	6	28	0	34	15	5	5	9	0	0	34
XHH	6	28	0	34	15	5	5	9	0	0	34
HXH	4	28	0	32	11	9	3	9	0	0	32
XHFX	18	68	0	86	21	27	14	24	0	0	86
XFHX	18	114	0	132	39	34	32	27	0	0	132
XHBX	68	317	0	385	186	64	52	83	0	0	385
XBHX	62	287	0	349	168	50	42	89	0	0	349
XHEX	273	1071	0	1344	479	270	232	363	0	0	1344
XEHX	283	1062	0	1345	484	280	228	353	0	0	1345
XFEX	893	2345	0	3238	1276	663	697	602	0	0	3238
XEFX	959	2311	0	3270	1315	667	695	593	0	0	3270
XFBX	323	730	0	1053	500	150	166	237	0	0	1053
XBFX	272	819	0	1091	486	162	186	257	0	0	1091
B,E,H	171	609	0	780	351	129	109	191	0	0	780
B,E,F	558	1445	0	2003	891	317	337	458	0	0	2003

APPENDIX II. HOOK OBSERVATIONS BY DEPTH AND HOOK SPACING (B=BAITED, E=EMPTY, H=HALIBUT, F=OTHER FISH)
TABLE FOUR. CRUISE III (REPUBLIC)

HOOK COMB	DEPTH IN FATHOMS < 75	75-125	> 125	TOTAL	HOOK SPACING IN FEET 12	18	21	24	36	42	TOTAL
BB	201	1049	1960	3210	1363	3	1717	0	0	127	3210
BE	214	1954	3016	5184	1937	35	2769	0	0	443	5184
BF	33	163	463	659	282	3	305	0	0	69	659
BH	0	244	56	300	80	0	208	0	0	12	300
EB	224	1992	3008	5224	1957	32	2794	0	0	441	5224
EE	268	6816	10938	18022	4329	350	11263	0	0	2080	18022
EF	35	441	1285	1761	564	23	891	0	0	283	1761
EH	1	674	200	875	134	0	652	0	0	89	875
FB	25	157	478	660	280	6	307	0	0	67	660
FE	43	432	1264	1739	564	20	886	0	0	269	1739
FF	7	53	303	363	134	1	167	0	0	61	363
FH	0	39	26	65	16	0	38	0	0	11	65
HB	0	219	58	277	69	0	189	0	0	19	277
HE	1	713	185	899	148	0	664	0	0	87	899
HF	0	28	34	62	10	0	47	0	0	5	62
HH	0	74	20	94	7	0	81	0	0	6	94
*TOTAL	1052	15048	23294	39394	11874	473	22978	0	0	4069	39394
BBB	95	385	881	1361	571	0	757	0	0	33	1361
BBE	90	534	900	1524	660	3	785	0	0	76	1524
BBF	15	67	144	226	99	0	113	0	0	14	226
BBH	0	52	23	75	23	0	50	0	0	2	75
BEB	85	580	934	1599	710	4	783	0	0	102	1599
BEE	112	1142	1717	2971	1024	30	1642	0	0	275	2971
BEF	16	90	289	395	160	1	186	0	0	48	395
BEH	0	120	34	154	29	0	116	0	0	9	154
BFB	11	52	138	201	99	1	85	0	0	16	201
BFE	19	86	249	354	142	2	170	0	0	40	354
BFF	3	14	61	78	37	0	34	0	0	7	78
BFH	0	9	8	17	4	0	12	0	0	1	17
BHB	0	59	9	68	23	0	44	0	0	1	68
BHE	0	161	30	191	48	0	137	0	0	6	191
BHF	0	7	14	21	4	0	15	0	0	2	21
BHH	0	14	3	17	3	0	12	0	0	2	17
EBB	92	552	911	1555	666	2	808	0	0	79	1555
EBE	114	1183	1785	3082	1088	28	1669	0	0	297	3082
EBF	16	84	260	360	146	2	163	0	0	49	360
EBH	0	154	28	182	47	0	127	0	0	8	182

APPENDIX II. HOOK OBSERVATIONS BY DEPTH AND HOOK SPACING (B=BAITED, E=EMPTY, H=HALIBUT, F=OTHER FISH)
TABLE FOUR. CRUISE III (REPUBLIC)

HOOK COMB	DEPTH IN FATHOMS < 75	75-125	> 125	TOTAL	HOOK SPACING IN FEET 12	18	21	24	36	42	TOTAL
EEB	115	1140	1722	2977	1042	25	1632	0	0	278	2977
EEE	133	4829	8111	13073	2819	299	8443	0	0	1512	13073
EEF	16	296	815	1127	331	20	599	0	0	177	1127
EEH	1	453	135	589	91	0	435	0	0	63	589
EFB	11	82	262	355	139	4	169	0	0	43	355
EFE	20	297	812	1129	339	18	585	0	0	187	1129
EFF	3	30	181	214	72	1	104	0	0	37	214
EFH	0	25	11	36	10	0	18	0	0	8	36
EHB	0	134	38	172	43	0	115	0	0	14	172
EHE	1	469	131	601	83	0	451	0	0	67	601
EHF	0	16	16	32	4	0	25	0	0	3	32
EHH	0	53	10	63	4	0	57	0	0	2	63
FBB	14	46	138	198	102	1	82	0	0	13	198
FBE	9	86	277	372	138	4	185	0	0	45	372
FBF	2	7	56	65	34	1	25	0	0	5	65
FBH	0	17	3	20	5	0	13	0	0	2	20
FEB	21	82	264	367	143	3	182	0	0	39	367
FEE	19	286	816	1121	348	15	587	0	0	171	1121
FEF	3	23	148	174	59	2	71	0	0	42	174
FEH	0	37	17	54	9	0	36	0	0	9	54
FFB	3	12	69	84	36	1	42	0	0	5	84
FFE	4	31	169	204	71	0	98	0	0	35	204
FFF	0	7	55	62	23	0	23	0	0	16	62
FFH	0	1	5	6	2	0	2	0	0	2	6
FHB	0	8	5	13	3	0	7	0	0	3	13
FHE	0	28	16	44	11	0	26	0	0	7	44
FHF	0	1	3	4	1	0	3	0	0	0	4
FHH	0	1	1	2	0	0	1	0	0	1	2
HBB	0	60	21	81	20	0	59	0	0	2	81
HBE	0	134	32	166	41	0	110	0	0	15	166
HBF	0	4	3	7	3	0	3	0	0	1	7
HBH	0	19	1	20	4	0	16	0	0	0	20
HEB	1	163	42	206	44	0	151	0	0	11	206
HEE	0	457	120	577	87	0	427	0	0	63	577
HEF	0	28	14	42	12	0	23	0	0	7	42
HEH	0	53	7	60	4	0	51	0	0	5	60
HFB	0	8	5	13	5	0	7	0	0	1	13
HFE	0	14	22	36	4	0	29	0	0	3	36
HFF	0	2	5	7	1	0	5	0	0	1	7
HFH	0	4	1	5	0	0	5	0	0	0	5
HHB	0	14	6	20	0	0	19	0	0	1	20
HHE	0	50	4	54	5	0	45	0	0	4	54
HHF	0	4	1	5	1	0	4	0	0	0	5
HHH	0	5	5	10	0	0	9	0	0	1	10
*TOTAL	1044	14861	22993	36898	11776	467	22687	0	0	3968	36898
BBBB	46	158	483	687	266	0	407	0	0	14	687
EEEE	68	3537	6283	9888	1917	257	6598	0	0	1116	9888
FFFF	0	0	15	15	9	0	5	0	0	1	15
HHHH	0	0	2	2	0	0	2	0	0	0	2
*TOTAL	114	3695	6783	10592	2192	257	7012	0	0	1131	10592
#SKATES	8	187	301	496	98	6	291	0	0	101	496
#HOOKS	1060	15235	23595	39890	11972	479	23269	0	0	4170	39890
#B	451	3443	5536	9430	3684	41	5041	0	0	664	9430
#E	532	10059	15649	26240	7050	411	15818	0	0	2961	26240
#F	76	692	2103	2871	1000	27	1420	0	0	424	2871
#H	1	1041	307	1349	238	0	990	0	0	121	1349
HHX	0	68	11	79	6	0	68	0	0	5	79
XHH	0	68	14	82	7	0	70	0	0	5	82
HXH	0	76	9	85	8	0	72	0	0	5	85
XHFX	0	48	65	113	19	0	84	0	0	10	113
XFHX	0	72	48	120	31	0	68	0	0	21	120
XHBX	0	399	108	507	133	0	338	0	0	36	507
XBHX	0	450	107	557	150	0	386	0	0	21	557
XHEX	2	1306	353	1661	285	0	1215	0	0	161	1661
XEHX	2	1229	371	1602	259	0	1178	0	0	165	1602
XFEX	86	805	2458	3349	1102	40	1693	0	0	514	3349
XEFX	69	818	2507	3394	1100	46	1714	0	0	534	3394
XFBX	50	285	940	1275	548	12	588	0	0	127	1275
XBFX	66	310	908	1284	557	6	590	0	0	131	1284
B,E,H	1	866	204	1071	252	0	756	0	0	63	1071
B,E,F	92	510	1601	2203	868	16	1055	0	0	264	2203

APPENDIX II. HOOK OBSERVATIONS BY DEPTH AND HOOK SPACING (B=BAITED, E=EMPTY, H=HALIBUT, F=OTHER FISH)
TABLE FIVE. CRUISE IV (ALASKA QUEEN II)

HOOK	DEPTH IN FATHOMS				HOOK SPACING IN FEET						
COMB	< 75	75-125	> 125	TOTAL	12	18	21	24	36	42	TOTAL
BB	803	174	0	977	0	640	0	C	278	59	977
BE	675	383	0	1058	0	616	0	C	296	146	1058
BF	179	52	0	231	0	142	0	C	63	26	231
BH	31	7	0	38	0	28	0	C	7	3	38
EB	709	406	0	1115	0	652	0	0	312	151	1115
EE	3520	5572	0	9092	0	4393	0	0	2381	2318	9092
EF	633	733	0	1366	0	630	0	0	373	363	1366
EH	115	42	0	157	0	74	0	C	38	45	157
FB	162	36	0	198	0	119	0	0	56	23	198
FE	644	750	0	1394	0	649	0	C	383	362	1394
FF	206	213	0	419	0	208	0	0	131	80	419
FH	25	5	0	30	0	13	0	C	10	7	30
HB	34	4	0	38	0	26	0	0	6	6	38
HE	119	41	0	160	0	77	0	C	39	44	160
HF	17	6	0	23	0	11	0	C	10	2	23
HH	9	1	0	10	0	5	0	C	2	3	10
*TOTAL	7881	8425	0	16306	0	8283	0	C	4385	3638	16306
BBB	448	68	0	516	0	337	0	0	160	19	516
BBE	250	86	0	336	0	213	0	C	92	31	336
BBF	73	15	0	88	0	65	0	C	17	6	88
BBH	17	1	0	18	0	15	0	C	1	2	18
BEB	251	66	0	317	0	198	0	C	92	27	317
BEE	310	273	0	583	0	332	0	0	164	87	583
BEF	78	32	0	110	0	56	0	0	27	27	110
BEH	27	5	0	32	0	23	0	C	6	3	32
BFB	48	6	0	54	0	37	0	0	14	3	54
BFE	89	37	0	126	0	71	0	C	38	17	126
BFF	36	9	0	45	0	29	0	C	11	5	45
BFH	5	0	0	5	0	4	0	C	0	1	5
BHB	12	1	0	13	0	12	0	0	0	1	13
BHE	13	6	0	19	0	13	0	C	5	1	19
BHF	3	0	0	3	0	1	0	C	2	C	3
BHH	3	0	0	3	0	2	0	C	0	1	3
EBB	266	91	0	357	0	233	0	0	94	30	357
EBE	337	272	0	609	0	342	0	0	167	100	609
EBF	77	31	0	108	0	58	0	0	35	15	108
EBH	12	5	0	17	0	11	0	0	5	1	17
EEB	331	295	0	626	0	350	0	C	177	99	626
EEE	2601	4581	0	7182	0	3489	0	C	1859	1834	7182
EEF	429	559	0	988	0	459	0	0	252	277	988
EEH	70	31	0	101	0	38	0	C	30	33	101
EFB	71	24	0	95	0	51	0	C	28	16	95
EFE	418	534	0	952	0	433	0	0	247	272	952
EFF	117	158	0	275	0	132	0	C	82	61	275
EFH	19	2	0	21	0	5	0	C	10	6	21
EHB	15	3	0	18	0	9	0	C	5	4	18
EHE	82	32	0	114	0	54	0	C	23	37	114
EHF	9	5	0	14	0	7	0	C	6	1	14
EHH	5	1	0	6	0	2	0	0	2	2	6
FBB	64	11	0	75	0	55	0	C	14	6	75
FBE	71	17	0	88	0	48	0	C	29	11	88
FBF	21	6	0	27	0	14	0	C	9	4	27
FBH	1	0	0	1	0	1	0	C	0	C	1
FEB	92	31	0	123	0	74	0	C	32	17	123
FEE	431	569	0	1000	0	451	0	0	267	282	1000
FEF	94	130	0	224	0	101	0	C	75	48	224
FEH	14	4	0	18	0	11	0	C	1	6	18
FFB	34	4	0	38	0	26	0	C	8	4	38
FFE	122	160	0	282	0	134	0	0	86	62	282
FFF	47	43	0	90	0	44	0	C	33	13	90
FFH	0	3	0	3	0	3	0	C	0	C	3
FHB	4	0	0	4	0	2	0	0	1	1	4
FHE	14	2	0	16	0	6	0	C	7	3	16
FHF	5	1	0	6	0	3	0	C	2	1	6
FHH	1	0	0	1	0	1	0	C	0	C	1
HBB	17	1	0	18	0	12	0	C	3	3	18
HBE	10	3	0	13	0	8	0	C	2	3	13
HBF	4	0	0	4	0	3	0	C	1	C	4
HBH	1	0	0	1	0	1	0	C	0	C	1
HEB	17	8	0	25	0	17	0	C	4	4	25
HEE	85	24	0	109	0	50	0	C	24	35	109
HEF	15	5	0	20	0	9	0	0	10	1	20
HEH	2	2	0	4	0	1	0	C	1	2	4

APPENDIX II. HOOK OBSERVATIONS BY DEPTH AND HOOK SPACING (B=BAITED, E=EMPTY, H=HALIBUT, F=OTHER FISH)
TABLE FIVE. CRUISE IV (ALASKA QUEEN II)

HOOK	DEPTH IN FATHOMS				HOOK SPACING IN FEET						
COMB	< 75	75-125	> 125	TOTAL	12	18	21	24	36	42	TOTAL
HFB	6	1	0	7	0	4	0	0	3	0	7
HFE	5	5	0	10	0	5	0	0	3	2	10
HFF	6	0	0	6	0	2	0	0	4	0	6
HFH	0	0	0	0	0	0	0	0	0	0	0
HHB	3	0	0	3	0	3	0	0	0	0	3
HHE	6	1	0	7	0	2	0	0	2	3	7
HHF	0	0	0	0	0	0	0	0	0	0	0
HHH	0	0	0	0	0	0	0	0	0	0	0
*TOTAL	7714	8260	0	15974	0	8172	0	0	4272	3530	15974
BBBB	286	36	0	322	0	203	0	0	113	6	322
EEEE	2003	3850	0	5853	0	2862	0	0	1518	1473	5853
FFFF	14	10	0	24	0	10	0	0	12	2	24
HHHH	0	0	0	0	0	0	0	0	0	0	0
*TOTAL	2303	3896	0	6199	0	3075	0	0	1643	1481	6199
#SKATES	167	165	0	332	0	111	0	0	113	108	332
#HOOKS	8048	8590	0	16638	0	8394	0	0	4498	3746	16638
#B	1727	629	0	2356	0	1447	0	0	667	242	2356
#E	5088	6884	0	11972	0	5825	0	0	3182	2965	11972
#F	1049	1022	0	2071	0	1000	0	0	590	481	2071
#H	184	55	0	239	0	122	0	0	59	58	239
HHX	9	1	0	10	0	5	0	0	2	3	10
XHH	9	1	0	10	0	5	0	0	2	3	10
HXH	3	2	0	5	0	2	0	0	1	2	5
XHFX	34	12	0	46	0	22	0	0	20	4	46
XFHX	47	8	0	55	0	23	0	0	20	12	55
XHBX	62	8	0	70	0	46	0	0	12	12	70
XBHX	58	13	0	71	0	53	0	0	13	5	71
XHEX	226	77	0	303	0	149	0	0	73	81	303
XEHX	217	80	0	297	0	142	0	0	71	84	297
XFEX	1246	1461	0	2707	0	1264	0	0	745	698	2707
XEFX	1207	1437	0	2644	0	1232	0	0	711	701	2644
XFBX	309	68	0	377	0	231	0	0	102	44	377
XBFX	344	104	0	448	0	274	0	0	124	50	448
B,E,H	94	30	0	124	0	81	0	0	27	16	124
B,E,F	478	172	0	650	0	358	0	0	189	103	650

APPENDIX II. HOOK OBSERVATIONS BY DEPTH AND HOOK SPACING (B=BAITED, E=EMPTY, H=HALIBUT, F=OTHER FISH)
TABLE SIX. CRUISE V (REPUBLIC)

HOOK	DEPTH IN FATHOMS				HOOK SPACING IN FEET						
COMB	< 75	75-125	> 125	TOTAL	12	18	21	24	36	42	TOTAL
BB	130	0	516	646	397	0	188	0	33	28	646
BE	258	0	1787	2045	1027	0	656	0	186	176	2045
BF	90	0	161	251	148	0	74	0	17	12	251
BH	6	0	108	114	35	0	64	0	3	12	114
EB	246	0	1736	1982	992	0	653	0	168	169	1982
EE	368	0	5409	5777	2375	0	1467	0	891	1044	5777
EF	145	0	837	982	397	0	244	0	178	163	982
EH	6	0	853	859	255	0	260	0	155	189	859
FB	102	0	179	281	167	0	77	0	20	17	281
FE	127	0	829	956	370	0	239	0	174	173	956
FF	72	0	167	239	110	0	57	0	24	48	239
FH	4	0	87	91	34	0	24	0	22	11	91
HB	8	0	124	132	49	0	60	0	13	10	132
HE	8	0	826	834	248	0	259	0	143	184	834
HF	1	0	97	98	29	0	26	0	20	23	98
HH	0	0	190	190	66	0	62	0	17	45	190
*TOTAL	1571	0	13906	15477	6699	0	4410	0	2064	2304	15477
BBB	47	0	193	240	162	0	60	0	9	9	240
BBE	61	0	271	332	185	0	106	0	23	18	332
BBF	22	0	30	52	38	0	13	0	1	0	52
BBH	0	0	18	18	10	0	7	0	0	1	18
BEB	118	0	709	827	452	0	245	0	58	72	827
BEE	86	0	747	833	408	0	284	0	73	68	833
BEF	43	0	179	222	116	0	66	0	26	14	222
BEH	4	0	106	110	38	0	45	0	16	11	110
BFB	42	0	57	99	64	0	26	0	4	5	99
BFE	29	0	69	98	53	0	29	0	11	5	98
BFF	17	0	23	40	23	0	15	0	0	2	40
BFH	1	0	11	12	6	0	4	0	2	0	12
BHB	3	0	33	36	13	0	16	0	3	4	36
BHE	3	0	54	57	16	0	35	0	0	6	57
BHF	0	0	11	11	4	0	7	0	0	0	11
BHH	0	0	8	8	2	0	5	0	0	1	8
EBB	59	0	268	327	186	0	107	0	28	14	327
EBE	140	0	1279	1419	699	0	453	0	133	134	1419
EBF	40	0	110	150	83	0	48	0	11	8	150
EBH	6	0	71	77	22	0	42	0	3	10	77

APPENDIX II. HOOK OBSERVATIONS BY DEPTH AND HOOK SPACING (B=BAITED, E=EMPTY, H=HALIBUT, F=OTHER FISH)
TABLE SIX. CRUISE V (REPUBLIC)

HOOK COMB	DEPTH IN FATHOMS < 75	75-125	> 125	TOTAL	HOOK SPACING IN FEET 12	18	21	24	36	42	TOTAL
EEB	80	0	728	808	381	0	280	0	78	69	808
EEE	211	0	3625	3836	1603	0	899	0	600	734	3836
EEF	71	0	469	540	209	0	128	0	106	97	540
EEH	2	0	510	512	156	0	147	0	88	121	512
EFB	39	0	87	126	72	0	33	0	14	7	126
EFE	68	0	593	661	253	0	163	0	127	118	661
EFF	32	0	98	130	51	0	29	0	18	32	130
EFH	3	0	55	58	20	0	17	0	16	5	58
EHB	3	0	61	64	26	0	29	0	6	3	64
EHE	2	0	595	597	168	0	177	0	118	134	597
EHF	1	0	62	63	18	0	14	0	12	19	63
EHH	0	0	124	124	41	0	37	0	14	32	124
FBB	20	0	30	50	36	0	9	0	3	2	50
FBE	54	0	128	182	104	0	54	0	14	10	182
FBF	27	0	11	38	25	0	7	0	3	3	38
FBH	0	0	10	10	2	0	7	0	0	1	10
FEB	37	0	153	190	99	0	60	0	18	13	190
FEE	58	0	492	550	203	0	128	0	107	112	550
FEF	29	0	98	127	47	0	26	0	27	27	127
FEH	0	0	70	70	18	0	19	0	20	13	70
FFB	21	0	27	48	30	0	15	0	0	3	48
FFE	28	0	100	128	46	0	26	0	21	35	128
FFF	22	0	30	52	30	0	11	0	2	9	52
FFH	0	0	7	7	3	0	3	0	1	0	7
FHB	1	0	13	14	8	0	4	0	2	0	14
FHE	3	0	51	54	20	0	13	0	12	9	54
FHF	0	0	11	11	2	0	4	0	5	0	11
FHH	0	0	11	11	4	0	3	0	2	2	11
HBB	4	0	19	23	12	0	10	0	1	0	23
HBE	3	0	85	88	34	0	37	0	9	8	88
HBF	1	0	10	11	2	0	6	0	2	1	11
HBH	0	0	8	8	1	0	7	0	0	0	8
HEB	6	0	124	130	52	0	56	0	10	12	130
HEE	2	0	455	457	131	0	135	0	86	105	457
HEF	0	0	80	80	21	0	22	0	14	23	80
HEH	0	0	151	151	41	0	43	0	27	40	151
HFB	0	0	8	8	1	0	3	0	2	2	8
HFE	0	0	63	63	18	0	21	0	14	10	63
HFF	1	0	12	13	4	0	2	0	2	5	13
HFH	0	0	13	13	5	0	0	0	2	6	13
HHB	0	0	14	14	0	0	10	0	2	2	14
HHE	0	0	117	117	42	0	33	0	12	30	117
HHF	0	0	10	10	5	0	0	0	1	4	10
HHH	0	0	41	41	18	0	15	0	1	7	41
*TOTAL	1550	0	13706	15256	6642	0	4355	0	2012	2247	15256
BBBB	16	0	73	91	69	0	20	0	2	0	91
EEEE	123	0	2463	2586	1136	0	541	0	393	516	2586
FFFF	8	0	3	11	8	0	2	0	0	1	11
HHHH	0	0	11	11	5	0	3	0	0	3	11
*TOTAL	149	0	2550	2699	1218	0	566	0	395	520	2699
#SKATES	21	0	200	221	57	0	55	0	52	57	221
#HOOKS	1592	0	14106	15698	6756	0	4465	0	2116	2361	15698
#B	486	0	2586	3072	1611	0	987	0	241	233	3072
#E	779	0	8990	9769	4064	0	2662	0	1432	1611	9769
#F	310	0	1271	1581	686	0	401	0	243	251	1581
#H	17	0	1259	1276	395	0	415	0	200	266	1276
HHX	0	0	141	141	47	0	43	0	15	36	141
XHH	0	0	143	143	47	0	45	0	16	35	143
HXH	0	0	172	172	47	0	50	0	29	46	172
XHFX	2	0	167	169	47	0	51	0	35	36	169
XFHX	8	0	148	156	59	0	45	0	38	14	156
XHBX	15	0	221	236	95	0	102	0	23	16	236
XBHX	12	0	197	209	67	0	114	0	6	22	209
XHEX	16	0	1359	1375	408	0	438	0	240	289	1375
XEHX	12	0	1404	1416	424	0	431	0	260	301	1416
XFEX	249	0	1505	1754	701	0	432	0	311	310	1754
XEFX	282	0	1524	1806	748	0	445	0	318	295	1806
XFBX	203	0	340	543	331	0	144	0	38	30	543
XBFX	177	0	300	477	286	0	138	0	30	23	477
B,E,H	25	0	501	526	188	0	244	0	44	50	526
B,E,F	242	0	726	968	527	0	290	0	94	57	968

APPENDIX II. HOOK OBSERVATIONS BY DEPTH AND HOOK SPACING (B=BAITED, E=EMPTY, H=HALIBUT, F=OTHER FISH)
TABLE SEVEN. CRUISE VI (REPUBLIC)

HOOK	DEPTH IN FATHOMS				HOOK SPACING IN FEET						
COMB	< 75	75-125	> 125	TOTAL	12	18	21	24	36	42	TOTAL
BB	300	1202	112	1614	1104	0	323	0	110	77	1614
BE	285	2540	323	3148	1545	0	908	0	357	338	3148
BF	134	332	36	502	249	0	139	0	63	51	502
BH	4	208	13	225	128	0	47	0	27	23	225
EB	281	2572	321	3174	1567	0	915	0	350	342	3174
EE	423	6790	1333	8546	3157	0	2575	0	1223	1591	8546
EF	220	974	184	1378	451	0	404	0	238	285	1378
EH	14	874	147	1035	339	0	307	0	227	162	1035
FB	134	308	38	480	244	0	125	0	56	55	480
FE	216	993	180	1389	458	0	412	0	243	276	1389
FF	123	176	25	324	108	0	88	0	49	79	324
FH	5	85	16	106	32	0	32	0	26	16	106
HB	8	193	15	216	110	0	52	0	35	19	216
HE	17	875	143	1035	350	0	304	0	223	158	1035
HF	1	89	15	105	37	0	28	0	24	16	105
HH	0	173	35	208	78	0	71	0	45	14	208
*TOTAL	2165	18384	2936	23485	9957	0	6730	0	3296	3502	23485
BBB	154	489	42	685	522	0	109	0	35	19	685
BBE	77	567	60	704	436	0	169	0	59	40	704
BBF	67	89	6	162	104	0	34	0	10	14	162
BBH	1	50	3	54	35	0	11	0	5	3	54
BEB	117	916	93	1126	585	0	360	0	103	78	1126
BEE	93	1240	170	1503	752	0	405	0	160	186	1503
BEF	65	199	38	302	127	0	94	0	43	38	302
BEH	3	140	14	157	65	0	31	0	35	26	157
BFB	56	117	10	183	108	0	48	0	14	13	183
BFE	38	166	18	222	98	0	69	0	34	21	222
BFF	38	27	5	70	34	0	17	0	8	11	70
BFH	1	11	1	13	5	0	3	0	3	2	13
BHB	2	48	1	51	29	0	13	0	6	3	51
BHE	2	116	6	124	69	0	23	0	19	13	124
BHF	0	12	1	13	9	0	3	0	0	1	13
BHH	0	26	4	30	17	0	8	0	2	3	30
EBB	77	582	59	718	451	0	166	0	56	45	718
EBE	157	1651	225	2033	924	0	630	0	240	239	2033
EBF	43	188	26	257	107	0	82	0	36	32	257
EBH	2	129	8	139	77	0	29	0	15	18	139
EEB	86	1256	177	1519	753	0	414	0	165	187	1519
EEE	227	4308	932	5467	1913	0	1704	0	758	1092	5467
EEF	91	592	117	800	246	0	236	0	139	179	800
EEH	9	521	89	619	212	0	183	0	125	99	619
EFB	43	137	26	206	95	0	54	0	28	29	206
EFE	123	661	129	913	283	0	271	0	166	193	913
EFF	47	115	17	179	52	0	54	0	26	47	179
EFH	4	51	11	66	19	0	22	0	15	10	66
EHB	3	115	9	127	62	0	27	0	23	15	127
EHE	10	580	104	694	212	0	212	0	150	120	694
EHF	1	60	9	70	18	0	19	0	21	12	70
EHH	0	110	23	133	46	0	47	0	30	10	133
FBB	63	76	10	149	90	0	34	0	16	9	149
FBE	47	183	25	255	115	0	72	0	26	42	255
FBF	23	34	3	60	30	0	16	0	11	3	60
FBH	1	15	0	16	9	0	3	0	3	1	16
FEB	74	231	29	334	152	0	91	0	47	44	334
FEE	78	589	118	785	234	0	242	0	138	171	785
FEF	56	105	18	179	52	0	53	0	32	42	179
FEH	2	51	12	65	15	0	19	0	20	11	65
FFB	35	33	2	70	34	0	19	0	9	8	70
FFE	50	108	20	178	51	0	52	0	26	49	178
FFF	36	22	2	60	19	0	13	0	10	18	60
FFH	0	11	1	12	4	0	4	0	3	1	12
FHB	3	6	2	11	5	0	5	0	1	0	11
FHE	2	54	9	65	15	0	18	0	18	14	65
FHF	0	8	2	10	5	0	3	0	1	1	10
FHH	0	12	2	14	6	0	3	0	5	0	14
HBB	5	42	0	47	32	0	11	0	2	2	47
HBE	2	121	12	135	65	0	31	0	25	14	135
HBF	1	15	1	17	4	0	6	0	5	2	17
HBH	0	13	2	15	7	0	4	0	3	1	15
HEB	2	131	14	147	67	0	32	0	25	23	147
HEE	13	529	87	629	218	0	188	0	131	92	629
HEF	2	57	9	68	19	0	13	0	18	18	68
HEH	0	145	30	175	43	0	68	0	41	23	175

APPENDIX II. HOOK OBSERVATIONS BY DEPTH AND HOOK SPACING (B=BAITED, E=EMPTY, H=HALIBUT, F=OTHER FISH)
TABLE SEVEN. CRUISE VI (REPUBLIC)

HOOK COMB	DEPTH IN FATHOMS < 75	75-125	> 125	TOTAL	HOOK SPACING IN FEET 12	18	21	24	36	42	TOTAL
HFB	0	13	0	13	7	0	2	0	2	2	13
HFE	1	52	11	64	23	0	19	0	12	10	64
HFF	0	11	0	11	3	0	3	0	4	1	11
HFH	0	11	3	14	4	0	3	0	5	2	14
HHB	0	24	3	27	14	0	7	0	5	1	27
HHE	0	114	23	137	50	0	47	0	31	9	137
HHF	0	9	3	12	5	0	3	0	2	2	12
HHH	0	25	5	30	9	0	13	0	7	1	30
*TOTAL	2133	18119	2891	23143	9871	0	6644	0	3213	3415	23143
BBBB	83	240	22	345	283	0	42	0	15	5	345
EEEE	119	2736	663	3518	1187	0	1122	0	462	747	3518
FFFF	12	4	1	17	7	0	2	0	3	5	17
HHHH	0	3	0	3	0	0	1	0	2	0	3
*TOTAL	214	2983	686	3883	1477	0	1167	0	482	757	3883
#SKATES	32	265	45	342	86	0	86	0	83	87	342
#HOOKS	2197	18649	2981	23827	10043	0	6816	0	3379	3589	23827
#B	726	4313	488	5527	3043	0	1425	0	561	498	5527
#E	961	11398	2017	14376	5571	0	4267	0	2104	2434	14376
#F	484	1587	263	2334	848	0	663	0	383	440	2334
#H	26	1351	213	1590	581	0	461	0	331	217	1590
HHX	0	147	29	176	69	0	57	0	38	12	176
XHH	0	148	29	177	69	0	58	0	37	13	177
HXH	0	169	35	204	54	0	75	0	49	26	204
XHFX	2	156	23	181	65	0	49	0	40	27	181
XFHX	10	141	26	177	53	0	55	0	41	28	177
XHBX	16	347	25	388	197	0	93	0	62	36	388
XBHX	8	370	19	397	228	0	82	0	48	39	397
XHEX	31	1467	229	1727	600	0	486	0	361	280	1727
XEHX	28	1467	237	1732	584	0	491	0	374	283	1732
XFEX	419	1860	332	2611	870	0	778	0	443	520	2611
XEFX	425	1809	345	2579	855	0	762	0	434	528	2579
XFBX	267	580	76	923	472	0	243	0	104	104	923
XBFX	265	621	68	954	481	0	266	0	113	94	954
B,E,H	14	752	63	829	405	0	173	0	142	109	829
B,E,F	310	1104	162	1576	694	0	462	0	214	206	1576

APPENDIX III. FREQUENCY OF RUNS OF HALIBUT BY DEPTH AND HOOK SPACING.

RUN LENGTH	DEPTH IN FATHOMS < 75	75-125	> 125	TOTAL	HOOK SPACING IN FEET 12	18	21	24	36	42	TOTAL
TABLE ONE. ALL CRUISES COMBINED											
#HOOKS	26904	100507	42605	170016	66218	17931	53457	8551	9993	13866	170016
1 H	418	3329	1405	5152	1732	296	1876	241	470	535	5152
2 H	14	231	156	403	127	10	155	8	50	53	403
3 H	1	25	31	57	21	0	26	1	5	4	57
4 H	0	1	4	5	0	0	4	0	0	1	5
5 H	0	1	2	3	0	0	1	0	1	1	3
8 H	0	0	1	1	1	0	0	0	0	0	1
TABLE TWO. CRUISE I (CHELSEA)											
#HOOKS	2961	26061	1923	30985	19746	0	11239	0	0	0	30985
1 H	23	606	65	694	447	0	247	0	0	0	694
2 H	0	12	2	14	10	0	4	0	0	0	14
TABLE THREE. CRUISE II (CHELSEA)											
#HOOKS	11026	31952	0	42978	17701	9058	7668	8551	0	0	42978
1 H	185	742	0	927	346	186	154	241	0	0	927
2 H	5	28	0	33	15	5	5	8	0	0	33
3 H	1	0	0	1	0	0	0	1	0	0	1
TABLE FOUR. CRUISE III (REPUBLIC)											
#HOOKS	1060	15235	23595	39890	11972	479	23269	0	0	4170	39890
1 H	1	698	272	1171	224	0	637	0	0	110	1171
2 H	0	64	12	76	7	0	65	0	0	4	76
3 H	0	5	2	7	0	0	6	0	0	1	7
5 H	0	0	1	1	0	0	1	0	0	0	1
TABLE FIVE. CRUISE IV (ALASKA QUEEN II)											
#HOOKS	8048	8590	0	16638	0	8394	0	0	4498	3746	16638
1 H	166	53	0	219	0	112	0	0	55	52	219
2 H	9	1	0	10	0	5	0	0	2	3	10
TABLE SIX. CRUISE V (REPUBLIC)											
#HOOKS	1592	0	14106	15698	6756	0	4465	0	2116	2361	15698
1 H	17	0	920	937	281	0	306	0	167	183	937
2 H	0	0	119	119	35	0	35	0	15	34	119
3 H	0	0	24	24	12	0	9	0	1	2	24
4 H	0	0	4	4	0	0	3	0	0	1	4
5 H	0	0	1	1	0	0	0	0	0	1	1
8 H	0	0	1	1	1	0	0	0	0	0	1
TABLE SEVEN. CRUISE VI (REPUBLIC)											
#HOOKS	2197	18649	2981	23827	10043	0	6616	0	3379	3589	23827
1 H	26	1030	148	1204	434	0	332	0	248	190	1204
2 H	0	126	25	151	60	0	46	0	33	12	151
3 H	0	20	5	25	9	0	11	0	4	1	25
4 H	0	1	0	1	0	0	1	0	0	0	1
5 H	0	1	0	1	0	0	0	0	1	0	1