2000 ICES Annual Science Conference
Theme: Efficiency, selectivity and impacts of passive fishing gears
CM 2000/J:04
27-30 September 2000
Brugge, Belgium

Efficiency and Species Selectivity of Fabricated Baits used in Alaska Demersal Longline Fisheries

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Abstract

A species-selective fabricated bait was developed and tested for the Alaska demersal longline fishery targeting sablefish (*Anoplopoma fimbria*) and Pacific halibut (*Hippoglossus stenolepis*). Trials took place on commercial longline vessels near Seward, Alaska during July and September, 1999. The fabricated bait fished as well or better than herring (control bait) for sablefish and Pacific halibut, while reducing bycatch of spiny dogfish shark (*Squalus acanthias*), skate (*Raja spp*.), arrowtooth flounder (*Atheresthes stomias*), and Pacific cod (*Gadus macrocephalus*) by more than 10x. Hook timers demonstrated that this novel bait released attractants over a longer period of time than herring. This project was a collaborative effort among numerous individuals from Alaska Fisheries Development Foundation, Alaska SeaLife Center, Center for Applied Regional Studies, MARCO Marine, Seattle, and Wildlife Conservation Society. The research was funded by Alaska Science and Technology Foundation.

Introduction

The potential benefits of using artificial (= fabricated) baits for longline fisheries include higher catches, enhanced species selectivity (i.e., lower bycatch and discard), consistent product (quality, price, and size), enhanced safety, and lower bait loss. Various fabricated baits have been tested for commercial longline fisheries, including nylon bags containing minced-raw fish (Løkkborg 1991) and reinforced polyurethane impregnated with feeding attractants that occur in natural baits (Løkkborg 1990). Although results of trials designed to test these (and other) fabricated baits have been promising, the binder, reinforcement, and attractant have been problematic or cost prohibitive.

The field study described herein took place in Alaska on small longline vessels that targeted demersal groundfish (Pacific halibut and sablefish). The ultimate objective of this experiment was to test the utility of longline baits fabricated from processed Alaskan seafood wastes. Specific objectives included: (1) observe fish behavior while approaching and ingesting fabricated and natural baits, (2) determine catch rates for fabricated versus natural baits, (3) evaluate potential species selectivity of the fabricated bait, and (4) determine the catch for fish over time (hours) for both fabricated and natural baits (i.e., how long do the baits fish?).

Methods

Field trials took place near Seward, Alaska during July and September, 1999 (Figure 1). The fishing vessel *Sebrika* was employed during the July trial, whereas the *F/V Rocinante* was chartered during the September experiment. Groundlines consisted of three skates (total groundline length = 1,650 m). Two hundred hooks (snap-on gear) were fished each set; half the hooks were baited with herring and half were baited with fabricated bait. Bait type was alternated every 10th hook (with a space of 20 to 60 m between bait types). The purpose of this space between bait types was to inhibit potential leading from one bait type to the next. This design resulted in a balanced data set (i.e., paired comparisons between herring and fabricated bait).

Sixty-two sets were made during July and September 1999. Four sets were made during each complete fishing day. Two sets were usually made during partial fishing days (e.g., days running to or from the fishing grounds). Set duration (= amount of time that bait was in the water) ranged from 2.8 to 8.7 hours. Attempts were made to fish equal numbers of short and long sets each day in the same area. Fishing depth ranged from 72 to 310 m.

Six bait formulas were used during the 1999 trials. Fabricated baits A1, A2, and A5 were comprised of pollock waste, whereas A6 was comprised of fish waste from a different species. Two softer formulas (A3 and A4) were created. Few sets were made using A3 and A4; hence, results from these sets were not included in any analyses.

More than 13.5 t of fish were caught throughout the course of this study. Pacific halibut and sablfish were the principal target species (total catch > 7 t). The dominant bycatch species were Pacific cod (3.4 t), spiny dogfish shark (1.2 t), skate (0.9 t), and arrowtooth flounder 0.3 t. Most Pacific cod (along with all other bycatch species) were discarded. The survival of the discarded Pacific cod was probably low (their stomachs and air bladders were distended). The survival of most other discarded fish (i.e., those without air bladders) was probably high.

Hook Timers**:** Hook timers, capable of recording up to 99 hook motions per minute over any period of time, were attached to gangions during one or two sets each day. During the July field trial, gangions holding hook timers were only 2 to 3 m from adjacent hooks. This close proximity of neighboring hooks made interpretation of hook-timer data difficult (in some cases). Hence, the space between gangions holding hook timers and adjacent baited hooks was increased to approximately 20 m during the September field trial.

Underwater Camera System**:** Underwater video was used to observe fish behavior while approaching and taking baited hooks. Observations were also used to interpret motions detected by hook timers. A metal frame that measured 2m x 2 m (base) by 2.1 m was used to hold a self-contained video system (SIT camera provided by National Marine Fisheries Service, RACE Division, Seattle, Washington). A simulated longline was made by attaching line across the base of the frame and snapping hooks onto the line (see Kaimmer, In Press). Hook timers were attached to one or two gangions. Most successful observations were made at depths less than 65 m using ambient light.

Results

Relative catch between herring and fabricated bait: Sample sizes were large enough to provide catch comparisons for four types of fabricated bait identified as A1, A2, A5, and A6. Baits A1, A2, and A5 were made of pollock wastes, whereas fabricated bait A6 consisted of an attractant derived from a different fish species.

Catch performance of A2 was poor relative to that of herring for all species (Figure 2). Differences in catch between A2 and herring were significant for Pacific cod, arrowtooth flounder, spiny dogfish shark, and longnose skate ($p \leq 0.05$; Table 1). Even though differences were not statistically significant for Pacific halibut and sablefish (Table 1), the apparent trend (see Figure 2) prompted the decision to concentrate efforts on other bait types.

Formula A1 was the primary fabricated bait tested during the initial field trial. This bait showed promise for catching Pacific halibut and sablefish, whereas it appeared to select against other species (Figure 3). Differences in catch between A1 and herring were significant for Pacific cod, arrowtooth flounder, and longnose skate ($p \leq 0.05$; Table 1).

Results using formula A1 led to the development of A5 (i.e., slight modifications were made to A1). Formula A5 caught more halibut and sablefish than were caught using herring (Figure 4). In addition, this fabricated bait selected against species that are normally discarded by fishers who target halibut and sablefish (Figure 4). Bycatch was reduced by approximately 10x (all species combined) using A5 relative to herring. Differences in catch between A5 and herring were significant for Pacific cod, spiny dogfish shark, and longnose skate (Table 1).

A final formula (A6) contained an attractant that was derived from a species other than pollock (= Pacific cod). Formula A6 caught more halibut than herring, but slightly fewer sablefish (these differences were not statistically significant; Figure 5, Table 1). One extremely positive result for this formula was the absence of bycatch (Figure 5). For example, 158 Pacific cod and 186 spiny dogfish shark were caught on hooks baited with herring, whereas A6 caught only 1 Pacific cod and 3 spiny dogfish shark on the same number of baited hooks.

Length frequency distribution and bait sizes: Fabricated baits A1, A5, and A6 were combined to provide length frequency distributions. Sablefish size distributions were similar between fabricated bait and herring (Figure 5a), whereas halibut size distributions differed between these bait types (Figure 5b). The average size of halibut caught by herring was 98 cm, whereas halibut caught by fabricated bait averaged 88.6 cm in length.

The difference in halibut size distributions between herring and fabricated bait may be caused by differences in bait size. Randomly selected baits (cut herring and cut fabricated bait) were measured for length, width, depth, and weight (Table 2). In general, herring pieces were larger than pieces of fabricated bait (in one or more dimensions). Fabricated baits averaged 19 g, whereas weights of cut herring were 26, 27.4, and 19.3 g for the body, head, and tail pieces, respectively.

Underwater video and hook-timer data: The simulated longline apparatus was set 26 times during July and September field seasons. Most successful sets were made at depths less than 65 m using ambient light. Visibility was poor using artificial light at deeper depths and the light source was not compatible with the SIT camera.

Fish were observed in 16 of the 26 sets. Pacific halibut, Pacific cod, sablefish, yelloweye rockfish, quillback rockfish, flathead sole, and one unidentified fish species approached the bait. Few fish were actually caught by this simulated longline; hooking success was low.

Small fish (flathead sole and unidentified roundfish) tore at the bait using quick, sporadic strikes; these fish were never hooked. This ambush behavior rarely produced more than 20 motions-per-minute (Figure 6a and 6b). It is important to note that these small fish preferentially "attacked" herring over the fabricated bait. Figure 6a shows bait activity (movement) caused by numerous unidentified small roundfish picking at the herring immediately after the apparatus reached the bottom. This activity stopped after the bait was cleaned from the hook (approximately 35 min.; Figure 6a). The unidentified small fish paid no attention to the fabricated bait (A1) until after a halibut was momentarily hooked at 1 hr. 20 min.(Figure 6b). Some of the fabricated bait was still on the hook when the cage was recovered.

Many larger fish (e.g., sablefish, Pacific halibut, and Pacific cod) either (a) inspected the bait (herring and fabricated) and swam away, (b) sucked the bait into their mouths then spat it back out, or (c) became hooked but escaped within minutes. Large fish that were hooked fought vigorously during the initial minutes after taking the bait; this activity typically resulted in more than 50 motions-per-minute. Once caught, these fish alternated between periods of vigorous movements and periods of little or no motion (Figure 7). Activity of hooked fish generally decreased over time.

Bait performance relative to soak duration: Underwater video observations, coupled with hook timer data, were necessary to determine the point at which fish become hooked. These data showed that, in most cases, more than 50 motions per minute was indicative of large fish becoming hooked. Fewer than 50 motions per minute normally was associated with small fish or scavengers (Figure 6a) or with fish that took the bait but immediately escaped (Figure 6b). Figure 8 clearly shows the moment that a halibut first took the bait (i.e., 3 hours after the bait entered the water). This halibut was caught and landed by the vessel. Figure 9 shows the activity of a large fish that took the bait, was hooked for some time, but escaped.

The distribution of hooking times (= first moment that more than 50 motions per minute was recorded by the hook timer) suggests that fabricated bait attracted fish over a longer period of time than herring (Figure 10). This figure includes only cases where hooked fish were landed by the vessel (e.g., Figure 8). Unidentified fish that were hooked but escaped were not included (e.g., Figure 9). The hooking-time distribution shows that the herring stopped "fishing" much sooner than the fabricated bait. Approximately 80% of the fish caught on herring were hooked between 0.5 and 1.5 hours after the bait entered the water. No fish were caught on herring after 3.0 hours. Highest catches using fabricated bait, on the other hand, were recorded between 1.0 and 2.0 hours after baits entered the water (Figure 10); fabricated baits continued catching halibut and sablefish to 5.0 hours after the soak began.

Catch ratios were also used to evaluate relative-bait performance over soak duration. Ratios were calculated for each set as A / H, where A = number of halibut and sablefish caught using fabricated bait and H = number of halibut and sablefish caught using herring. The data set used for this analysis was balanced and blocked by day (i.e., equal number of short and long soaks, each day, were included). The ratio (A / H) increased with soak duration for A5 and A6 (Figure 11), suggesting that the fabricated bait increasingly outperformed herring as soak duration increased. The relative catch between A1 and herring, on the other hand, was constant with soak time (Figure 11). It is possible (and likely) that attractant release rates varied among fabricated bait formulas.

Figure 12 illustrates one example of the importance of prolonged-release rates for attractants, especially at deeper fishing depths. Descent (= sinking) time of the longline (measured at the center using time-depth recorders) increased linearly with depth. The longline took 15 minutes to reach bottom at the shallowest depth (= 100 m), and 45 minutes to reach bottom at the deepest locations (= 300 m).

Discussion

One potential benefit of the fabricated bait described herein is its species-selectivity characteristics. Baits A5 and A6 were extremely effective at catching halibut and sablefish, but inhibited the catch of other species (e.g., Pacific cod, dogfish shark, and skate). Others have shown species selective properties for various natural baits. For example, Løkkeborg et al. (1989) found that Atlantic cod responded less frequently to mackerel bait than to haddock. Woll et al. (1998) showed that use of grenadier bait in longline fisheries targeting Greenland halibut resulted in very little bycatch relative to baits typically used by those fishers (e.g., squid). The CPUE for the target species was higher using grenadier than using squid, whereas the bycatch (mostly grenadier) was reduced to almost zero.

The public, environmental organizations, and resource managers are beginning to show little tolerance for fisheries that exhibit high bycatch and waste. Use of species-selective baits, such as A5 or A6, would not only benefit those species that are commonly caught using herring and subsequently discarded (many dead), but would also benefit the Alaska longline fishery. Use of these selective baits would increase the amount of Pacific cod available for retention by Pacific cod directed fisheries, while at the same time demonstrate environmental responsibility by this fishery. This bycatch-reduction benefit of A5 and A6 would enhance the image of the Alaskan longline fishery as environmentally friendly and responsible.

The second important trait demonstrated by the fabricated bait was its extended "fishing" time; this bait attracted fish over a longer period of time than herring. Herring virtually stopped fishing within 2 hours after being submerged in water (whereas A5 and A6 fished up to 5 hours). If one considers the longline-sinking rate (Figure 12), and if it is assumed that herring effectively fishes only 2 hours after being submerged, then actual bottom-fishing time at 300 m would have been approximately 1 hour and 15 minutes (using herring). Some suggest that catch may depend on tidal currents and other factors that take place during limited periods of the day (e.g., Løkkeborg and Pina 1997). If this is true, then use of a bait that fishes over extended periods will increase the likelihood catching fish.

The extended fish-attraction time for halibut and sablefish using A5 and A6 relative to herring (Figure 10) may be due to a more gradual or prolonged release of the attractant. Laboratory studies showed that the fabricated bait developed by this research team attracted Pacific cod for up to 8 hours after being soaked in water (Goldhor and Giurca, unpublished data). The relatively longer fishing time shown for A5 and A6 (Figure 10) could also be due to the species-selective characteristic demonstrated by the fabricated bait. Underwater video demonstrated that small fish (flathead sole and unidentified roundfish) bit and nibbled at herring until the bait was cleaned from the hook. These species paid little attention to the fabricated bait. Other species (shark, skate, etc.) also preferentially took herring over fabricated bait. Hence, halibut and sablefish competed with bycatch and scavenger species for hooks baited with herring, whereas the target species had little competition for hooks baited with A5 and A6. Thus, herring-baited hooks became saturated faster (due to excessive bycatch) than hooks baited with fabricated bait.

The size of sablefish caught during these trials was independent of bait type. Pacific halibut caught on fabricated bait, on the other hand, were generally smaller than those caught on herring. We attribute this size-selectivity pattern to bait size. The International Pacific Halibut Commission recently conducted studies that clearly show larger halibut prefer larger bait (S. Kaimmer, IPHC, personal communication). Hence, simply cutting the fabricated bait larger may result in catches of larger Pacific halibut.

Acknowledgements

Numerous individuals assisted with the set-up, logistics, and conduct of field work. All project collaborators (Chris Mitchell and Richard Drake, AFDF; Drs. Susan Goldhor and Radu Giurca, CARS; Hal Cook and Mimi Fielding, Marco Marine; Susan Inglis, Alaska SeaLife Center) provided ideas, suggestions, and guidance that led to the successful application of the field experiment. Richard Drake (AFDF) took the lead in obtaining permits, locating fishing vessels, handling various forms and procedures, and coordinating all project collaborators. Drs. Goldhor and Giurca (CARS) provided endless ideas regarding baits to test and how those baits should be tested. They (along with Richard Drake) also worked extremely hard preparing baits for the field season. Hal Cook and Mimi Fielding (Marco Marine) provided practical guidance for this experiment. Susan Inglis provided use of resources at the Alaska SeaLife Center (lab and freezer space). Chuck Adams and Richard Drake helped collect data on board the longline vessels. The Captains and crew of the *F/V's Rocinante and Sebrika* not only worked in a professional manner, but they went beyond their contractual obligations to ensure the success of this project. Ressurection Bay Seafoods and Seward Fish Co., local processors in Seward, provided work space on the docks and use of cranes for off-loading. Thanks to Craig Rose, Scott McIntyre and Gary Stauffer with the National Marine Fisheries Service RACE Division for the use of their underwater video camera system. We sincerely thank Svein Løkkeborg and Rene Holst, who provided valuable advice and guidance during the planning stages of this research.

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Table 1. Paired t-tests: mean difference in catch per set (numbers) between herring (H) and fabricated bait (A) using various formulas during July and September field seasons combined. Each set consisted of 200 baited hooks (100 herring and 100 fabricated). Four formulas of fabricated bait (A1, A2, A5, and A6) were tested against herring. N = number of sets. Mean Difference = $(\sum(H_i - A_i)) / N$, where H_i = number caught by herring during set *i*, A_i = number caught by fabricated bait during set *i*, and N = number of sets with that species present in the catch. * = significant at $p \leq 0.05$, ** = significant at $p \leq 0.01$, and *** = significant at $p \leq 0.001$.

Bait		Halibut	Sablefish	PCOD	ATF	Dogfish	LN Skate
A2	N	6	3	3	6	4	7
	Mean Difference	4.0	4.7	11.0*	7.7*	2.0*	2.3*
A1	N	17	11	17	16	6	12
	Mean Difference	0.9	0.2	16.0***	1.4*	2.3	2.1***
A5	N	19	14	18	12	19	10
	Mean Difference	-0.8	-0.9	18.7***	1.3	6.9***	1.4*
A6	N	12	12	10	10	12	5
	Mean Difference	-0.6	2.8	15.7**	1.3***	15.3**	1.6

PCOD = Pacific Cod
Dogfish = Spiny Dogfish Shark
LN Skate = Longnose Skate
ATF = Arrowtooth Flounder

Table 2. Average length, width, depth, and weight of fabricated bait and herring (body, head, and tail) used during July and September field trials. Cut pieces were randomly selected from certain sets during both seasons.

Bait	Body part	N	Length (mm)	Width (mm)	Depth (mm)	Weight (g)
Fabricated	.	166	48.19	27.62	13.03	19.01
Herring	body	40	45.93	29.78	22.03	25.99
	head	19	62.79	43.47	20.26	27.42
	tail	25	65.00	35.04	15.92	19.32

Figure 1. Chart showing sampling locations near Seward, Alaska during July and September, 1999.

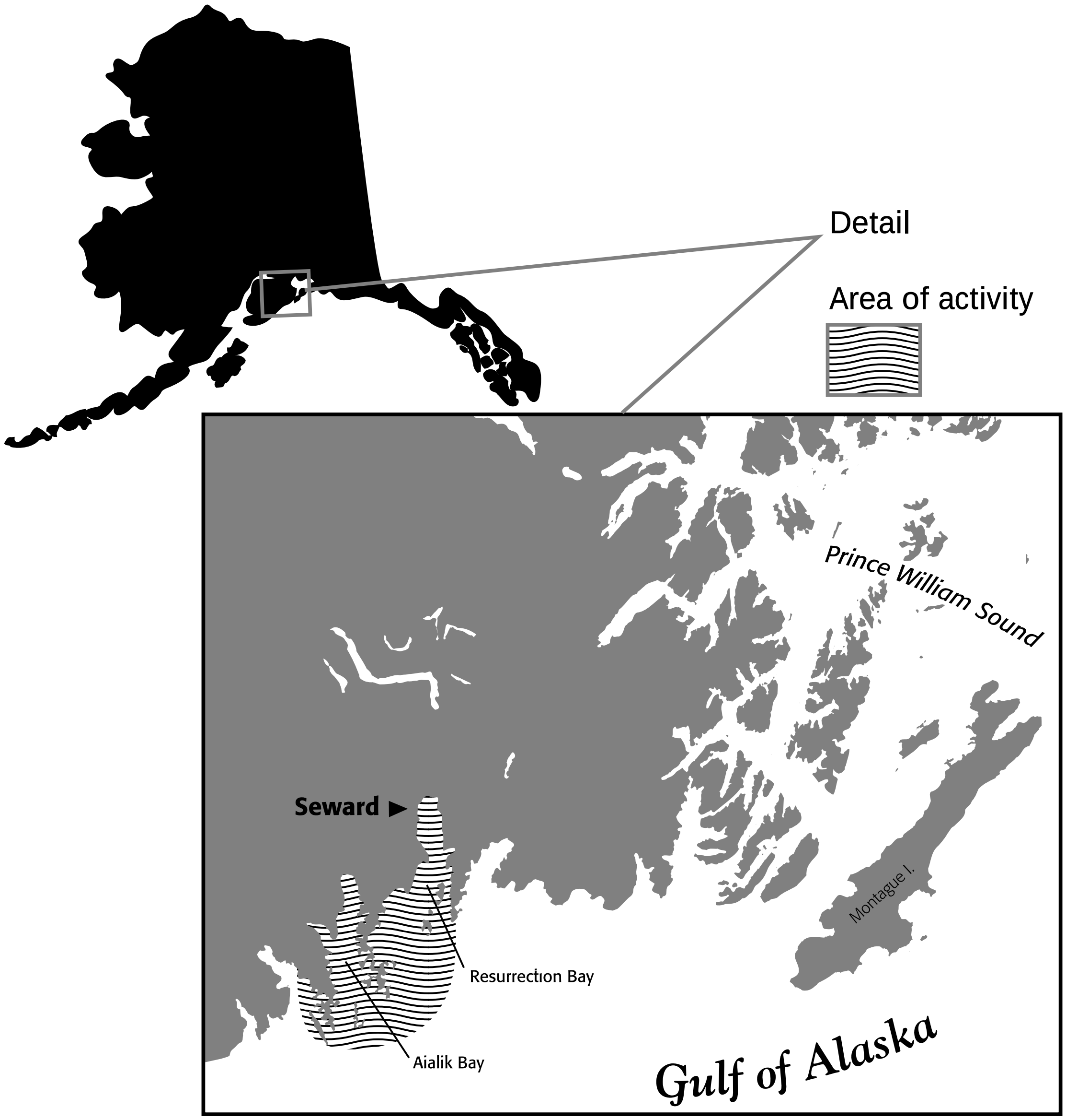


Figure 2. Longline catch for six species using herring and fabricated-bait A2. Comparisons were paired on the same longline sets; the number of hooks baited with herring and fabricated bait is equal. See Table 1 for sample sizes.

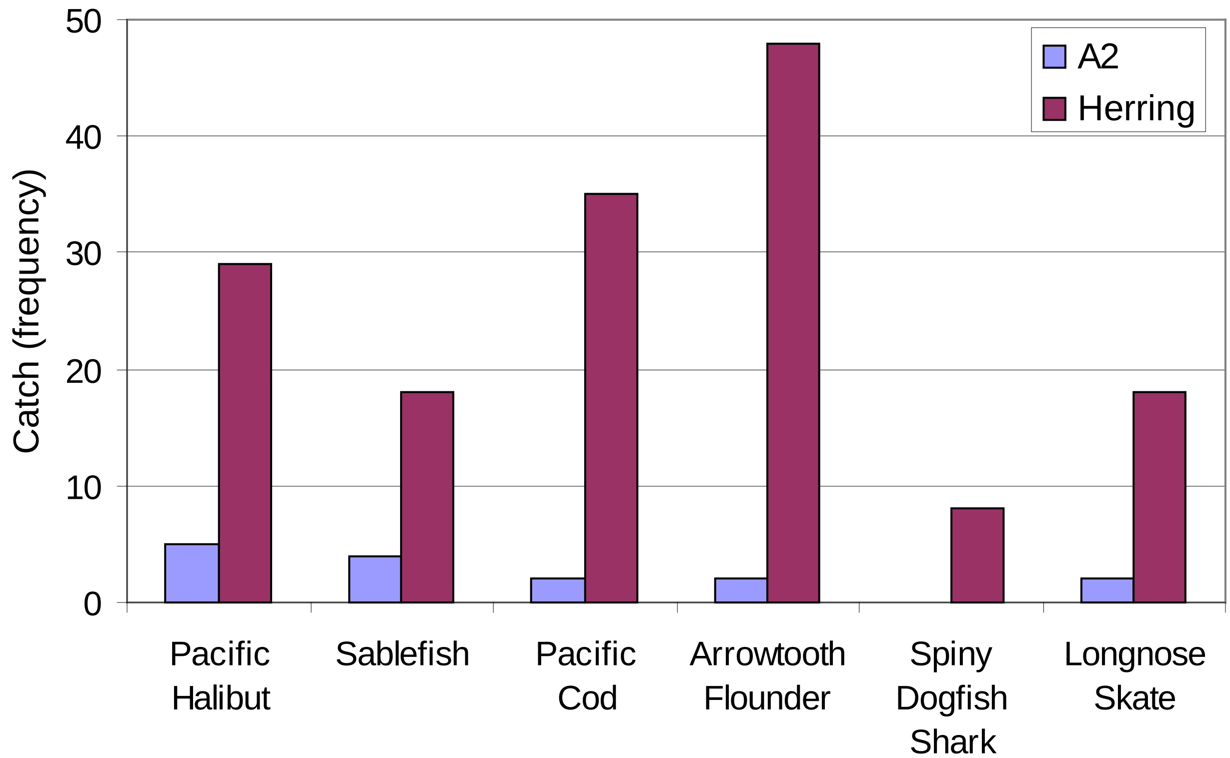


Figure 3. Longline catch for six species using herring and fabricated-bait A1. Comparisons were paired on the same longline sets; the number of hooks baited with herring and fabricated bait is equal. See Table 1 for sample sizes.

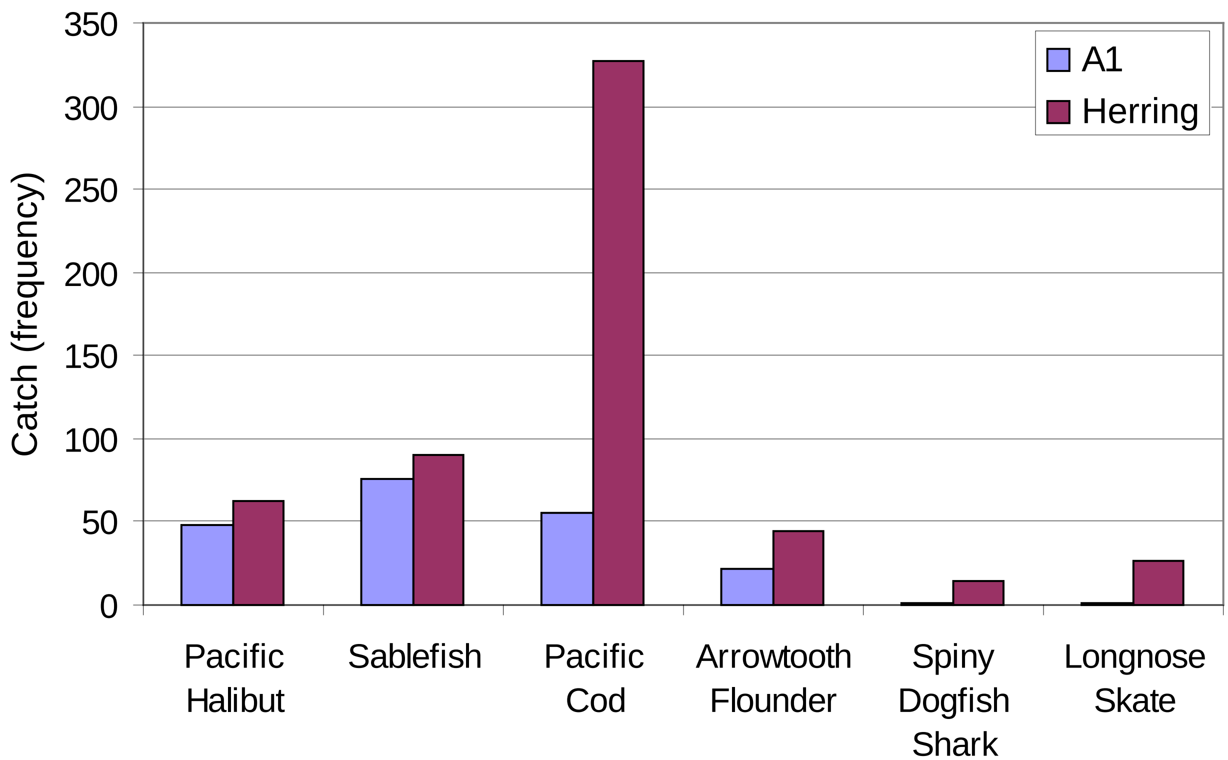
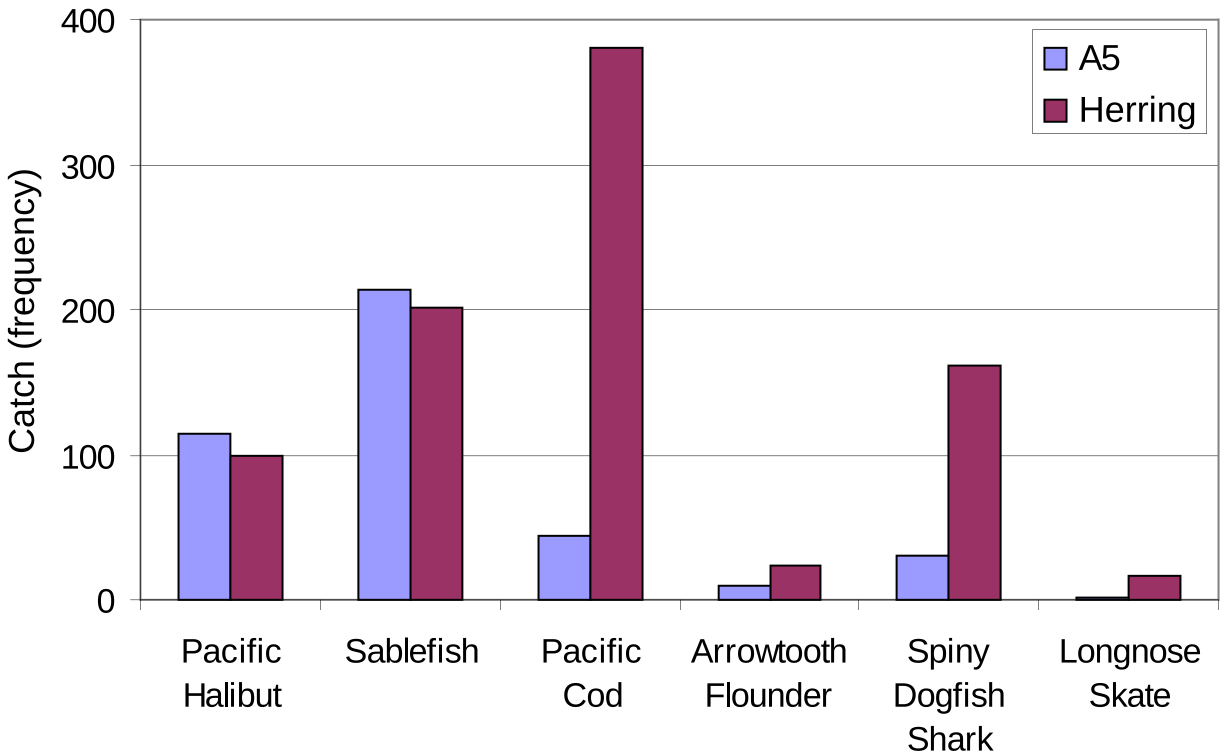


Figure 4. Longline catch for six species using herring and bait A5 or bait A6. Comparisons were paired on the same longline sets; the number of hooks baited with herring and fabricated bait is equal. See Table 1 for sample sizes.



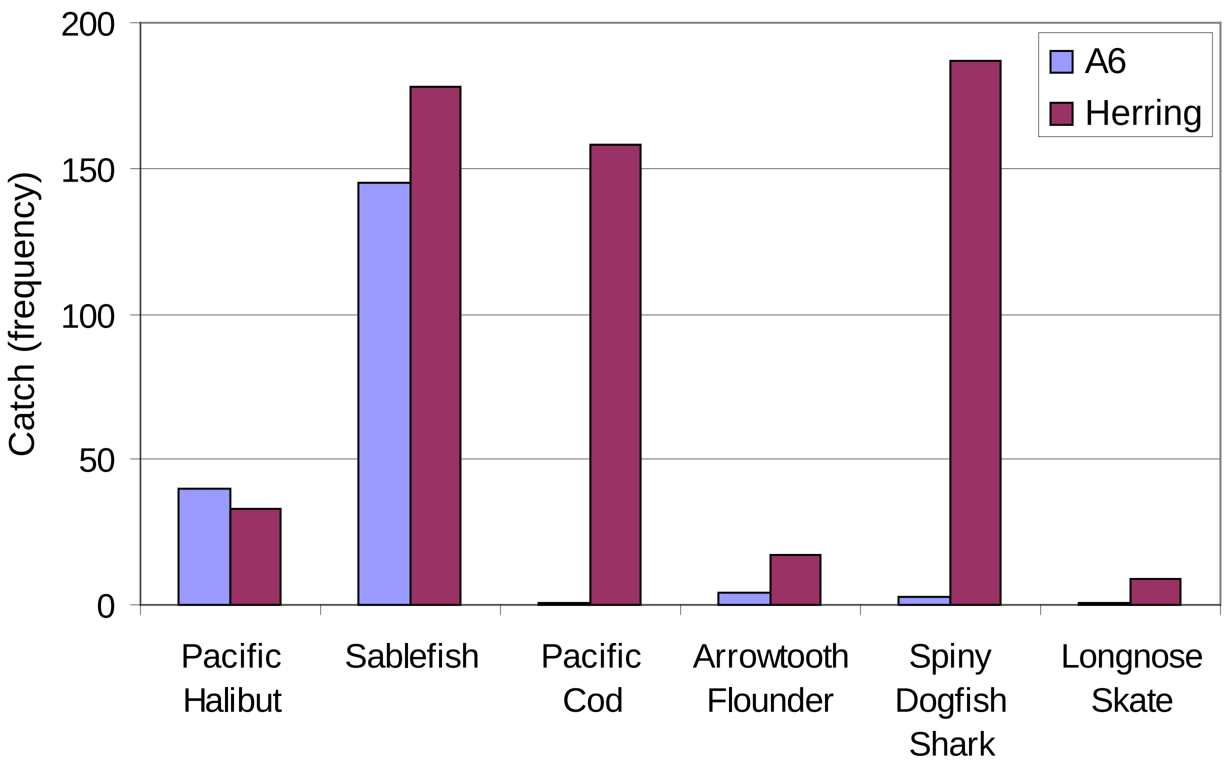
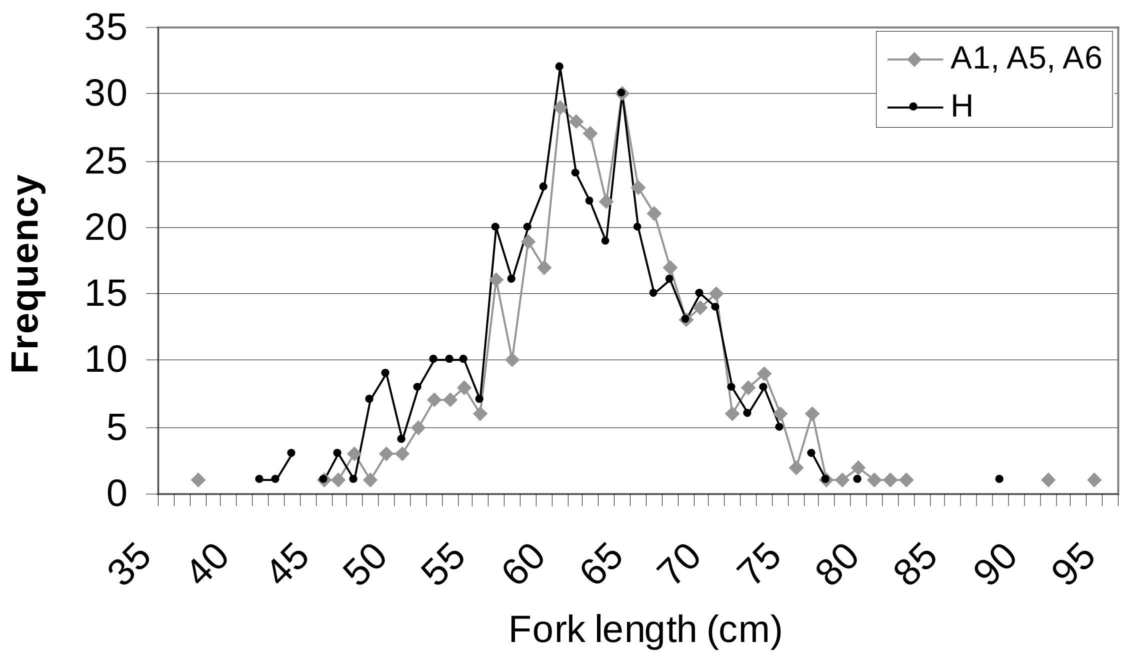


Figure 5. Length frequency distributions for (A) sablefish and (B) Pacific halibut caught using fabricated baits A1, A5, and A6 (combined) and herring (H). Length groups are 1 cm for sablefish and 10 cm for Pacific halibut (i.e., 45 = 40 to 49 cm, 55 = 50 - 59 cm, etc.)

A



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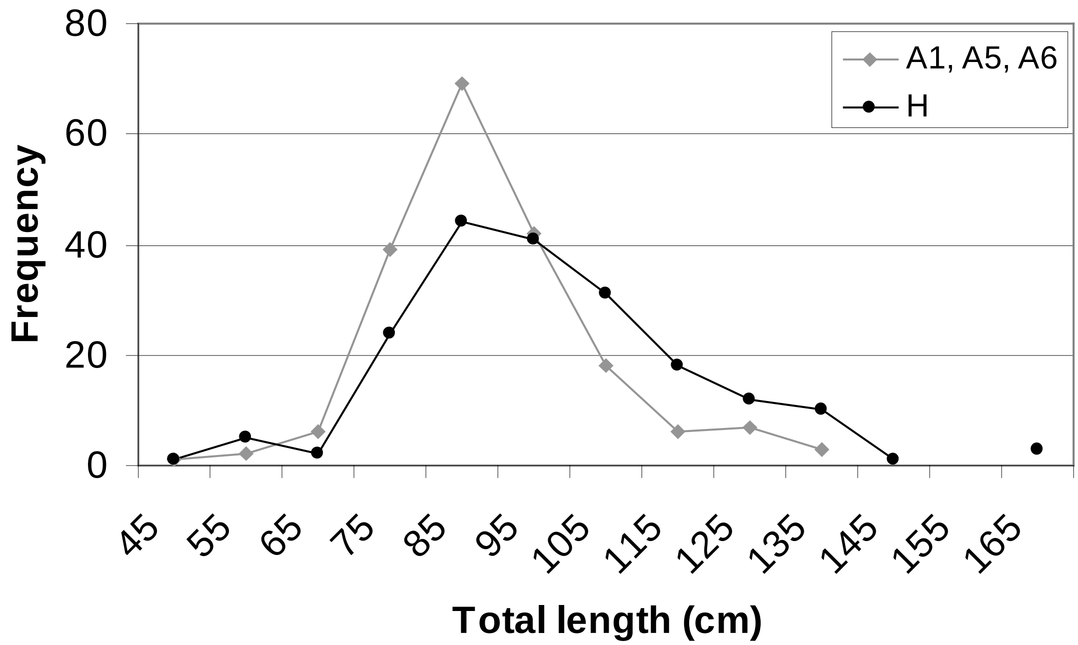
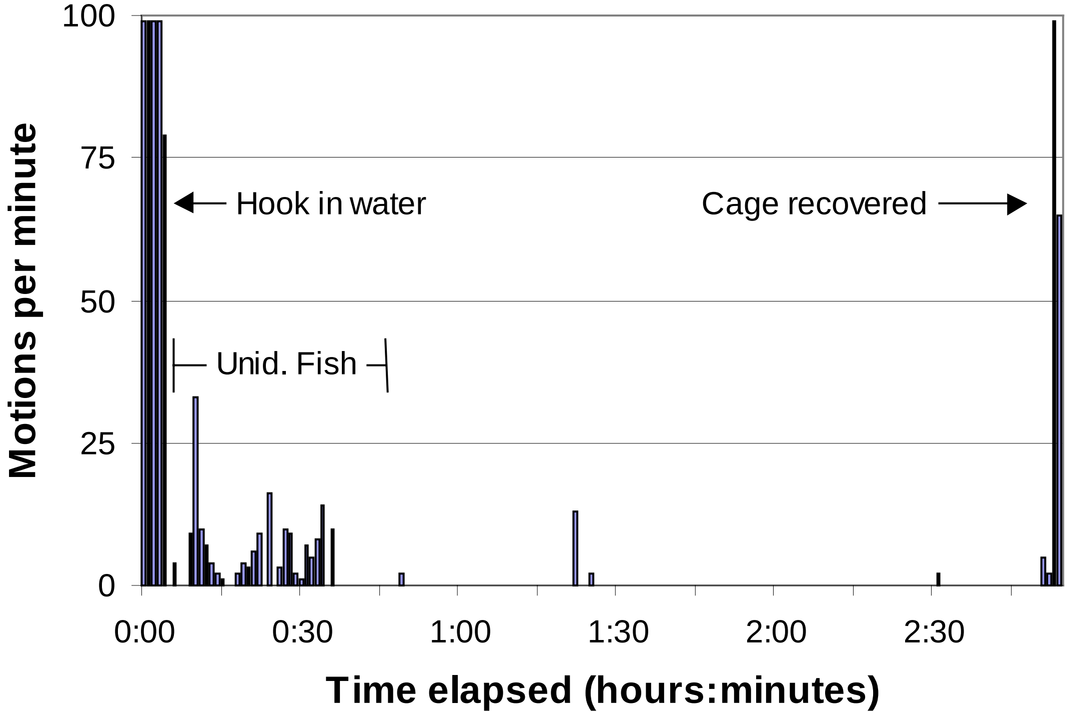


Figure 6. Hook-timer data taken on simulated-longline apparatus. Observations of fish activity were recorded by video. Two hooks were fished at the same time, one baited with herring and one baited with fabricated-bait A1. (A) Herring-baited hook - motion was caused by unidentified round fish (10 - 15 cm) rushing and biting at the bait, until all bait was stripped from the hook. (B) Hook baited with A1 - one halibut was briefly hooked, whereas unidentified roundfish (scavengers) seemed uninterested.

A



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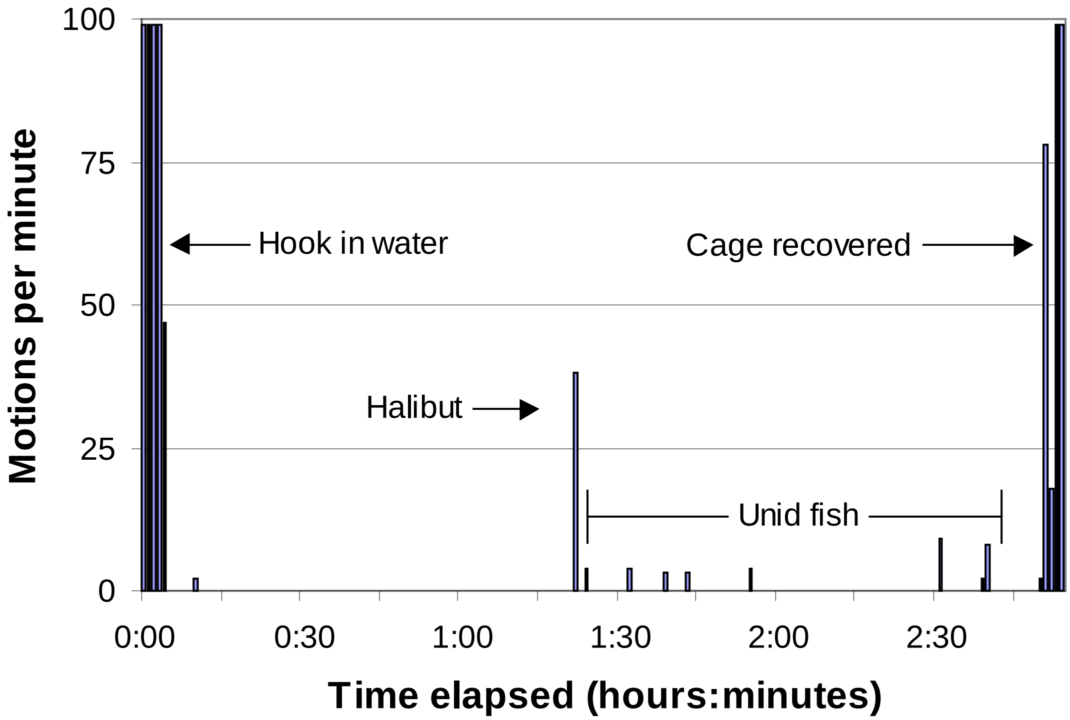

Figure 7. Actual longline set. Hook-timer movement (motions per minute) for a sablefish that was hooked and caught on herring.

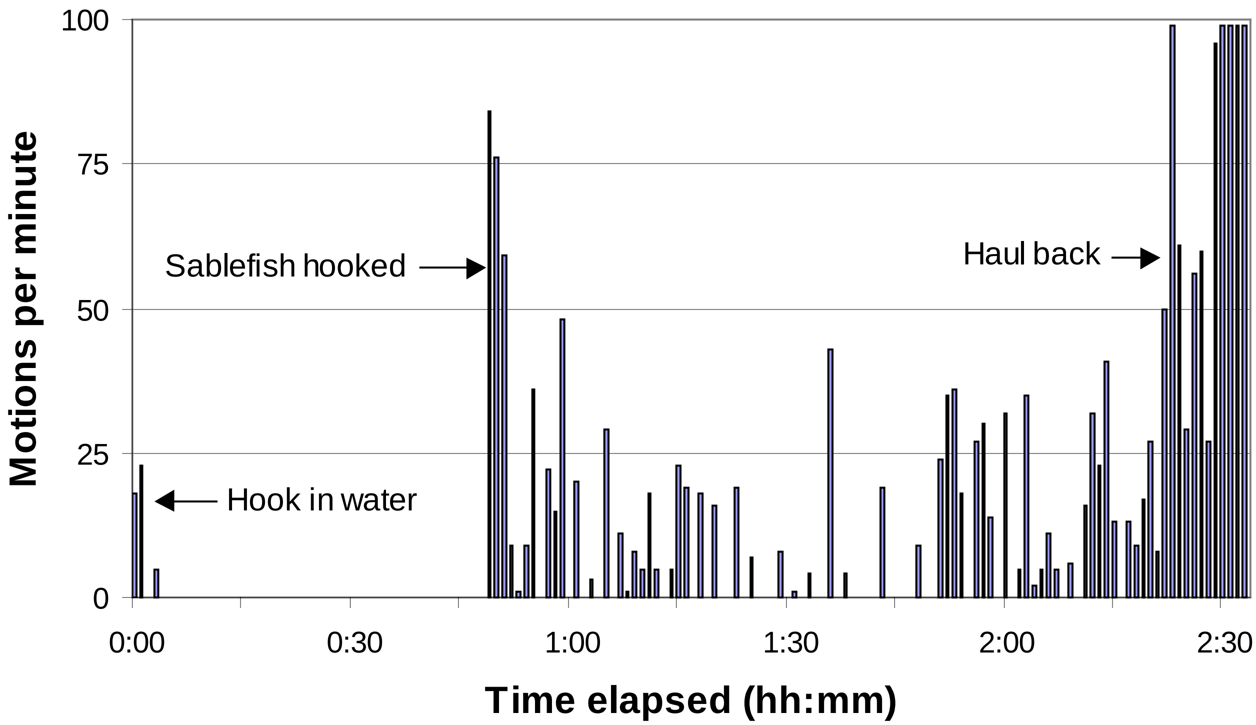

Figure 8. Actual longline set. Hook-timer movement (motions per minute) for a halibut that was hooked and caught on a longline hook baited with fabricated bait during actual fishing operations. This fish became hooked more than 3 hours after the bait entered the water.

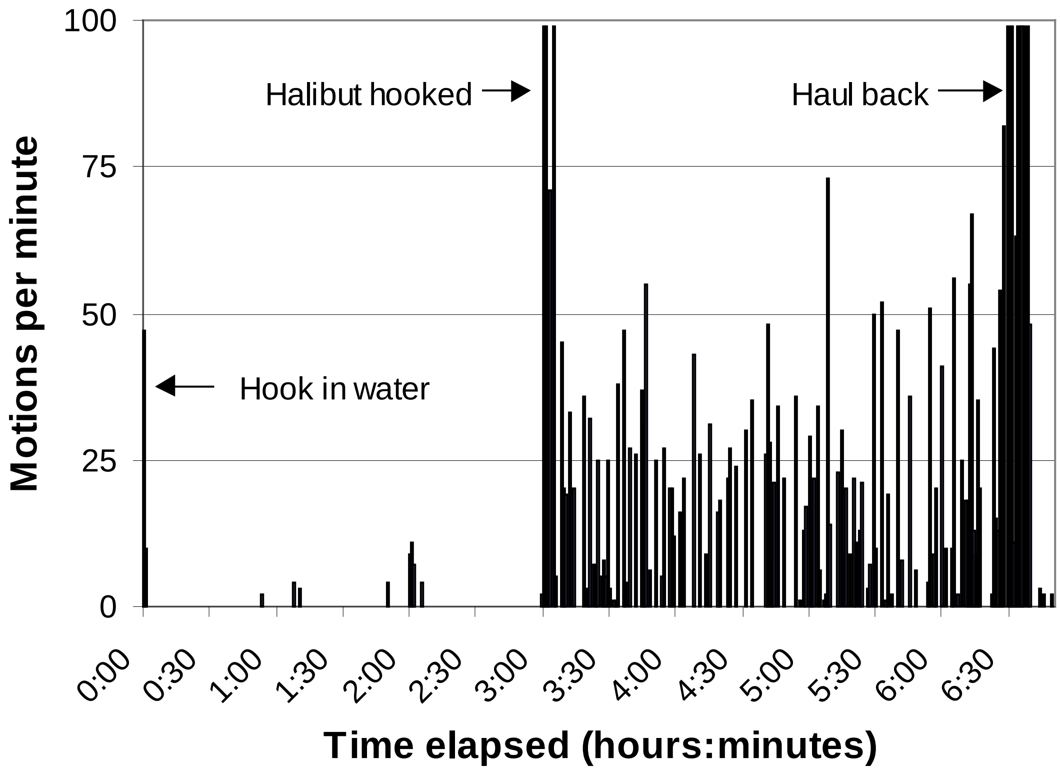

Figure 9. Actual longline set. Hook-timer movement (motions per minute) for a fish that was hooked, but subsequently escaped. Set = moment hook and bait entered the water.

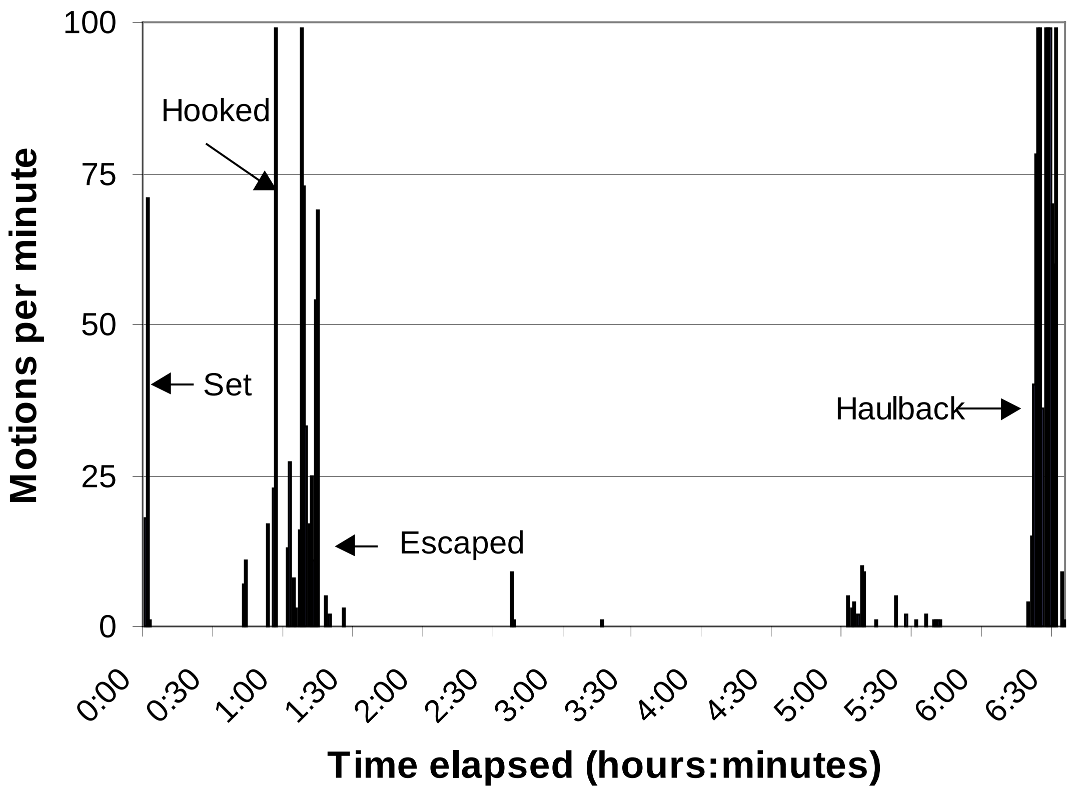

Figure 10. Actual longline sets. Distribution of hooking times (= first occurrence that hook timers detected 50 motions per minute) for Pacific halibut and sablefish caught using herring (gray) and fabricated bait (black) during the 1999 field season. Sample sizes were 14 and 32 for fabricated-bait and herring-caught fish, respectively. Longline-soaking duration ranged from 2.7 to 7.2 hours. **NOTE: 0.5 = ≤ 0.5 hours, 1 = > 0.5 hours and ≤ 1 hour, etc.**

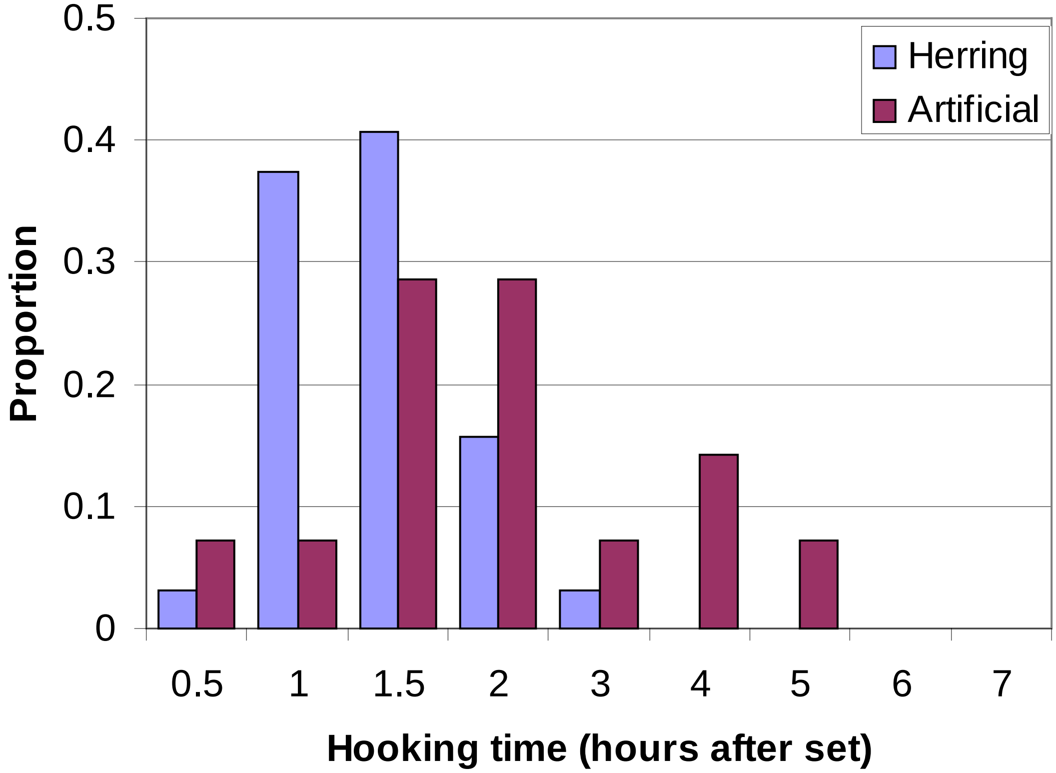

Figure 11. Catch ratio (A_i / H_i) versus soak duration (hours), where A_i = number of halibut and sablefish caught using fabricated bait for set *i*, and H_i = number of halibut and sablefish caught using herring for set *i*. Catch for A1, A5, and A6 included. Soak duration represents the amount of time bait was in the water.

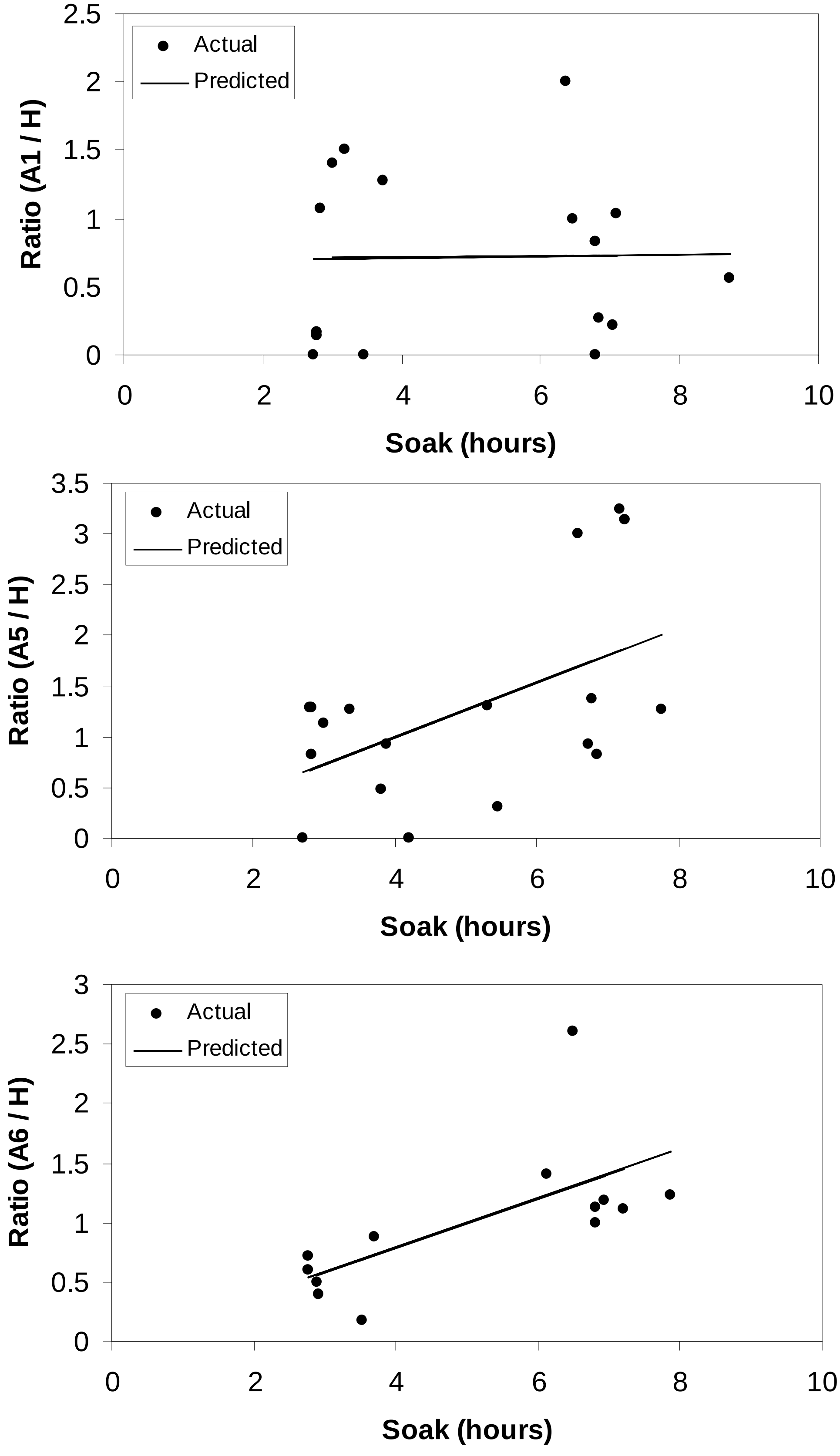

Figure 12. Time (hours) for the center of the longline to reach the bottom during setting (descent or sinking time). The regression equation is y = -0.0547 + 0.0027(x), where y is hours and x meters.