Effect of hook competition on survey CPUE

William G. Clark

Abstract

The catch of halibut at setline survey stations is reduced by other species that take the bait. Hook competition is highest in Area 2A and lowest in Areas 4B and 4D. Despite some differences in catch composition, overall hook competition varies little among Areas 2B, 2C, 3A, 3B, and 4A.

Background

In the 2006 assessment (Clark and Hare 2007) the staff estimated coastwide abundance by fitting the standard assessment model to a coastwide data set, and then estimated exploitable biomass in each regulatory area by apportioning the total in proportion to an estimate of stock distribution derived from the setline survey. Specifically, an index of abundance in each area was calculated by multiplying setline CPUE (running 3-year average) by total bottom area between 0 and 300 fm. The logic of this index is that survey CPUE can be regarded as an index of density, so multiplying it by bottom area gives a quantity proportional to total abundance. The estimated proportion in each area is then the index value for that area divided by the sum of the index values.

This procedure assumes that survey catchability (the constant of proportionality between CPUE and the density of halibut on the bottom) is the same in all areas. But the CPUE of halibut is reduced by the number of baits taken by other species, and if the strength of this effect varies among areas the result would be differences in survey catchability among areas. In particular, it has long been suspected that the large number of dogfish caught in Area 2B depressed survey CPUE of halibut there, and almost certainly it does. Similarly, the large number of cod caught in Area 4 can be presumed to lower the CPUE of halibut there.

This paper reports estimates of the effect of hook competition on the survey CPUE of halibut in each regulatory area. It turns out that the effect is very similar in all regulatory areas except 2A and 4B, so the simple procedure used in the 2006 assessment was sound for the most part.

Mathematical treatment of hook competition

The sequence of events that occurs when a baited longline is set and various species go after the bait has been studied theoretically and experimentally for decades (Sigler 2000 and references therein). Mathematically the process of baits being removed from a longline by different species is the same as the process of fish being removed from a population by different fisheries and natural predators. We can represent each kind of bait taker as removing a certain proportion of the baits per unit time, so that the number of baits B_i taken by a given species i during a soak time T is given by the familiar catch equation:

$$B_i = F_i \cdot B_0 \cdot \left(1 - \exp\left(-Z \cdot T\right)\right) \Big/ Z$$

where F_i is the instantaneous rate of bait removal by species *i*, B_0 is the initial number of baited hooks, and $Z = \sum_j F_j$ is the sum of the instantaneous rates applied by all bait takers. This formulation has been found to describe quite well the actual sequence of catches during the first few hours of soaking in experiments where the time of each capture was recorded by a hook timer (Sigler 2000; Somerton and Kikkawa 1994). After the first few hours the rates of bait removal by all takers drops off, either because the remaining bait has lost its scent or because the bait takers in the vicinity of the gear have been depleted. This has also been observed for halibut in unpublished hook timer experiments conducted by IPHC (Steven Kaimmer, IPHC, pers. comm.). Beyond a certain point, therefore, soak time does not matter.

In the IPHC setline survey every string soaks for at least five hours, and there is no significant difference in CPUE between shorter and longer soaks in any area. (Set time is also insignificant.) Soak time can therefore be regarded as effectively the same for all survey sets, and the term *T* can be left out of the bait removal equation.

The instantaneous rate of bait removal by halibut can be taken to be proportional to the local density of halibut, and depending on size and gear selectivity some proportion of halibut that take a bait will also be hooked and caught, so the catch per skate of halibut C_h will be proportional to the density of halibut D_h multiplied by the last term in the bait removal equation:

$$C_h = k \cdot B_h = k \cdot F_h \cdot B_0 \cdot \left(1 - \exp\left(-Z\right)\right) \big/ Z = k' \cdot D_h \cdot B_0 \cdot \left(1 - \exp\left(-Z\right)\right) \big/ Z$$

where *k* and k' are constants of proportionality. In this equation, $\left(1 - \exp\left(-Z\right)\right)$ is the fraction of baits removed by all takers during the active period, and $\left(1 - \exp\left(-Z\right)\right) \big/ Z$ is the average number of baits remaining over the course of the active period as a proportion of the initial number. If this term is the same in all areas, then survey CPUE is a consistent index of density across areas. Otherwise survey CPUE does not index density consistently across areas. Equivalently, if the fraction of baits taken is the same in all areas, then survey CPUE is a consistent index of density.

It is interesting to note that the effect of hook competition on the comparability of survey CPUE is wholly determined by the total bait removal rate *Z*. The species composition of the bait takers makes no difference. If 80% of the baits are taken in both Area X and Area Y (meaning that *Z* is the same), and the catch in Area X is all halibut and the catch in Area Y is half halibut and half dogfish, the survey CPUE’s of halibut in the two areas will accurately reflect the relative densities of halibut.

Comparison of bait removal rates among areas

Figure 1 shows raw hook count data from the setline survey by area. In most areas 10-20% of the bait is recovered. The exceptions are Area 2A, where only 7% is recovered, and Area 4B, where a third of the bait is recovered. That is also true of stations on the Bering Sea edge in Areas 4A and 4D, but the overall rates for Area 4A and 4CDE are in the usual range. The recovery rate for all areas combined is 14%, which is a little low because in recent years all hooks have been counted in Area 2B while only 20% have been counted elsewhere, and the Area 2B recovery rate is 12%.

Table 1 shows the bait removal rates calculated from the raw data in Figure 1. Halibut are minor players in all areas except 2C, 3A, and 3B. The "Other" category, dominated by whatever species send back empty hooks or skins, are the major players in all areas. The last column is the ratio of the coastwide to the area-specific value of $\left(1-\exp\left(-Z\right)\right)/Z$. It is the multiplier that should be applied to each area's survey CPUE to make all of them consistent.

Variances of the correction factors were calculated by the jackknife method, leaving out one year at a time, on the grounds that year-to-year changes are the major sources of variance in survey data. The standard deviations of the correction factors were 0.05 for Area 2A, 0.02 for Areas 2B, 2C, 3A, and 3B, and 0.01 for Areas 4A, 4B, and 4CDE. So as a statistical matter they are almost all significantly different from one, but in most cases there is very little practical difference.

Discussion

While the standard catch equation performs reasonably well in predicting the timing of catches during the first few hours of soaking, it is not perfect. The rate at which baits are taken has been found to vary over time in different ways for different gears and target species, and Sigler (2000) reports substantial variation among stations. The estimate of the average number of baited hooks fishing during the active period is based on the observed proportion of bait recovered and an assumed rate of decline based on the catch equation. It is at therefore an approximation, and small differences among areas in the estimate are not reliable even though they may be statistically significant.

Hook competition is not the only possible cause of differences among areas in setline survey catchability. Differences in temperature may affect survey catchability directly or indirectly (Stoner et al. 2006). The availability of natural prey may also affect the desirability of the bait (Stoner 2004). Factors such as these are almost surely responsible for the substantial year-to-year variability of survey CPUE and may also cause some consistent differences among areas.

References

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Table 1. Bait recovery fractions, total instantaneous bait removal rates *Z*, and various species-specific removal rates F_i, by area. The last column shows the multiplier that should be applied to each area's survey CPUE to make survey CPUE a consistent index of density across areas. Except as noted below, all data from 2001-2006 were used. The "Other" category in this table includes emtpy hooks and skins.

				Instantaneous rates by species					
Area	**Stations**	**Fraction recovered**	***Z***	**Halibut**	**Cod**	**Dogfish**	**Sablefish**	**Other**	**Correction factor**
2A	504	0.07	2.66	0.06	0.00	0.09	0.21	2.30	1.25
2B	1014	0.12	2.16	0.14	0.00	0.27	0.09	1.65	1.07
2C	653	0.15	1.89	0.28	0.01	0.08	0.12	1.40	0.97
3A	2222	0.10	2.30	0.47	0.07	0.38	0.10	1.29	1.12
3B	1328	0.15	1.92	0.55	0.18	0.01	0.07	1.12	0.98
4A	664	0.18	1.70	0.23	0.24	0.00	0.03	1.20	0.91
4B	528	0.34	1.09	0.08	0.10	0.00	0.01	0.90	0.72
4D	336	0.34	1.07	0.10	0.20	0.00	0.00	0.77	0.71
4CDE*	204	0.18	1.74	0.06	0.29	0.00	0.00	1.39	0.92
EBS*	82	0.13	2.03	0.04	0.29	0.00	0.00	1.69	1.02
All	7313	0.14	1.97	0.25	0.07	0.18	0.08	1.38	1.00

* The Area 4CDE data are all stations fished in the eastern Bering Sea in 2006, including the shelf stations, island stations, 4D edge, and 4A edge. The "EBS" data are just the eastern Bering Sea shelf stations fished in 2006.

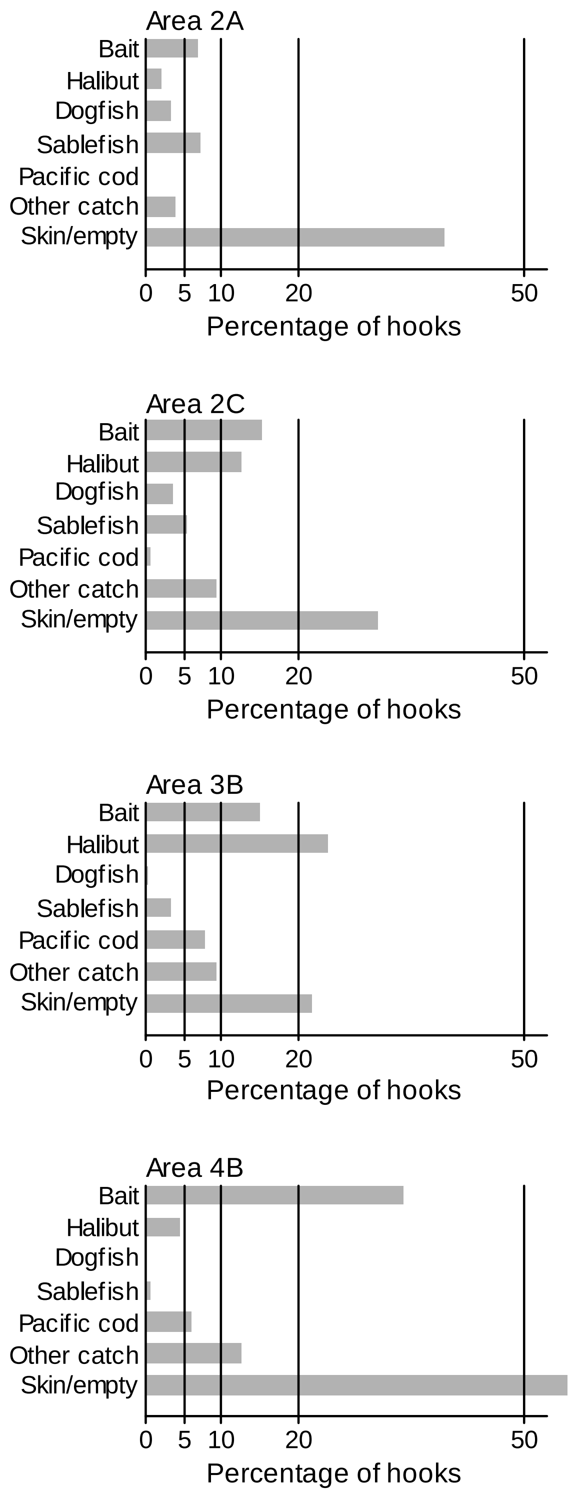

Figure 1. Survey hook contents by area, 2001-2006 data combined.