Estimates of commercial longline selectivity for Pacific halibut (*Hippoglossus stenolepis*) from multiple marking experiments

William G. Clark

Stephen M. Kaimmer

International Pacific Halibut Commission
250 Ocean Teaching Building
University of Washington
Seattle, Washington 98145
E-mail address (for W. G. Clark): bill@iphc.washington.edu

The term "selectivity" refers to the relationship between the size (or age) of a fish and its vulnerability to a given kind of fishing gear. A selectivity schedule, along with other parameters, is normally estimated in the course of fitting a stock assessment model, and the estimated schedule can have a large effect on both the estimate of present stock abundance and the choice of an appropriate harvest rate. The form of the relationship is usually not known and not well determined by the data, and equally good model fits can often be obtained with different plausible specifications of selectivity. Choosing among the model fits and associated abundance estimates in this situation is problematic (Sigler, 1999; Sullivan et al., 1999).

The selectivities of different gears can be compared by fishing the gears side by side, but without knowing the size composition of the stock being fished, it is impossible to determine the form of the selectivity functions. Therefore, one has to make some assumptions about them in order to locate estimates (Millar and Fryer, 1999, and references therein). In this case, too, equally good fits can often be obtained with a variety of assumed forms (Huse et al., 2000; Woll et al., 2001); therefore the true form cannot be determined by simple fishing experiments.

Mark-recapture data can yield direct and reliable estimates of selectivity because in this situation the size composition of the fished stock is known (Myers and Hoenig, 1997). In this note, we report estimates of the commercial longline selectivity of Pacific halibut (*Hippoglossus stenolepis*) based on the large number of mark-recapture experiments conducted by the International Pacific Halibut Commission (IPHC) in the 1960s, 1970s, and 1980s. A similar analysis was done by Myhre (1969), but he used data from only two experiments; the present study uses data from more than 100 experiments.

Materials and methods

Kaimmer (2000) described all IPHC tag data for all varieties of external tags in setline and trawl catches dating back to 1925. We also used tag data for all varieties of tags (except the small strap type); however, our data were for tags released during setline catches only and our data dated back to 1960, the first year of recorded data in the computer release and recovery IPHC database. The total number of tags released was over 100,000, of which more than 13,000 were recovered in the commercial longline fishery. About half of the releases were at systematically placed setline survey stations that covered a large part of an IPHC regulatory area (Fig. 1). The other half were at "spot" fishing locations, deliberately chosen to produce good catches, either for marking or for gathering data on the performance of different gear types. For our study, an experiment was defined as all releases of a given tag type in a given regulatory area in a given year during either survey or spot fishing operations (not both), where at least 10 fish were released. Between 1960 and 1990 there were 131 such experiments.

These data are not usable for estimating exploitation rates or migration rates because of uncertainty concerning things like recovery effort and reporting rates, but they can be used to estimate commercial selectivity. In the case of a single experiment, a straightforward plot of short-term recovery rate by length at release will show how selectivity changes with length. The absolute recovery rates will depend on usually unknown factors (tagging, fishing, and natural mortality rates; tag loss and reporting rates), but the relative recovery rates should depend mainly on selectivity (barring large variations in length with any of the unknown factors).

Myers and Hoenig (1997) showed how data from many experiments can be combined to obtain a single set of selectivity estimates. To summarize their derivation, let $\pi_{i,l}$ be the recovery rate of fish of length l in experiment i. This rate is treated as the product of a length-specific commercial selectivity s_l, which is the same for all experiments, and an experiment-specific recovery rate r_i that combines all the unknown factors mentioned above. Thus $\pi_{i,l}=r_i \cdot s_l$ and $\log\pi_{i,l}=\log r_i+\log s_l$. This has the form of a generalized linear model with a log link function and a binomial variance; therefore the point and variance estimates can be obtained in standard fashion.

Some rule has to be chosen for scaling the selectivities to make the model determinate. The most common rule is to require that the maximum selectivity be 1.0, but that can involve using a scaling factor that is poorly determined by the data if the maximum occurs in a length group with few releases and recoveries. To avoid this problem, the rule used in

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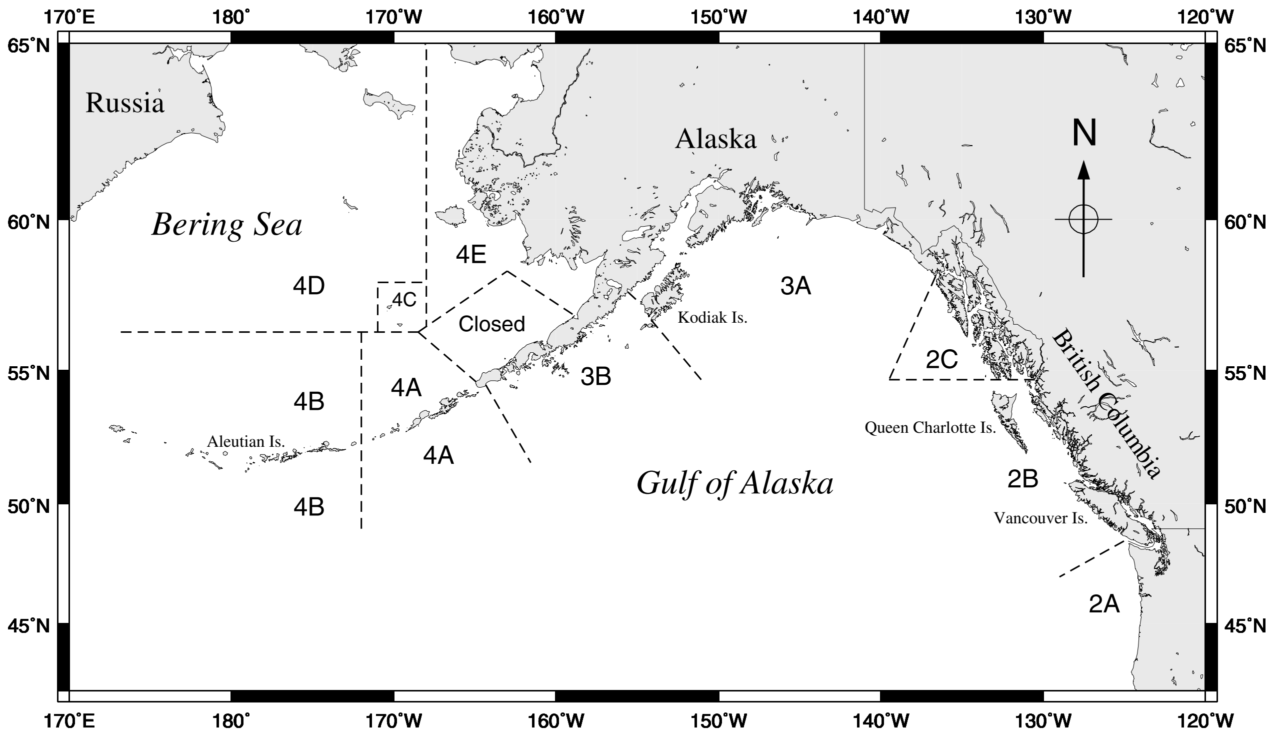

Figure 1

International Pacific Halibut Commission regulatory areas. The area marked "closed" is permanently closed to directed halibut fishing.

our study was to define selectivity to be 1.0 at 120 cm. Estimated selectivity could therefore exceed 1.0 at other lengths.

Results

Figure 2 shows the estimates of commercial length-specific selectivity in areas 2B, 2C, 3A, and 3B obtained by the method of Myers and Hoenig (1997) with the use of all available data in each area. There were insufficient data in area 4 to calculate useful estimates. The estimates in Figure 2 were calculated by using all recoveries from each release during the first two years at liberty, including recoveries from outside the release area and recoveries from unknown locations. Estimates computed by using only recoveries from the area of release were no different from those obtained by using all of the recoveries.

In all areas, commercial selectivity in the period of 1960–90 appears to increase with length up to a maximum and then decline. In area 2B, the peak occurs at about 110 cm and there is a substantial decline thereafter, to around half the peak value. In Alaska (areas 2C, 3A, 3B), selectivity peaks at a much larger size (about 150 cm). Thereafter the decline is about as steep as in area 2B, but not as large because so little of the length composition remains beyond 150 cm.

Recoveries from releases at spot fishing locations show a selectivity pattern similar to that for the entire dataset. The same is true of survey releases, except in area 2B where the selectivity pattern does not show a decline among larger fish. But this impression depends on a small number of recoveries, and therefore it may be false.

Discussion

In previous modeling of length-specific selectivity, the IPHC staff generally assumed some kind of asymptotic function, with full selection occurring at 110–130 cm. A function of this form is consistent with video observations of halibut behavior when they are hooked (Kaimmer, 1999), and it produces satisfactory fits to the observed length compositions of survey and commercial setline catches in the annual stock assessment. It is also consistent with the conventional view that hook selectivity varies little with size among fish large enough to take the bait (Lokkeborg and Bjordal, 1992). But the large body of mark-recapture data shows a different pattern: selectivity declining after the peak at 110 cm in area 2B, and not reaching a peak until 150 cm or so in Alaska. These patterns are, in fact, quite similar to those reported by Myhre (1969).

Commercial fishing selectivity reflects ground selection by the fleet, as well as size selection by the gear. It is therefore possible that the selectivity of commercial setline gear on a given ground has the expected asymptotic form, but ground selection has the effect of targeting certain size groups and thereby producing a different selectivity schedule. In area 2B, for example, the best catch rates may be achieved by targeting smaller fish; whereas in Alaska it may be more profitable to target larger fish.

If the decline in selectivity in area 2B were the result of the commercial fishery targeting areas where the fish are smaller, one would expect to see the decline in data from survey releases (which are done over the whole area), but not in data from releases at spot fishing locations (most of which are customary commercial fishing locations). However, the mark-recapture data show the opposite pattern, if anything; therefore ground selection does not appear to be the explanation.

When length-specific selectivity is allowed to be dome-shaped in the stock assessment model (rather than forced to be asymptotic), the estimated commercial selectivities turn out to be quite similar in pattern to the mark-recapture estimates, including the differences among areas. But the selectivities estimated for the IPHC systematic setline survey are asymptotic or ramp-shaped, rather than dome-shaped. They indicate that ground selection by the commercial fishery really does have an effect on the form of commercial selectivity, contrary to what the mark-recapture data may indicate.

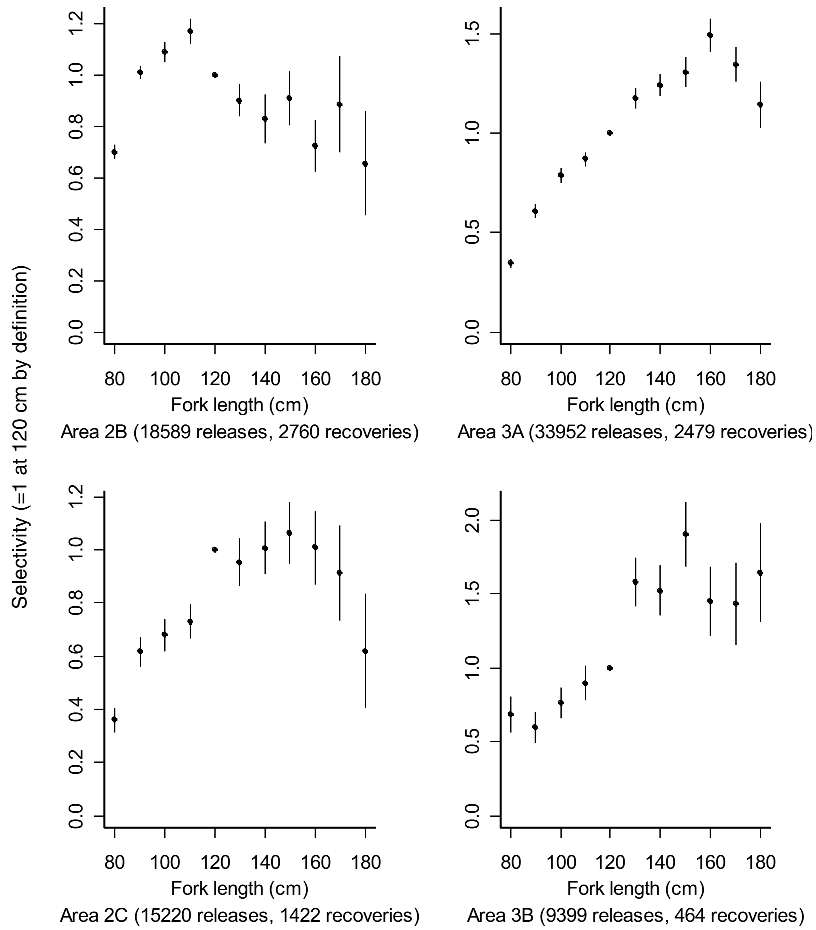

Figure 2

Estimates of length-specific commercial selectivity (±1 standard deviation) for Pacific halibut (*Hippoglossus stenolepis*) based on all releases 1960–90, by regulatory area. The scale was set by defining selectivity to be 1.0 at 120 cm, so that value has no standard deviation, and other values can and do exceed 1.0.

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