Effects of gear type, hook spacing, and hook size on commercial selectivity and catchability

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Abstract

Analysis of commercial length composition and CPUE data from 2000-2004 shows only small differences in commercial selectivity associated with gear differences. Gear type (fixed or snap) and hook spacing have a large effect on commercial CPUE; hook size does not. Re-estimation of the relationship between hook spacing and CPUE yields a formula close to the one that has been in use for many years.

Background

A variety of longline gear is used in the halibut fishery. The important features that differ are gear type (how the gear is set and retrieved), hook spacing, and hook size.

Gear type

All longline gear consists of a stout groundline with hooks attached on short (2-4 ft) gangions (leaders) at intervals of typically 3-25 ft. The gangions can be permanently attached to beckets on the groundline, in which case the gear is called “fixed hook” or “fixed” gear. This type of gear is usually baited, stored, and set in coils of 50-200 hooks each. (The coils are tied end to end during setting to make up a long string.) On smaller vessels the groundline is often stored on a large drum, and the gangions are snapped onto the groundline with clips during setting and removed when the gear is hauled back. This is called “snap-on” or just “snap” gear. A few large vessels use a third type, the Mustad Autoline system, in which the gear is stored on racks and baited, set and replaced mechanically. The hooks are fixed, but the operation is quite different from manual baiting, setting and hauling.

Manually set fixed gear was the original gear in the halibut fishery and still accounts for about half the hooks fished. Snap gear appeared in the 1950s and now accounts for about 40%, with the remaining 10% being autoline.

Hook spacing

The hooks can be attached to the groundline at smaller or larger intervals. This is important because the catch per hook is usually higher if the hooks are more widely spaced.

Hook size

All vessels use circle hooks but there is some variation in size. Nearly all the hooks used in halibut fishing are size 13, 14, 15, or 16, with size 13 being a smaller hook suitable for cod or sablefish and size 16 being a large halibut hook.

Common configurations

Sablefish gear is usually size 13 or 14 hooks fixed to the groundline at 3-4 ft intervals; likewise cod gear (including autoline). Many operators use these gears in directed halibut fishing because they participate in both fisheries. Halibut gear is usually size 15 or 16 hooks spaced at

longer intervals, 10-20 ft. As a practical matter it is not even possible to achieve a short spacing when setting snap gear, so snap gear is mainly larger hooks at larger spacings. Because of the prevalence of these common configurations, there is a correlation between hook spacing and hook size, with smaller hooks used at the smaller spacings (Fig. 1).

Treatment of gear differences in the halibut assessment

The Commission did an experimental study of the effect of hook spacing on catch rates in the 1970s (Hamley and Skud 1978), when the fishery used J-hooks instead of the present circle hooks. They found that the catch rate at a spacing of H ft was $1.52 \cdot (1 - \exp(-0.06 \cdot H))$ times the catch rate at a spacing of 18 ft. This relationship has been used to standardize both commercial and survey effort to the equivalent 18 ft effort ever since.

In an attempt to maintain a consistent value of commercial CPUE, the staff uses only conventional fixed hook effort with a hook spacing greater than 4 ft to calculate the commercial CPUE used in the assessment. Snap gear effort is not used because snap CPUE is generally lower than fixed hook CPUE in the commercial fishery, even though the two gears have the same catch rates when fished side by side in experiments (Myhre and Quinn 1984). (In Area 2B snap gear effort is used with an ad hoc correction.) Autoline gear is excluded, and the minimum 4 ft spacing excludes sablefish gear.

Meanwhile the age and length compositions of the commercial catch are estimated from all landings caught with all gears. These age compositions determine the model estimate of the commercial selectivity schedule, which is then used to predict the commercial CPUE, which refers to only a subset of fixed hook catches. So if the selectivity of the fixed hook gear used to calculate CPUE is different from that of the fishery as a whole, there is an inconsistency between the commercial CPUE and catch at age data.

The effect of hook size has never been considered in the assessment. It is not an issue for the survey, which always uses a size 16 hook, but it may be in the commercial fishery.

For purposes of the assessment, the important gear issues at present are the size of any differences in selectivity among gear types, the accuracy of the longstanding hook spacing adjustment, and the effect of hook size on catchability. These issues can be investigated by analyzing the commercial data because we are interested in commercial fishery selectivity and catchability. They can be quite different from what is observed in experiments because the fishery values are affected not just by the properties of the gear but also by how, when, and where the gear is fished.

Selectivity comparisons

Differences in selectivity between gears will appear as differences in the length frequencies of the respective catches. Figure 2a shows commercial length frequencies by regulatory area and hook spacing for the 2000-2004 commercial samples, numbering some 87,000 fish. Each plotted length frequency represents at least 300 fish. There are some differences among spacings: more small fish are caught at the smallest spacing and fewer at the largest, but overall the length frequencies are quite similar and none is very different from the pooled length frequency in an area. The greatest differences appear in Area 4B and are most likely the result of the small number of samples from there (only about 100 from Area 4B compared with 300 from Areas 3B and 4A, and 800-1100 from Areas 2B, 2C, and 3A).

Figure 2b shows the same comparisons by hook size and again the differences are small, again except in Area 4B. Figure 2c compares gear types. Autoline gear catches more small fish

than fixed or snap gear, but there is little difference between fixed and snap gear, and the fixed gear length frequencies are very close to the pooled length frequencies. The picture changes somewhat if catches taken with hook spacing of 4 ft or less are excluded from the fixed hook length frequencies, as is done when calculating commercial CPUE (Fig. 2d). In this case the fixed hook length frequencies are still quite similar to the pooled length frequencies, but the correspondence is noticeably not as good in Areas 3A, 4A, and 4B. This comparison argues for including all fixed hook data in the CPUE calculation.

Catchability comparisons

Figure 3 shows mean relative CPUE by gear type, hook spacing, and hook size for the 2000-2004 data tabulated in Figure 1, amounting to some 220 million hooks fished. The relative CPUE values were calculated by dividing each CPUE datum by the unweighted mean of fixed and snap CPUE at 10-20 ft hook spacing in the appropriate area (pooling over years and hook sizes). The figure shows the data for all areas; area-specific plots are similar in appearance but less orderly and with more missing points (due to sparse data in some categories).

The relationship between hook spacing and CPUE is about the same for fixed and snap gear, and the ratio of snap to fixed CPUE is also about the same at all hook spacings. For both gear types, CPUE at a given spacing tends to increase slightly with hook size, but not consistently. These patterns are well described by a simple linear model of log CPUE with a full set of area/year effects, one gear type effect, one set of hook spacing effects, and one set of hook size effects, both of the latter applying to both gear types. When this model is fitted to the data, it shows that, other things being equal, the difference in CPUE between the smallest and largest hook size is less than 15%, while the difference between the smallest and largest hook spacings is more than a factor of three. Overall snap CPUE is estimated to be 65% of fixed hook CPUE.

Because the effect of hook size is so small, it can be disregarded and a simpler model fitted to estimate just a gear type effect and a single set of hook spacing effects. Because of the correlation between hook spacing and hook size, this model will in fact capture most of the effect of the hook size differences. The empirical hook spacing effects estimated in this way are plotted in Figure 4, rescaled so as to equal one at a spacing of 18 ft like the Hamley and Skud (1978) formula. A straight line fits the points quite well, giving the simple formula that CPUE at a spacing of H ft is $0.3282 + 0.0382 \cdot H$ times CPUE at a spacing of 18 ft.

This formula is fairly close to the Hamley-Skud formula over the range where the latter has been applied. At a spacing of 5 ft, the new estimate is 0.5 instead of the old 0.4, and at 25 ft is 1.3 instead of 1.2. The use of the old formula in the assessment has therefore been appropriate.

Conclusions

The stock assessment has tacitly assumed: (i) that fixed hook gear with a spacing greater than 4 ft has the same selectivity as the commercial fishery as a whole; (ii) that the Hamley-Skud hook spacing formula can be applied to commercial fishery catchability, both J-hook and C-hook; and (iii) that hook size doesn't matter. The analysis above shows that these assumptions held approximately, but also that sablefish gear should be included in commercial CPUE and the hook spacing formula should be updated.

While the empirical estimates of hook spacing effects suggest a linear relationship with a positive intercept, the form of the Hamley-Skud correction makes more sense. The number of fish caught by a given length of longline gear must be determined by the density of fish. So long as the number of hooks is sufficient, the number of fish caught by a given length of gear will be

the number of fish in the vicinity willing and able to take a hook, regardless of the number of hooks available. If the length of the string is *L* and the number of catchable fish is *C* and the hook spacing is *H*, then the catch per hook will be $C/(L/H) = H \cdot C/L$. The catch per hook must go to zero as hook spacing goes to zero, as in the Hamley-Skud formula. At very large hook spacings the catch per hook must level off because it cannot exceed one. On both counts, it seems sensible to retain the Hamley-Skud correction.

References

Hamley, J.M., and Skud, B.E. 1978. Factors affecting longline catch and effort: II. Hook-spacing. Int. Pac. Halibut Comm. Sci. Rep. 64.

Myhre, R.J., and Quinn, T.J. 1984. Comparison of efficiency of snap gear to fixed-hook setline gear for catching Pacific halibut. Int. Pac. Halibut Comm. Sci. Rep. 69.

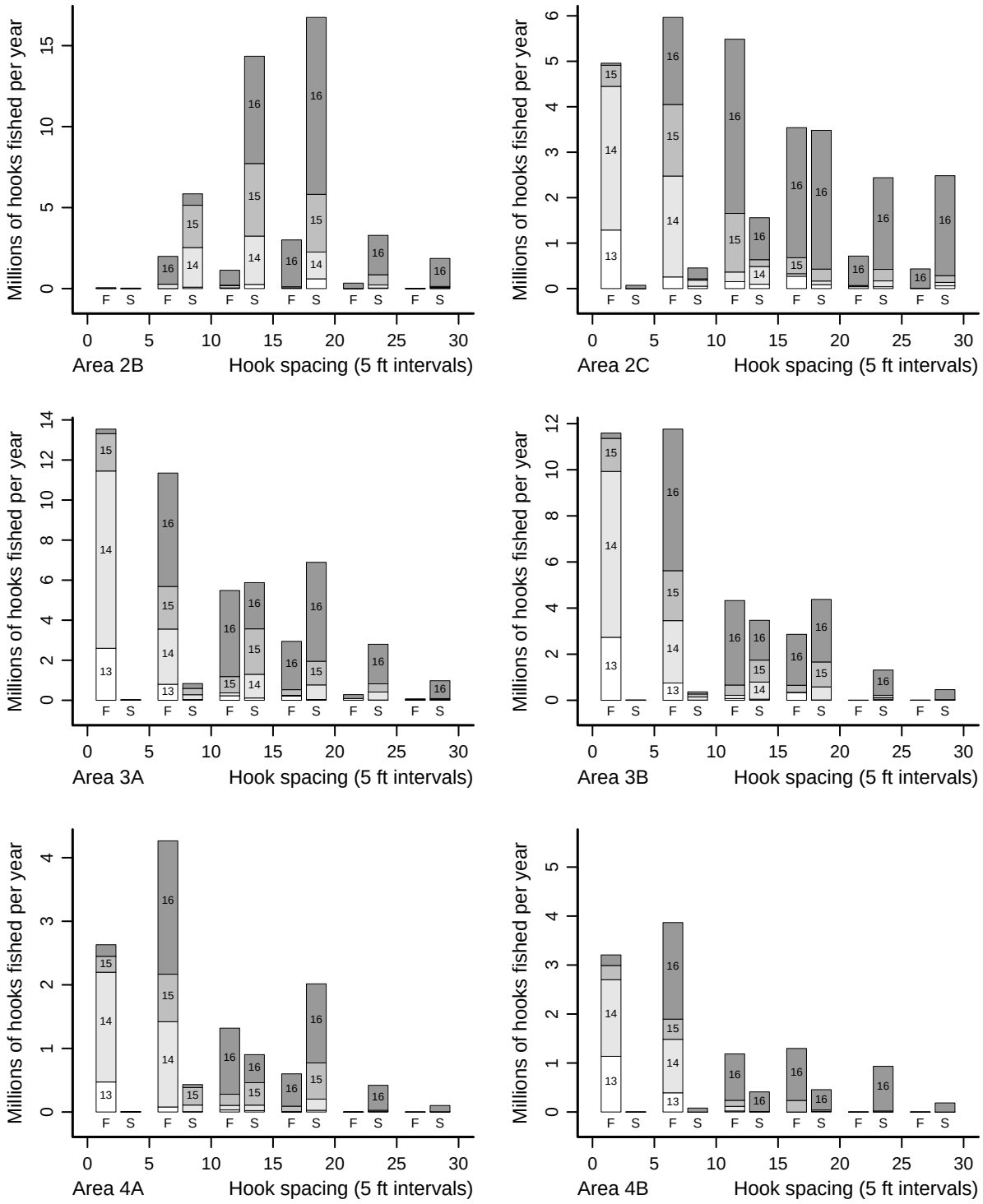

Figure 1. Breakdown of average annual fishing effort (2000-2004) by area, hook spacing, gear type (F = fixed, S = snap), and hook size (the numbers 13-16 in the bars). Autoline effort not shown; it amounts to about 10% of coastwide effort, almost all fished in Areas 3 and 4 with size 13 and 14 hooks at 3-4 ft spacing.

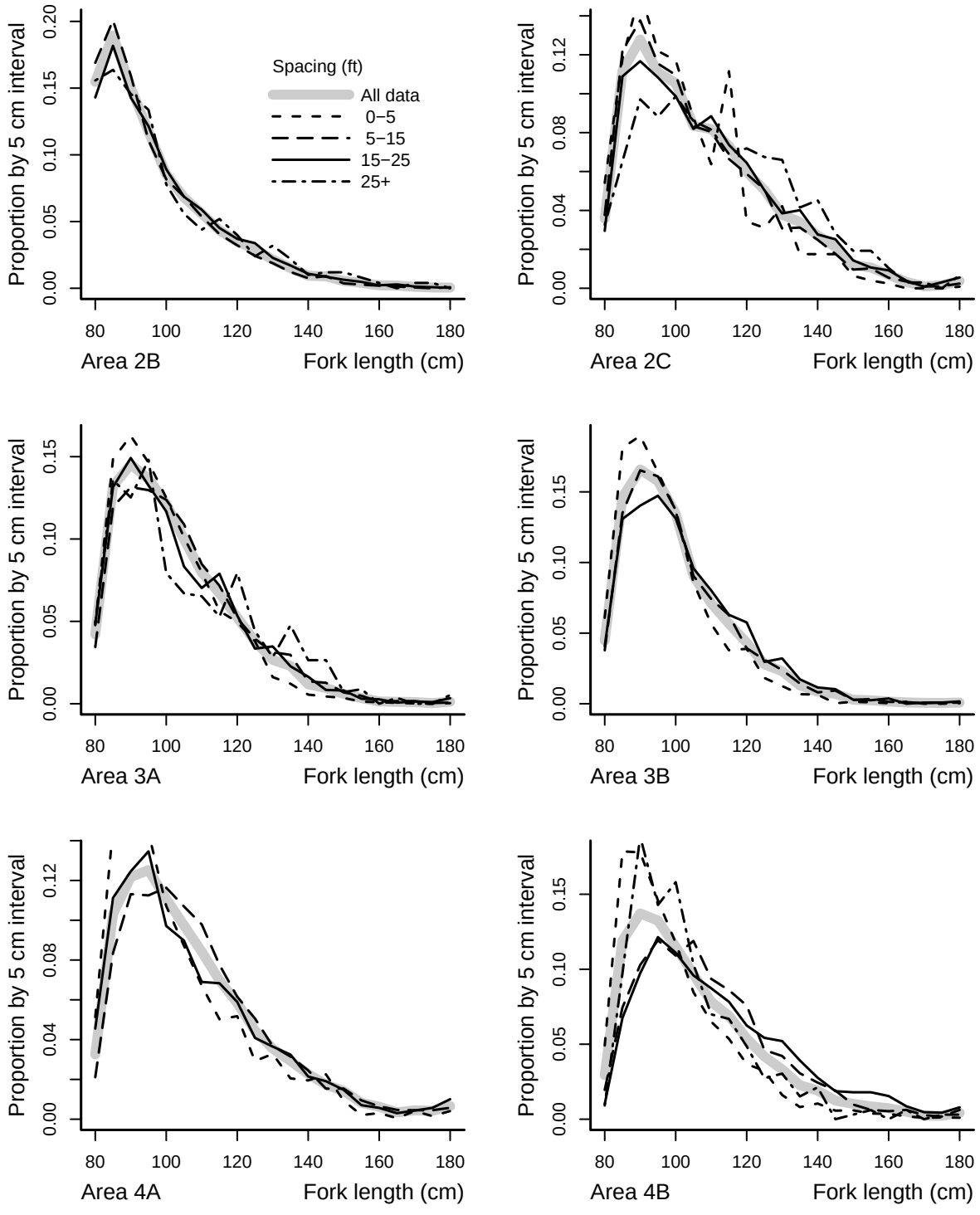

Figure 2a. Length frequencies of commercial landings (2000-2004) by hook spacing.

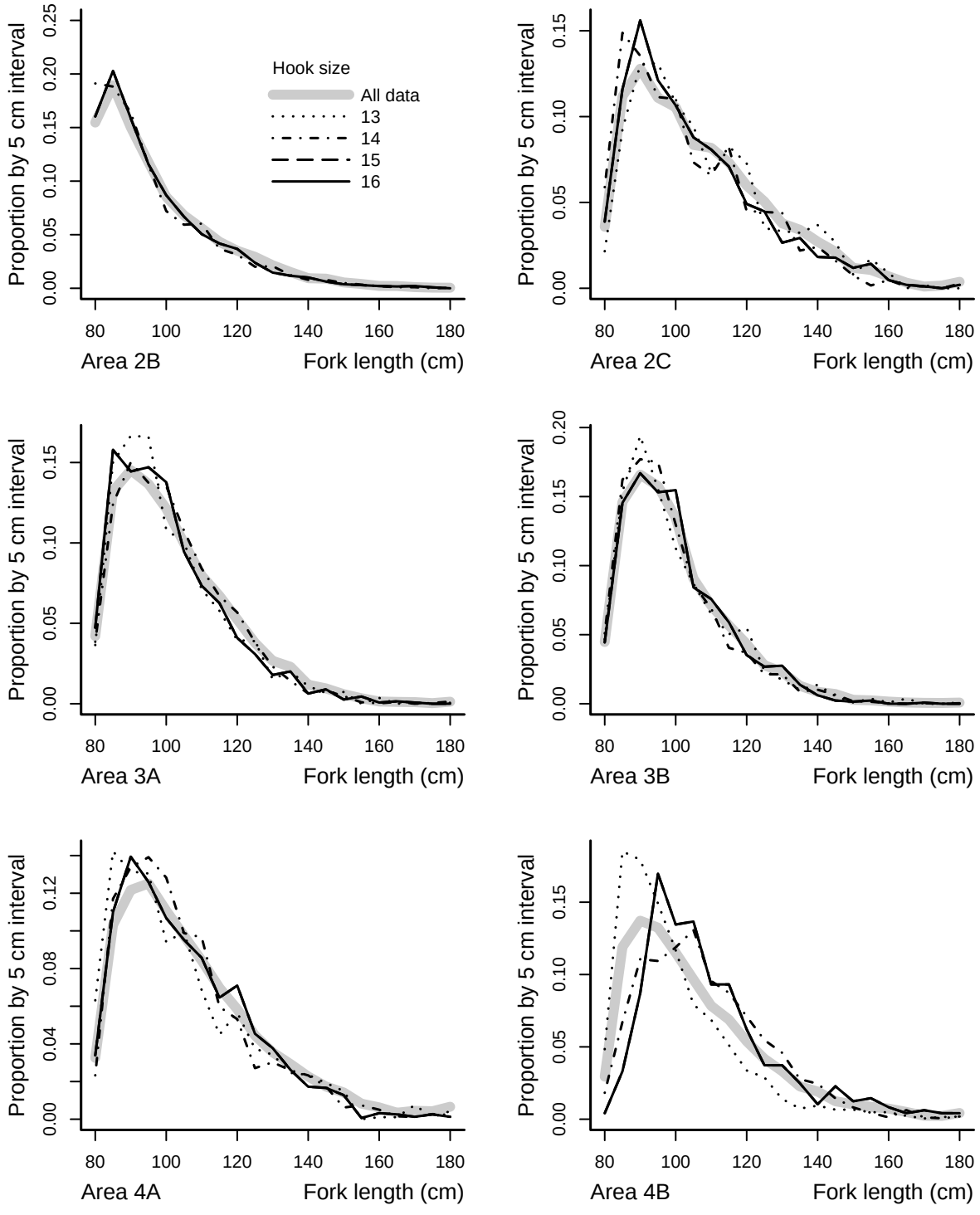

Figure 2b. Length frequencies of commercial landings (2000-2004) by hook size.

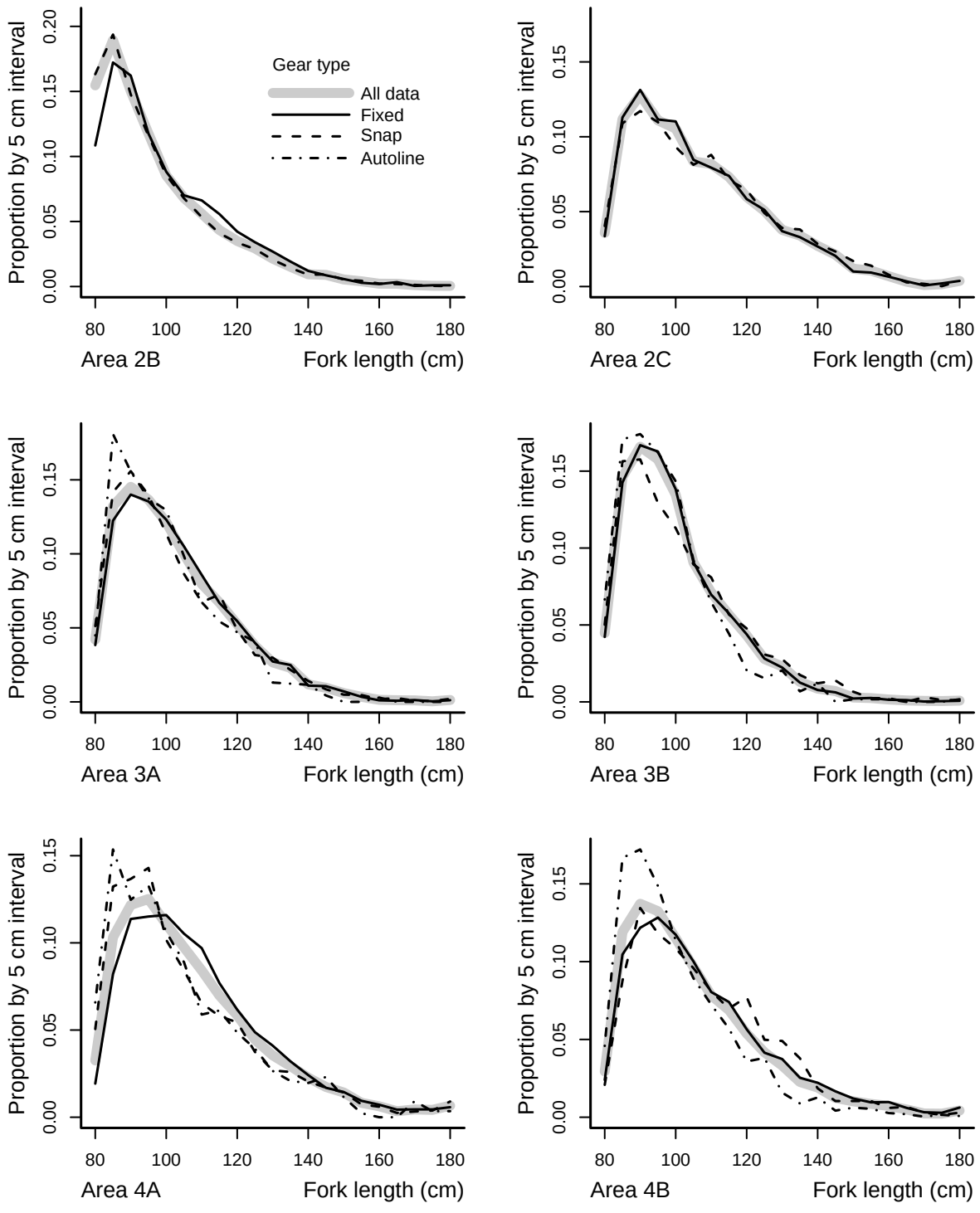

Figure 2c. Length frequencies of commercial landings (2000-2004) by gear type.

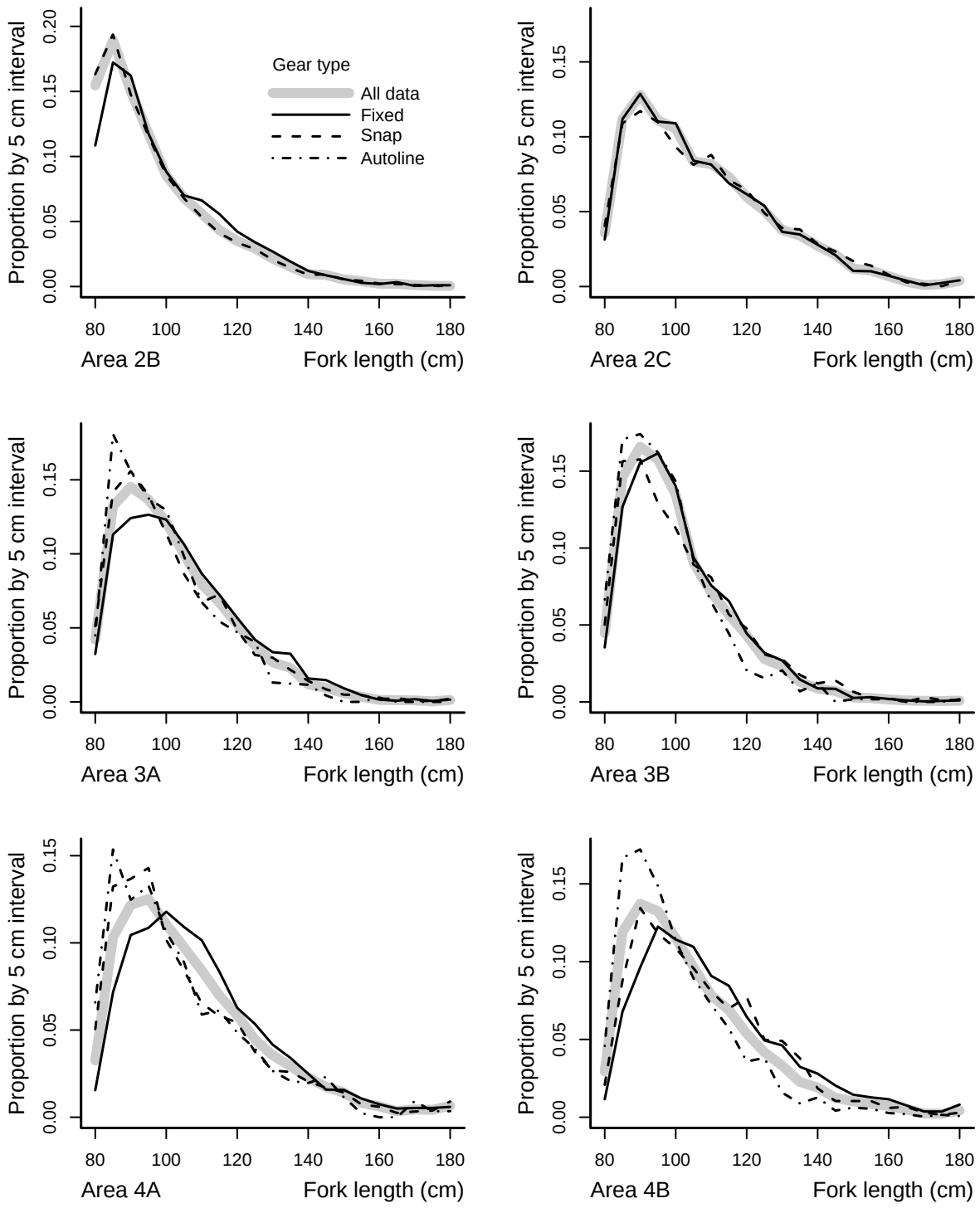

Figure 2d. Same as Figure 2c, but excluding fixed hook gear with hook spacing of 4 ft or less.

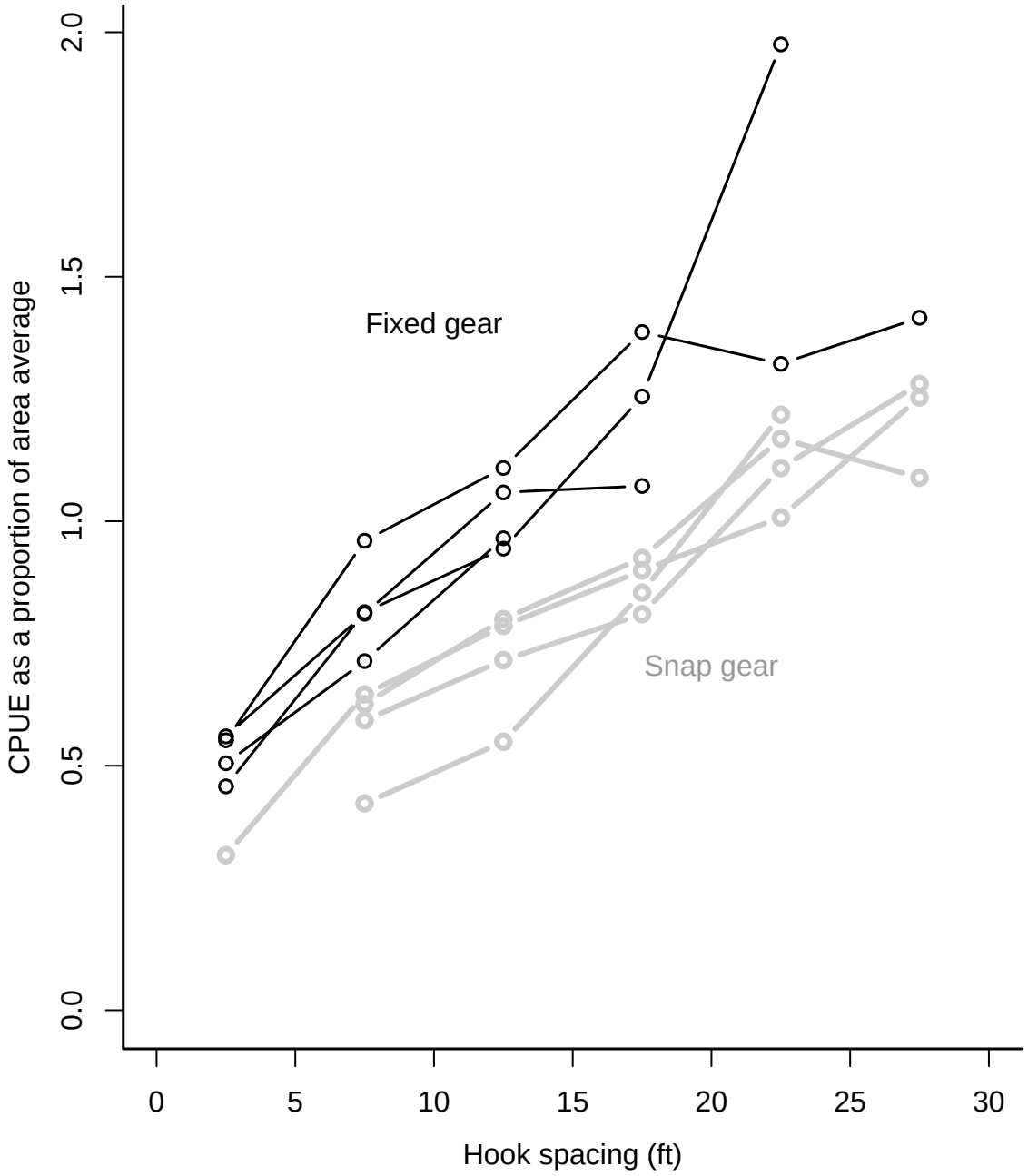

Figure 3. Commercial CPUE as a function of hook spacing, plotted by gear type and hook size. The separate lines for each gear type refer to the different hook sizes, with CPUE generally incrreasing with hook size. The reference CPUE level is the unweighted average of fixed and snap CPUE at 10-20 ft spacing in the area of each datum. Autoline values (not shown) are similar to snap values at the same spacing.

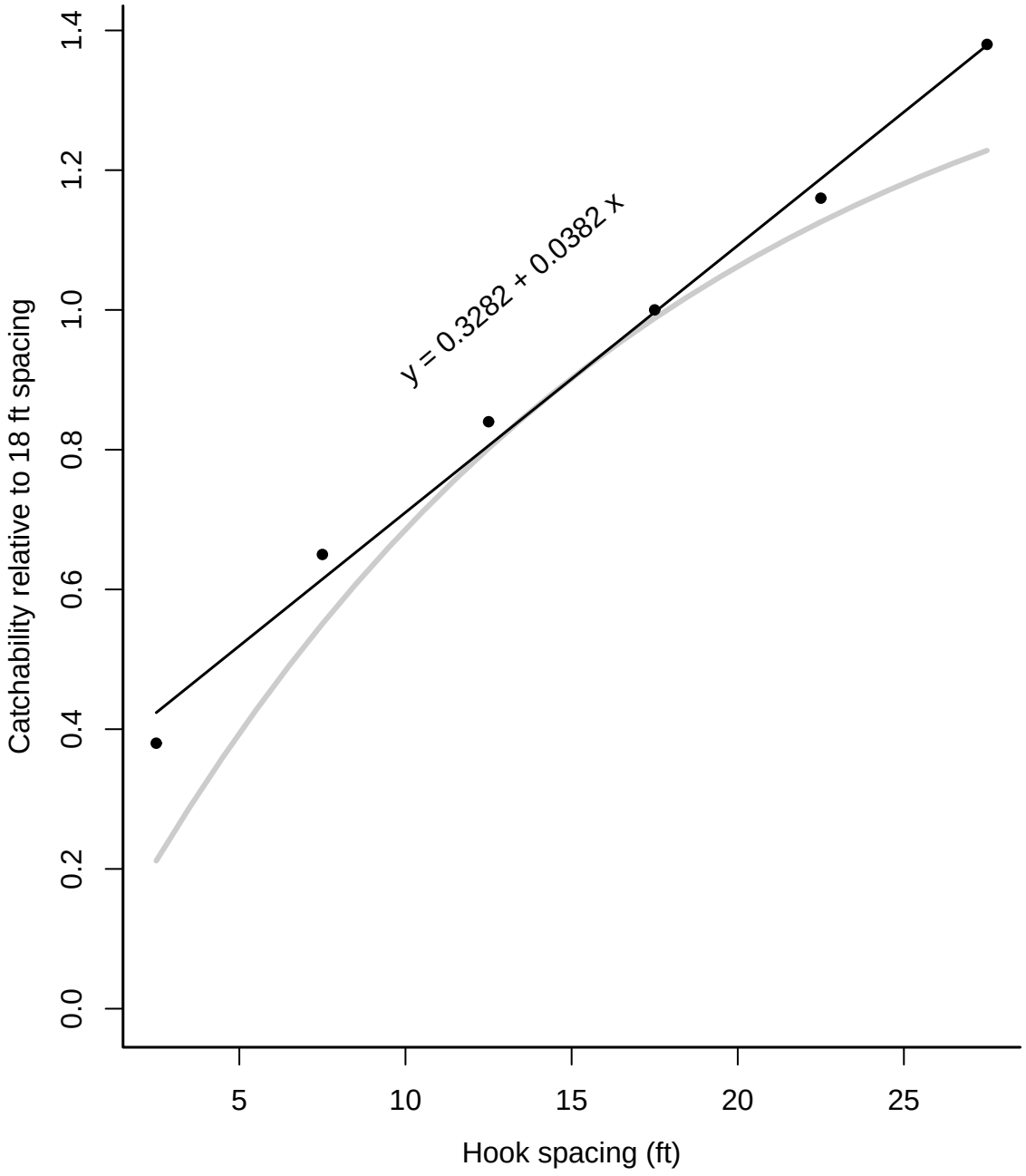

Figure 4. Empirical estimates of catchability relative to 18 ft spacing (points), a straight line fitted to them (black line), and the longstanding hook spacing adjustment (gray line) from Hamley and Skud (1978).