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EFFECTIVENESS AND SIZE SELECTIVITY OF TRAWL GEAR IN ARCTIC SURVEYS

by

William Dickson
Institute of Fishery Technology Research
Bergen, Norway

INTRODUCTION

It is well known that every kind of fishing gear gives a biassed sample, both as to species and to length distribution. Of particular concern in Arctic surveys has been the undersampling of small cod and haddock by bottom trawl. It was also becoming apparent that the use of different sweep lengths was probably affecting the bias of the samples. Already a shrimp trawl was used as the standard bottom trawl so as to avoid escapes through the meshes of the forward part of the trawl. A rockhopper groundrope was introduced experimentally to cut down on escapes which occurred between the bobbins, and experiments were conducted with different sweep lengths twice and half the length of the 40 m sweeps used on the standard sampling rig. This paper includes data that have been acquired this year, and adds it to the store of what has been collected in the past few years. It also attempts to relate the results to each other in such a way that the biasses can be understood, and to some extent corrected.

BOBBINS AND ROCKHOPPERS

The escape of fish under the fishing line of this same sampling trawl was discussed by Engås and Godø (1987). They extrapolated the results of what was caught in bags under the fishing line to what would escape over the whole bobbin groundrope. Results may as well be extrapolated to the whole width of the trawl (Y_n). They also gave what was caught by the bobbin rigged trawl for the same series of hauls. As a concept, the bobbin trawl net efficiency f_{nb} may be described as:

f_{nb} = catch/(catch + escapes) or catch/encounters

The bags would not be able to measure all kinds of escapes viz:

A very few fish pass the wing ends, re-cross this line, and swim out.

More seriously some of the bigger fish (mostly cod) will remain swimming in front of the ground rope when the gear is hauled.

Some fish (mostly bigger haddock) may swim up and over the headline.

Nevertheless, the values of f_{nb}, which can be obtained from these bag experiments, are the best available to date, and provide a useful starting point. Using a bobbin spread of 11.5 m and a net spread of 19.5 m, the data may be presented as in Table 1 for cod.

In a similar way the net efficiency of the rockhopper gear may be estimated for effectively the escapes over the 11.5 m width of the bobbins would now be transferred to the catch, while the escapes at the ground between groundrope spread and net spread remain. Thus arises the rockhopper net efficiency f_{nrh} in Table 1. The sum of catch comparison, which were made at that time and much more made recently, are also given in Table 1. The catch ratios are the ratios of the effective

spreads y_{eb}/y_{erh} as given in Table 1. The real values of f_{nb} and f_{nrh} must eventually begin to fall again with increasing fish length, and that they do not appear to do so in Table 1 is probably due to big cod continuing to stay ahead of the groundropes when the gear is hauled. Plots of f_{nb}/f_{nrh} and y_{eb}/y_{erh} are given in Figure 1.

The relationship between them may be expressed as

$$\frac{Y_{eb}}{Y_{erh}} = \frac{f_{nb}(y_{nb}+f_{sb}(y_{bb}-y_{nb}))}{f_{nrh}(y_{nrh}+f_{srh}(y_{brh}-y_{nrh}))} = \frac{f_{nb}}{f_{nrh}} \cdot \frac{(19.5+f_{sb}\ 42.5)}{(18+f_{srh}\ 35)}$$

The rockhopper gear has a little less spread because of the greater drag of the rockhoppers. The rockhopper groundrope was 300 kg in water, the bobbin groundrope 180 kg.

Even supposing the ratio of the last terms in brackets remain fairly close to unity, and now having a fair idea of the actual value of f_{nb} and f_{nrh} in the middle of the size range, one is still left with two unknowns in an equation like $Y_{eb} = f_{nb}(19.5+f_{sb}\ 42.5)$. Thus it is necessary to know at least one of the effective spread values, or alternatively one of the values of sweep efficiency. In another paper presented to this meeting, it is indicated that a value of $y_{eb} = 29$ m, for cod and haddock together, is quite reasonable for the middle size range. The value, which has customarily been used in survey, is 25 m. For the rockhoppers a value of $Y_{erh} = 34$ m was indicated.

Using this information on effective spread and starting with cod, Figs. 2 and 3 are used for smoothing f_{nb}, f_{nrh} and Y_{eb}/Y_{erh} so that one can do farther work based on the smoothed values in Table 2.

Using the values of effective spreads indicated for the upper middle size range and the values indicated in Table 2, one could proceed to solve the previous equations within these constraints. There are some additional general constraints.

At the lower end of the fish size range values of Y_e, f_s and f_n will either tend towards the origin or to zero at short fish lengths, Y_e will decrease in slope and should eventually have a negative slope, the same is true for f_n, while f_s should flatten at big fish lengths, but is unlikely to ever have a negative slope.

Before proceeding to develop results along these lines, it was suggested that the possible effect of the otterboards should be brought into the equations.

ALLOWING FOR OTTERBOARD EFFECTS

Otterboards are big enough to have an important effect on fish herding or avoidance, but whether the overall effect was beneficial or otherwise was never clear. Pony doors were widely used in Germany, but although tried elsewhere any advantage they had was not clear cut in commercial terms. When it came to analysing results of comparative fishing experiments with long, average and short sweeps, the short sweep case indicated that any large negative effect of otterboards was improbable. Negative effect is severe because fish are removed from the system. Similarly, any net positive effect seemed likely to be small. The positive effect is weaker because fish are not added to the system, only redistributed within it somewhat more favourably.

Analyses along these lines suggested that there were likely both positive and negative effects. A possible explanation is as shown in Fig. 4.

The waterflow from the otterboard flows over the top and round the back of it. Fish immediately on the inside of the board could be sucked out. Others could follow them. The sand cloud at this point is low down, and the area immediately behind the otterboard and over the low sand cloud may present itself as an escape route, particularly for fish which are

above otterboard height, but still below headline height. Other fish farther away react positively being herded toward the centre and turning toward the net as the otterboard passes them. The splitting line it is suggested is not immediately in front of the otterboards, but some very few metre inside them. Inside the splitting line the effect is positive, outside of it negative. The warp may also have some negative effect up to a height of say 8 m, which is only 1 or 2 m inside the otterboard. Ocassionally fish are seen escaping over the otterboard, more commonly few or any fish are seen near the otterboard. It is suggested that the positive effect, although weaker, acts over a wider area.

Proceeding to introduce this concept into the equations, let the positive effect be acting over a pathwidth R_{bi} (both boards, R_{bi} = board paths inward) and herding inwards from the splitting line. Let the negative effect be acting over a pathwidth R_{bo} (both boards, R_{bo} = board paths outwards) and removing fish from the system. Because of the negative effect, the amount of fish available to the gear is reduced in the proportion $(y_b-R_{bo})/Y_b$. Because of the positive effect the density of fish toward the centre is increased in the proportion $(Y_b-R_{bo})/(Y_b-R_{bo}-R_{bi})$, and the remaining path over which the sweeps and sand clouds herd fish, is $(Y_b-Y_n-R_{bo}-R_{bi})$. The equation thus becomes

$$Y_e = f_n(Y_n+f_s(Y_b-Y_n-R_{bo}-R_{bi}))\cdot(Y_b-R_{bo})/(Y_b-R_{bo}-R_{bi}).$$

Some preliminary calculations suggested that R_{bi} = 10 m and R_{bo} = 5 m would be suitable values. This means that the splitting line is 2.5 m inside each board, and what is inside the splitting line for a distance of 5 m is all herded toward the centre, being then more or less evenly distributed within the remaining pathwidth.

Using these equations modified for otterboard effect, Table 2 can now be extended into Table 3, giving reasonably balanced answers for values of sweep efficiencies f_{sb} and f_{srh}, also corresponding values of Y_{eb} and Y_{erh}, as well as the overall

gear efficiencies $f_b = Y_{eb}/Y_{bb}$ and $f_{rh} = Y_{erh}/Y_{brh}$.

The results for the bobbin gear and the rockhopper gear are collected together in Fig. 5. The slightly lower spreads of the rockhopper gear and the otterboard effects overlapping more of the sweep path give it a greater sweep efficiency.

EFFECTS OF LONG AND SHORT SWEEPS

All the comparisons between long, medium and short sweeps were made with the gear rigged with bobbins. The rigs are shown in Fig. 6. The 80 m sweep case introduces a 40 m single sweep between 40 m spreading wires and backstrops. The short sweep gear had the spreading wires attached to top and bottom of the otterboards in order to keep the headline height substantially the same as in the other two cases. Otterboard spreads Y_b and net spreads Y_n are taken from acoustic transponder equipment with information relayed acoustically back to the ship. It will be noticed that the spreads change a little from one set of experiments to another. This is because the experiments were done at various times and places, the 80m/40m comparisons being in fact collected over several years. Comparative catch data is taken from Engås (1987).

80 M/40 M COMPARISON

The average otterboard spread for the 80 m sweep gear was 76.5 m, its net spread 19.1 m. The average for the 40 m sweep gear was 57.8 and 19.5 m, respectively. Positive and negative otterboard path widths are taken as 10 m and 5 m. The values of net efficiency are not expected to be very different whether the sweeps are long or short, though this might not necessarily be true. Net efficiency for the longer sweeps is here given a 5% advantage because with the extra sweep weight the net should bite the ground better. Sweep

efficiency for the 40 m sweep rig is maintained the same as for the bobbin gear in the rockhopper comparison. Thus with some balancing between the various constraints, Table 4 arises.

The plots of Table 4 are given in Fig. 7. It would appear that the sweep efficiency for the 80 m sweeps is very low for small cod. Even making it zero does not allow the value of f_{n80} to correspond with f_{n40}. With the sand cloud well outside the wing end, the small cod must surely be passing over or under the sweeps near the net. For bigger cod there would appear to be a dramatic increase in sweep efficiency. The question is raised of whether the sweep efficiency is related to the amount of fish that the extra spread makes available.

40 M/20 M COMPARISON

Here the otterboard spread ratio was 63.5 m/39.5 m or 1.61, while the catch ratio for all sizes was 1.26. By day the catch ratio was only 1.1 and by night 1.36. Such results are not easily explainable except by the otterboard effect. With R_{bi} = 10 m and R_{bo} = 5 m as before, the sweep path of the 20 m sweep gear is almost overlapped by the otterboard effect, so that the overall efficiency of the 20 m sweep gear is good, particularly in daylight, suggesting that the magnitude of R_{bi} might be affected by visibility (Table 5 and Fig. 8). To enable calculations to be checked, the net spreads of the 40 m and 20 m sweep gear were 20 and 20.5 m, respectively.

HADDOCK

The same procedures are followed for haddock, starting with the bobbin v. rockhopper comparison.

Plots of Table 6 are given in Figs. 9 and 10. Thereafter the smoothed values are used in Table 7.

The curves shown in Figs. 9 and 10 show a much sharper rise than was the case with cod. The catch ratios between the two gears fall away from a maximum for bigger haddock. Table 8 and Fig. 11 give the overall comparisons between the two gears.

In this case at least the bobbin gear appears to have a drop in effective spread at the top end. Such is to be expected because bigger haddock are observed swimming over the head-line, and this may be more the case with the wider spread bobbin gear.

80 M/40 M COMPARISON, HADDOCK

Results are given in Table 9 and in Fig. 12.

Both the 40 m gear and the 80 m rig tend to reach maximum effective spread in the size range 40-50 cm. The 80 m rig appears to reach maximum at slightly lower length size. For haddock below about 25 cm, the 40 m rig gives the better selectivity.

40 M/20 M COMPARISON, HADDOCK

Haddock did not seem to be so well herded as cod by the 20 m sweep rig although they were not herded badly, catch ratio 40 m/20 m = 1.62, with the otterboard spread ratio 1.61. Because of this an otterboard effect of R_{bi} = 10 cm, R_{bo} = 5 m would not fit. Instead R_{bi} = 5 m and R_{bo} = 5 m was used. Catch ratios by length group are ragged, and for this reason smoothing was used. Results are given in Table 10 and Fig. 13.

Note that since catch ratios equal otterboard spread ratios, the overall efficiencies as seen in the last two lines of Table 9 are the same.

GENERAL CONCLUSIONS FOR SURVEY PURPOSES

1. The rockhopper groundrope with 40 m sweeps is much better than the bobbin groundrope in selecting small cod and small haddock, and is somewhat better for the larger fish also.

2. The 80 m sweep gear biasses the sample against small fish, both cod and haddock and in favour of larger fish. This last may be density dependant.

3. The herding of cod by the 20 m sweep gear is particularly good, probably due to otterboard effect, and perhaps also to the close proximity of the lower sweep to the ground. The 20 m sweep gear gives haddock catches almost exactly in proportion to its spread. The practical difficulty with this gear is getting a turn in the sweeps when connecting them up.

4. The change of trawl selectivity with length group rises much more steeply in the case of haddock for all the rigs used.

5. The fits of the selectivity curves are naturally poorer at the ends where there are few fish and where one has to extrapolate rather than interpolate.

6. Two known sources of selectivity bias remain unaccounted for big cod continuing to swim in front of the groundrope and big haddock escaping over the headline.

REFERENCES

Engås, A. and Godø, O.R. Escapement of fish under the fishing line of a Norwegian sampling trawl and its influence on survey results. Int.Symp.Fish.Acoust., Seattle, June 1987.

Engås, A. and Godø, O.R. 1987. The effect of different sweep lengths on length composition of bottom sampling trawl catches. Coun.Meet.int.Coun.Explor.Sea, C.M. 1987/B:16.

Table 1. Estimates of net efficiencies, their ratios and catch ratios for cod.

Length cm	f_{nb}	f_{nrh}	f_{nb}/f_{nrh}	y_{eb}/y_{erh}
5-9	0.09	0.62	0.15	-
10-14	0.10	0.68	0.15	0.04
15-19	0.10	0.63	0.16	0.05
20-24	0.20	0.67	0.30	0.27
25-29	0.24	0.69	0.35	0.41
30-34	0.23	0.68	0.34	0.40
35-39	0.34	0.73	0.47	0.48
40-44	0.48	0.78	0.62	0.58
45-49	0.37	0.74	0.50	0.55
50-54	0.58	0.83	0.70	0.55
55-59	0.54	0.81	0.67	0.62
59-	0.70	0.88	0.8	0.60

Table 2. Smoothed values of net efficiency and effective spread ratios.

Sizegroup	10/19	20/29	30/39	40/49	50/59	60+ cm
f_{nb}	0.10	0.21	0.32	0.44	0.55	0.64
f_{nrh}	0.61	0.67	0.71	0.76	0.80	0.84
y_{eb}/y_{erh}	0.18	0.35	0.50	0.60	0.68	0.70

Table 3. Resulting values of sweep efficiency, effective spread and overall efficiency with otterboard effect included.

Sizegroup	10/19	20/29	30/39	40/49	50/59	60+ cm
F_{sb}	0.33	0.43	0.51	0.52	0.52	0.54
f_{srh}	0.35	0.46	0.55	0.67	0.74	0.90
Y_{eb}	3.5	8	13	18	22.5	26.5 m
Y_{erh}	19	23	26	30	33	38 m
f_b	0.06	0.13	0.21	0.29	0.36	0.43
f_{rh}	0.36	0.43	0.59	0.57	0.62	0.72

Table 4. Effective spreads, net, sweep and overall efficiencies for the 80 m and 40 m sweep rigs.

Size group	7/17	17/27	27/37	37/47	47/57	57/67	67+ cm
f_{n40}	0.04	0.17	0.30	0.42	0.52	0.62	0.65
f_{n80}	0.02	0.14	0.32	0.43	0.55	0.65	0.68
Y_{e80}/Y_{e40}	0.36	0.76	1.05	1.36	1.63	1.76	1.67*
f_{s40}	0.3	0.42	0.49	0.52	0.53	0.53	0.54
f_{s80}	0.1	0.2	0.31	0.60	0.78	0.89	0.83
Y_{e40}	1.3	6.1	11.4	16.3	20.4	24.5	25.6 m
Y_{e80}	0.5	4.7	12.0	22.2	33.2	42.7	42.8 m
f_{40}	0.02	0.11	0.20	0.28	0.35	0.42	0.44
f_{80}	0.01	0.06	0.16	0.29	0.43	0.56	0.56

* catch ratio

Table 5. Effective spreads, net, sweep and overall efficiencies for the 40 m and 20 m sweep rigs.

Sizegroup	17/27	27/37	37/47	47/57	57/67	67+ cm
f_{n40}	0.17	0.30	0.42	0.52	0.62	0.65
f_{n20}	0.17	0.30	0.42	0.52	0.62	0.65
Y_{e40}/Y_{e20}	1.39	1.15	1.34	1.12	1.07	1.22
	1.19	1.24	1.26	1.26	1.26	1.26 *
f_{s40}	0.42	0.49	0.52	0.53	0.53	0.54
f_{s80}	0.64	0.74	0.80	0.86	0.84	0.90 **
Y_{e40}	6.6	12.3	17.7	22.1	26.3	27.8 m
Y_{e20}	5.5	9.9	14.0	17.5	20.9	22.1 m
f_{40}	0.10	0.19	0.28	0.35	0.42	0.44
f_{20}	0.14	0.25	0.35	0.44	0.53	0.56

* smoothed
** not critical because sweep path is now only 4 m

Table 6. Estimates of net efficiencies, their ratios, and catch ratios for haddock.

Length cm	f_{nb}	f_{nrh}	f_{nb}/f_{nrh}	y_{eb}/y_{erh}
10-14	0.045	0.61	0.07	0.22
15-19	0.06	0.61	0.10	0.22
20-24	0.51	0.75	0.68	0.59
25-29	0.63	0.85	0.74	0.85
30-34	0.68	0.87	0.78	0.94
35-39	0.57	0.90	0.63	0.97
40-44	0.81	0.92	0.88	0.84
45-49	0.83	0.93	0.89	0.73
50+	0.67	0.92	0.73	0.67

Table 7. Smoothed values of net efficiency and effective spread ratios.

Size group	10/19	20/29	30/39	40/49	50/59 cm
f_{nb}	0.12	0.55	0.70	0.75	0.72
f_{nrh}	0.6	0.8	0.91	0.94	0.91
y_{eb}/y_{erh}	0.22	0.78	0.82	0.81	0.62

Table 8. Effective spreads, sweep and overall efficiencies for the rockhopper and bobbin gears, including otterboard effect.

Size group	10/19	20/29	30/39	40/49	50/59 cm
f_{sb}	0.34	0.48	0.54	0.58	0.6
f_{srh}	0.35	0.48	0.65	0.79	0.9
y_{eb}	4.2	21.8	29.1	32.2	25.6
y_{erh}	18.9	27.9	35.5	39.7	41.3
f_b	0.07	0.35	0.47	0.52	0.41
f_{rh}	0.36	0.53	0.67	0.75	0.78

Table 9. Effective spreads, net, sweep and overall efficiencies for the 80 m/40 m comparison for haddock, including otterboard effect.

Sizegroup	7/17	17/27	27/37	37/47	47/57	57+ cm
f_{n40}	0.1	0.45	0.68	0.72	0.65	0.50
f_{n80}	0.1	0.47	0.71	0.76	0.68	0.53
y_{e80}/y_{e40}	0.79	1.18	1.44	1.53	1.81	1.49
f_{s40}	0.3	0.43	0.53	0.58	0.6	0.6
f_{s80}						
y_{e40}	3.3	16.3	26.6	29.2	26.8	20.6
y_{e80}						
f_{40}	0.06	0.28	0.46	0.51	0.46	0.36
f_{80}	0.03	0.25	0.50	0.58	0.63	0.40

Table 10. Effective spread, net, sweep and overall efficiencies, for the 40 m/20 m comparison for haddock, using a reduced otterboard herding effect.

Sizegroup	7/17	17/27	27/37	37/47	47/57	57+ cm
f_{n40}	0.1	0.45	0.68	0.72	0.65	0.50
f_{n20}	0.1	0.45	0.68	0.72	0.65	0.50
y_{e40}/y_{e20}	2.82	1.49	1.61	1.59	1.70	1.33 *
y_{e40}/y_{e20}	1.40	1.47	1.57	1.62	1.62	1.62 **
f_{s40}	0.3	0.43	0.53	0.58	0.6	0.6
f_{s20}	0.04	0.15	0.21	0.24	0.28	0.28 ***
y_{e40}	3.3	16.9	28.0	30.9	28.4	21.8
y_{e20}	2.4	11.5	17.8	19.1	17.5	13.5
f_{40}	0.05	0.27	0.44	0.49	0.44	0.34
f_{20}	0.06	0.29	0.45	0.48	0.44	0.34

* only 42 fish at 7/17 and 7 fish at 57+
** smoothed
*** not critical because sweep path is now only 9 m

COD

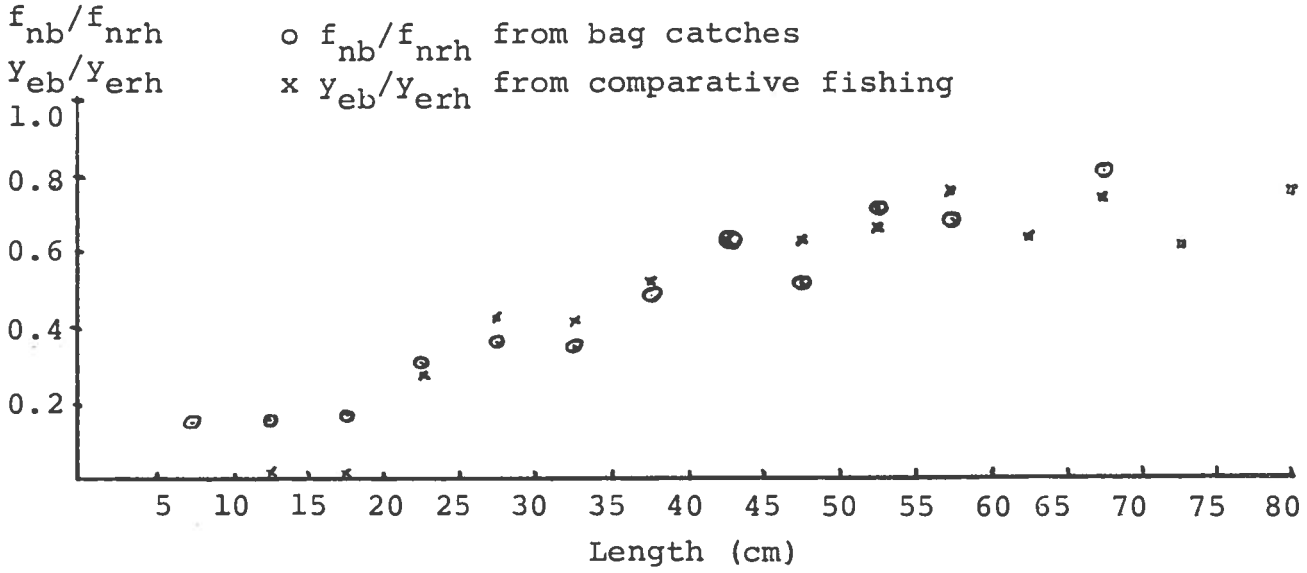

Figure 1. Net efficiency ratio and catch ratio for cod, bobbins and rockhoppers, both rigs with 40 m sweeps.

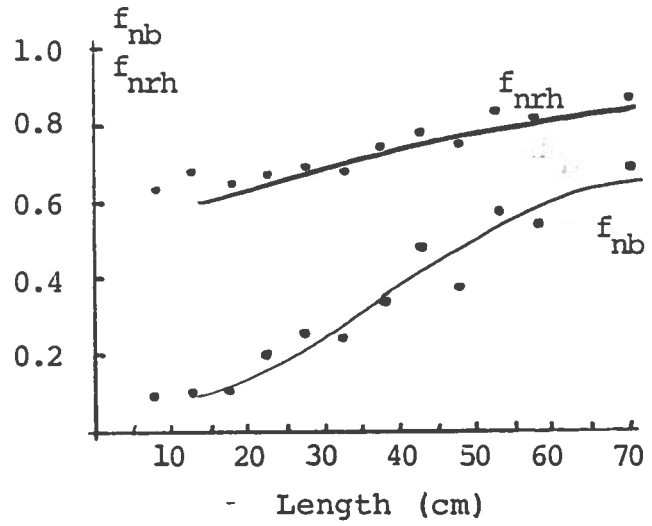

Figure 2. Net efficiencies, bobbins and rockhoppers.

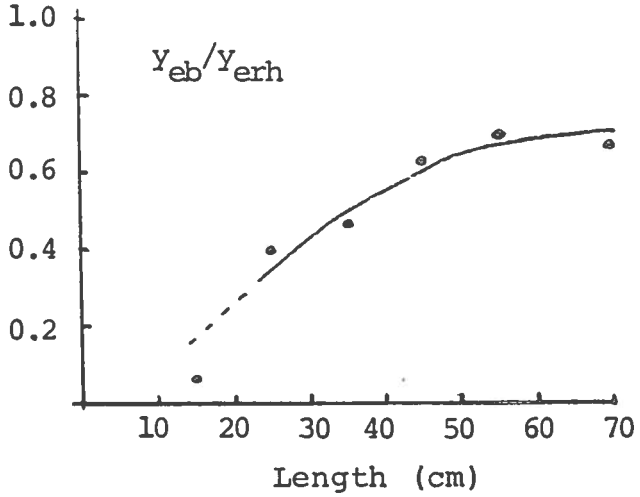

Figure 3. Smoothing the effective spread ratio, bobbins and rockhoppers.

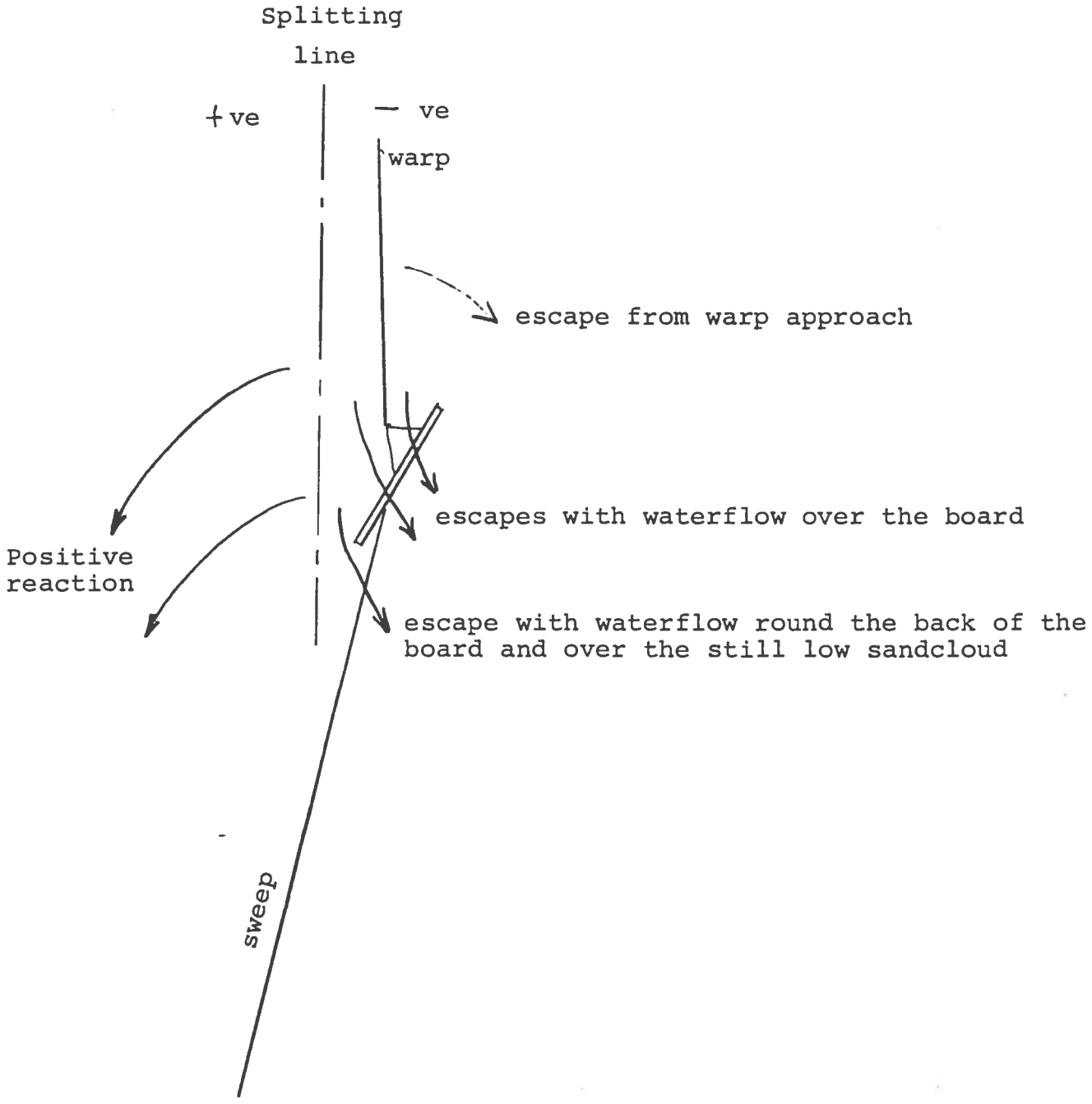

Figure 4. Positive and negative effects of otterboard. The negative effect removes fish from the system. The positive effect only redistributes them more favourably.

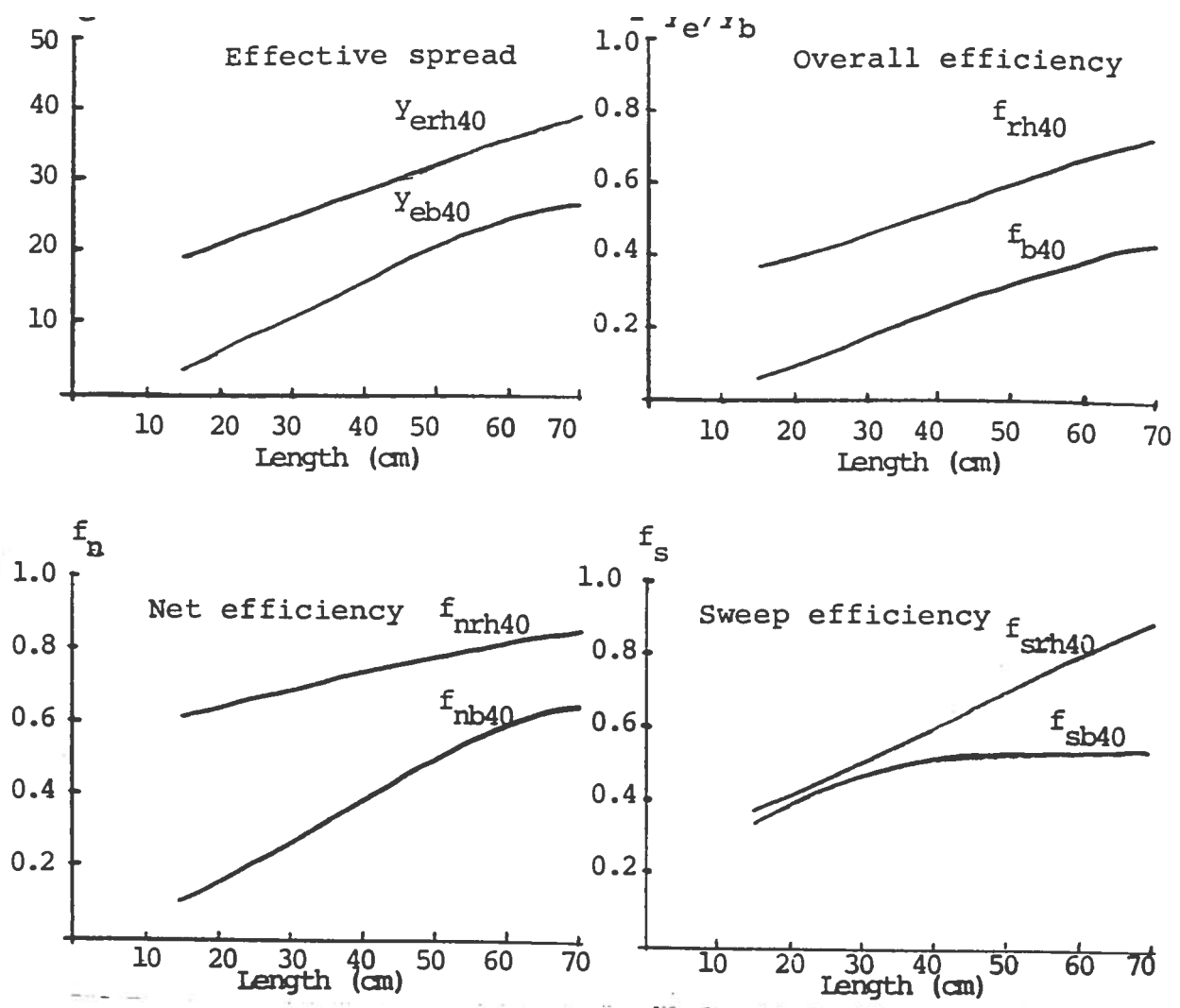

Figure 5. Effective spread, net efficiency, sweep efficiency and overall efficiency for bobbins and rockhoppers, both with 40 m sweeps. Positive otterboard effect 10 m, negative effect 5 m, cod.

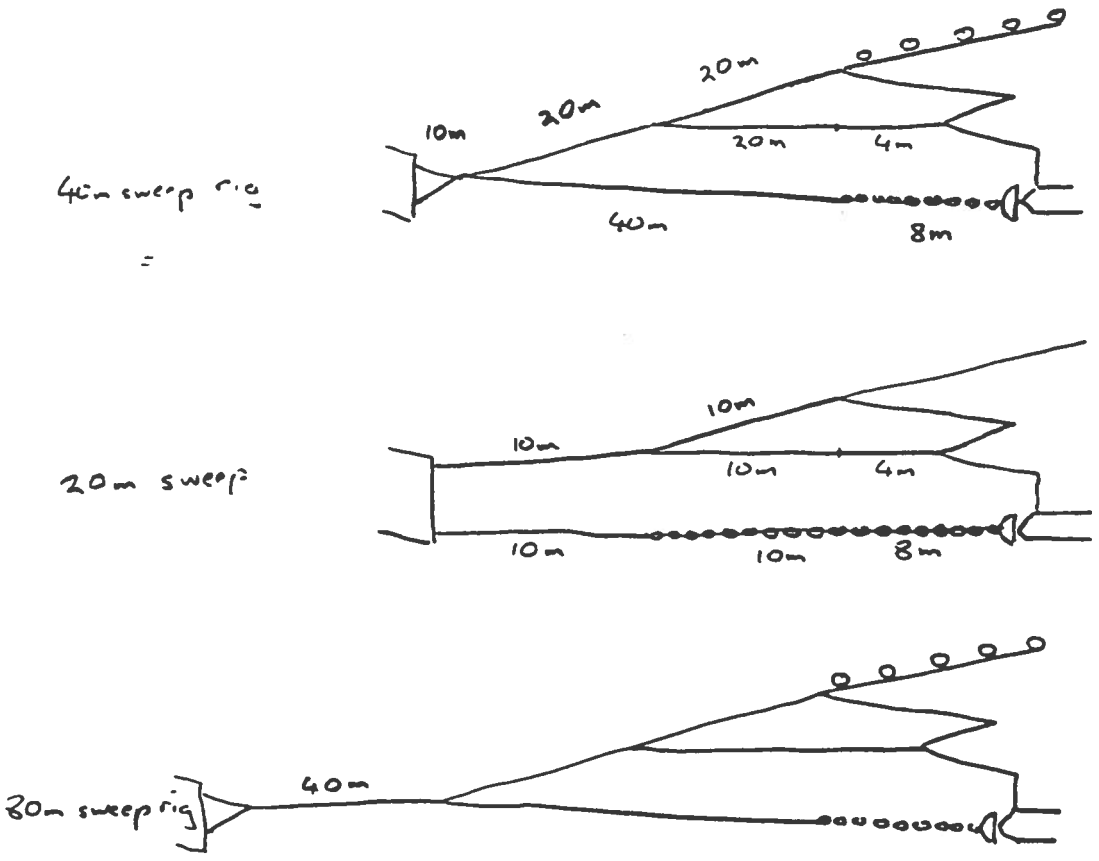

Figure 6. Long medium and short sweep rigs. Note the extra chain for ballasting in the lower sweep of the 20 m sweep rig.

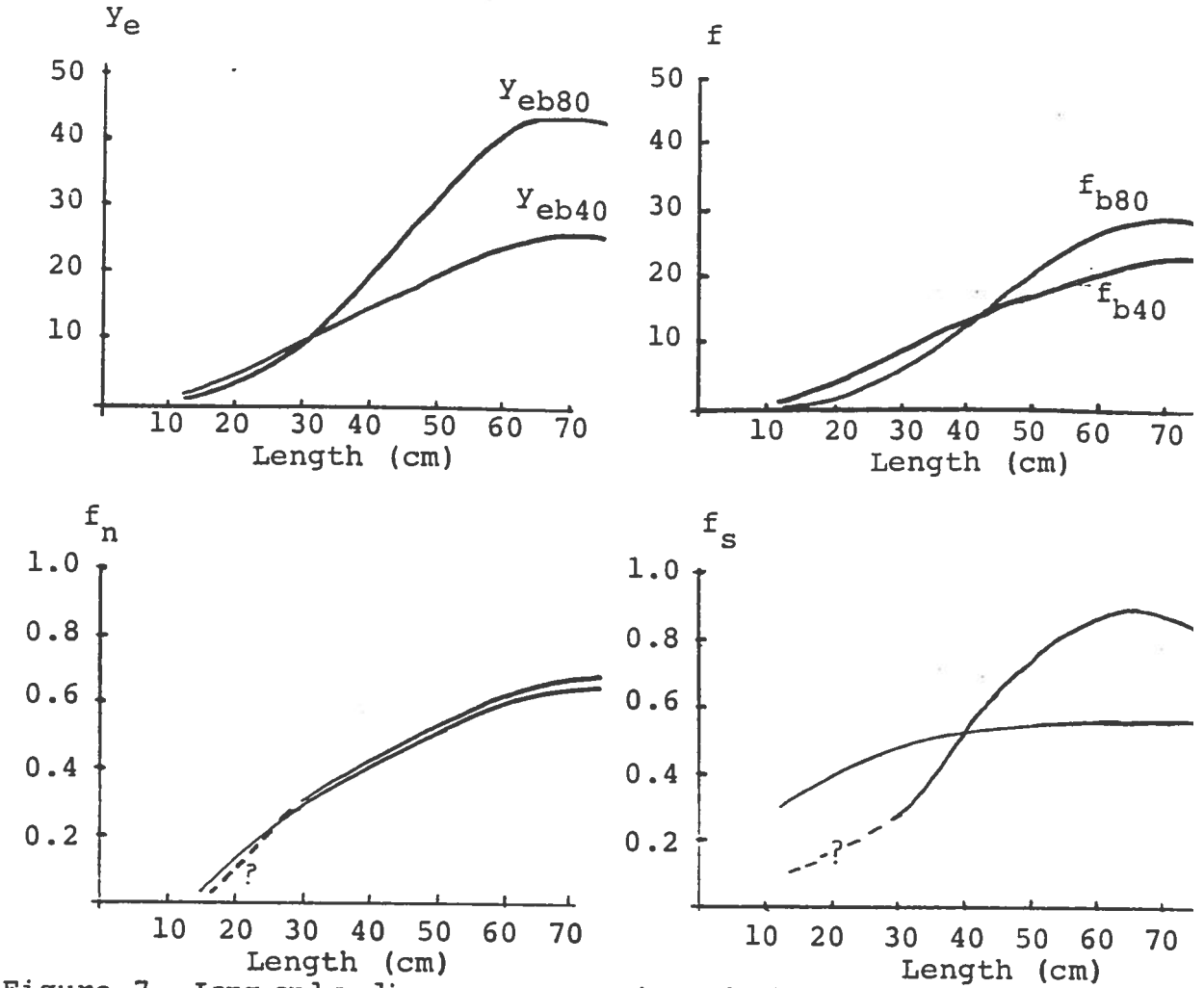

Figure 7. Long and medium sweep comparison, both with bobbin groundropes positive otterboard effect 10 m , negative effect 5 m, cod.

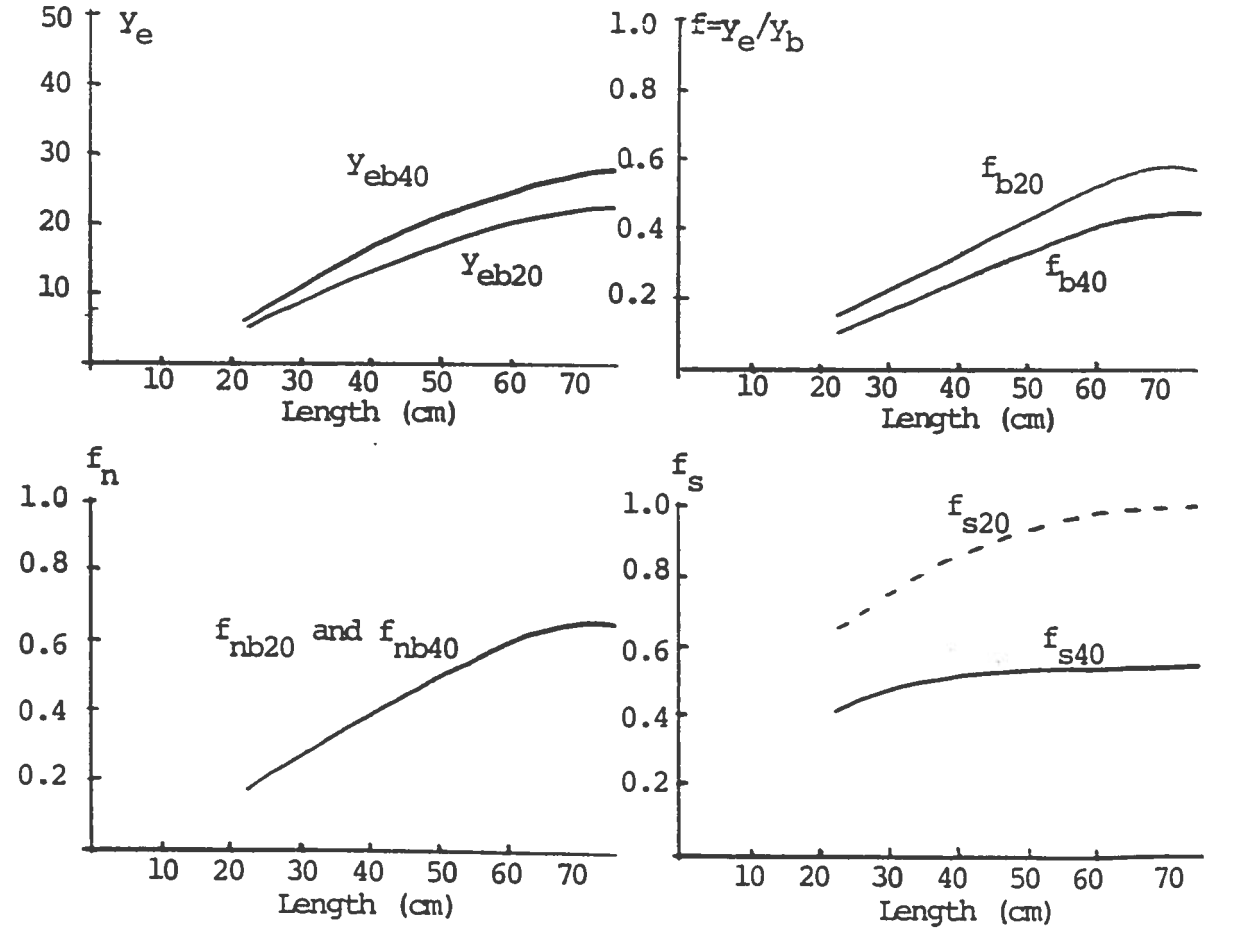

Figure 8. Medium and short sweep comparison, both with bobbin groundropes, positive otterboard effect 10 m, negative effect 5 m, cod.

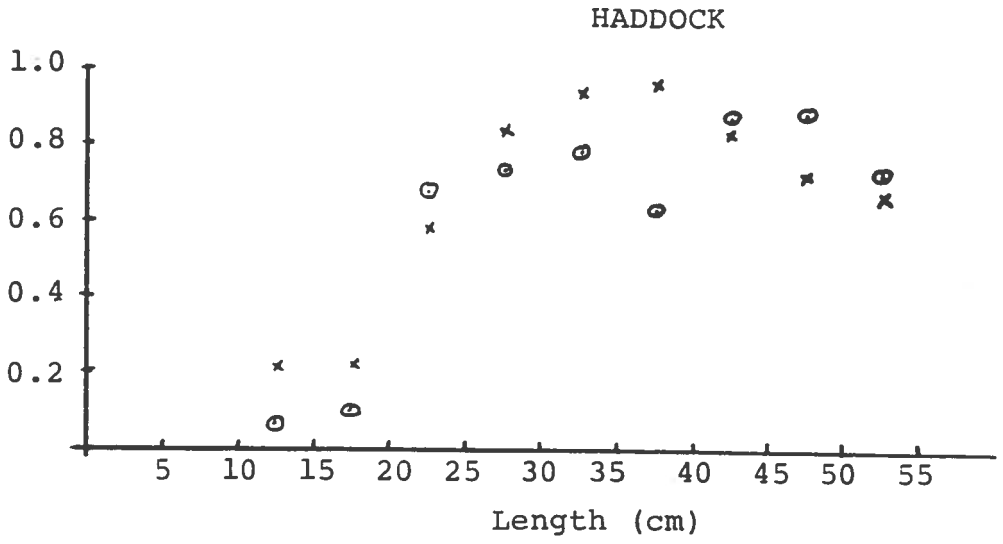

Figure 9. Net efficiency ratio and catch ratio for haddock, bobbins and rockhoppers both with 40 m sweeps.

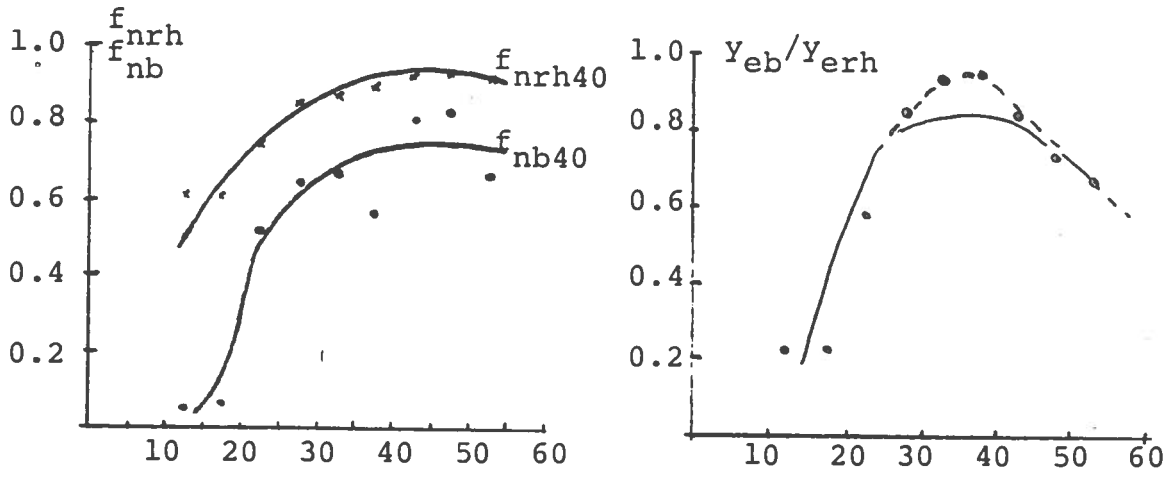

Figure 10. Smoothing the net efficiencies for bobbins and rockhoppers and smoothing the effective spread ratios.

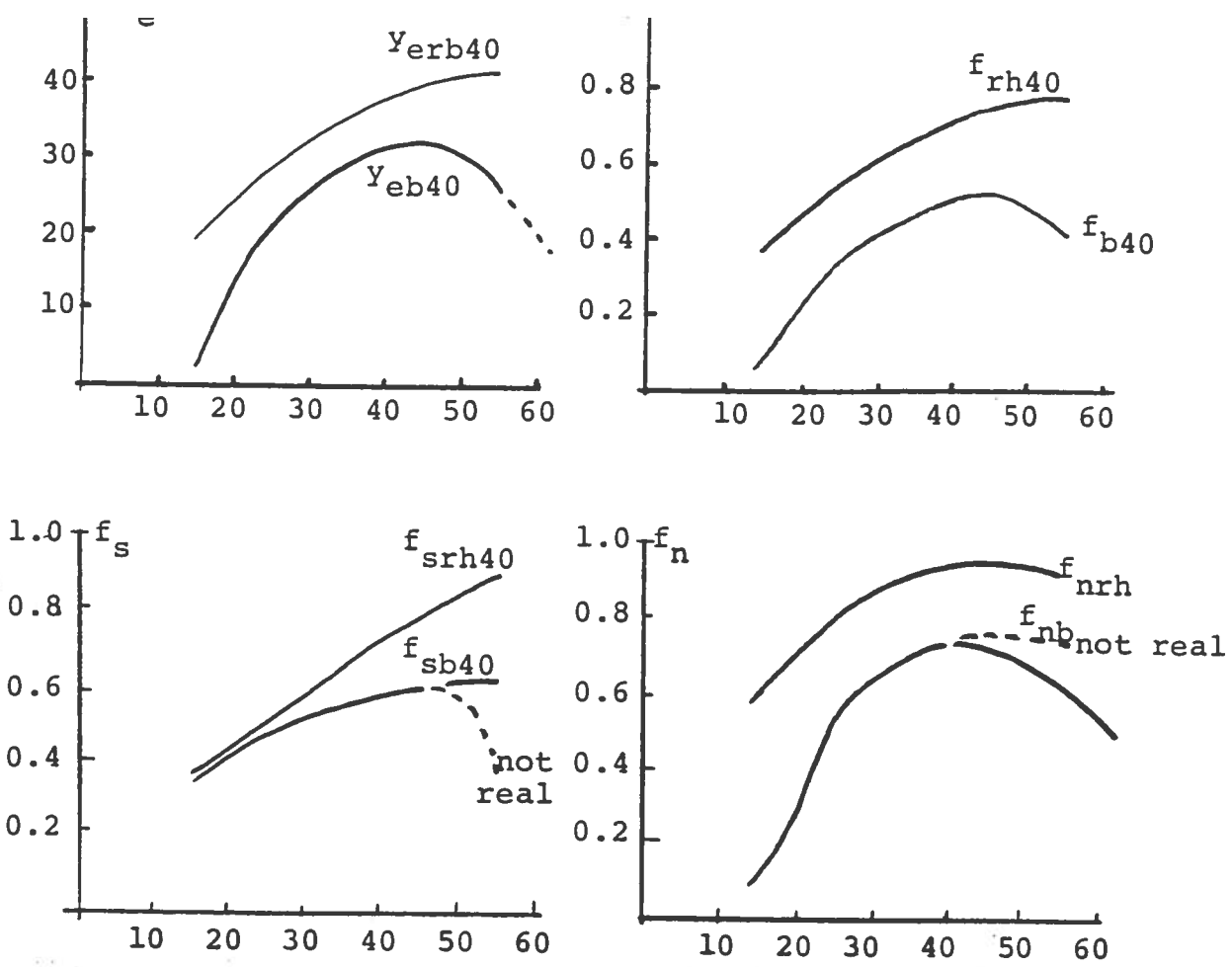

Figure 11. Effective spread net efficiency, sweep efficiency and overall efficiency for bobbins and rockhoppers, both with 40 m sweeps, positive otterboard effect 10 m, negative effect 5 m, haddock.

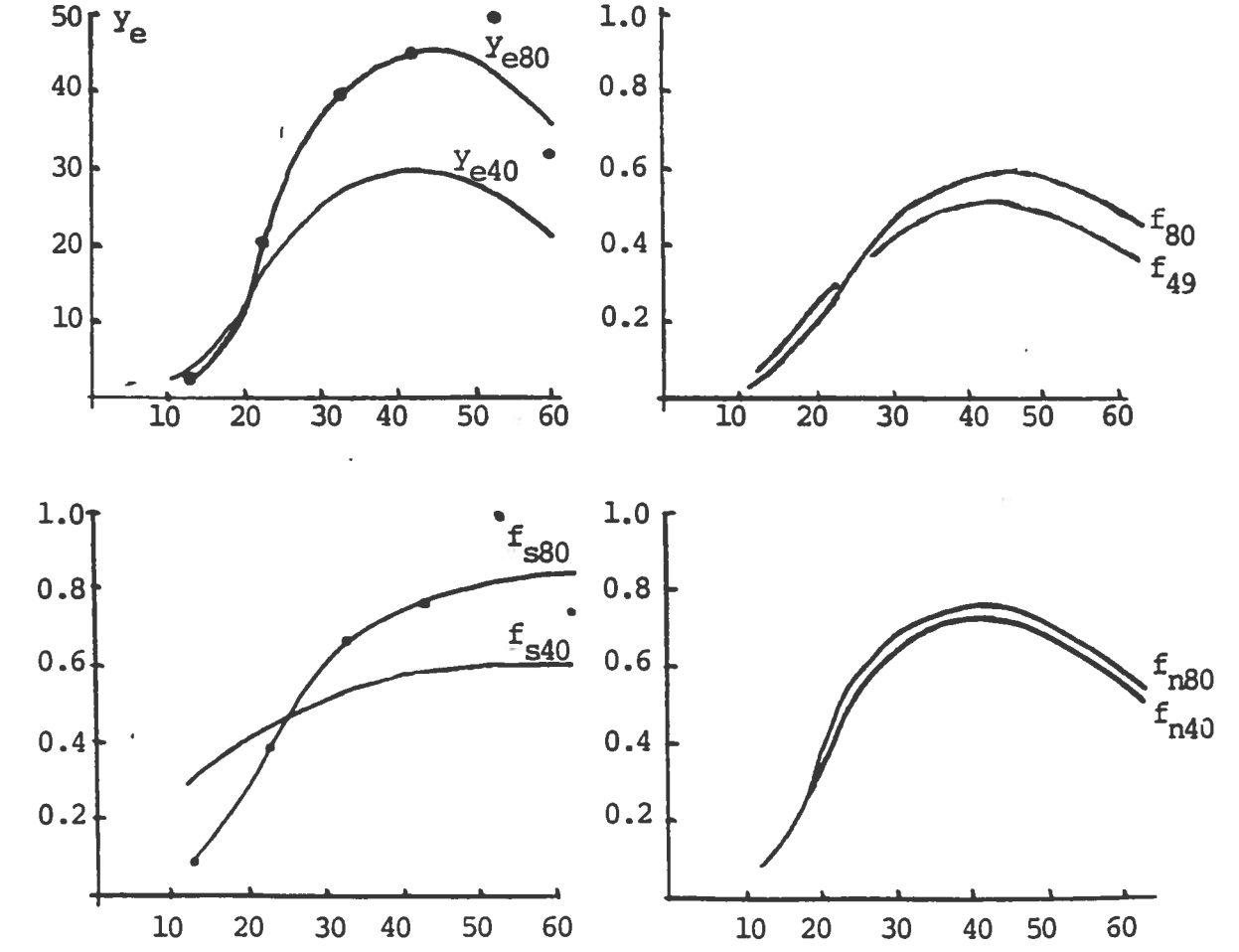

Figure 12. Long and medium sweep comparison, both with bobbin groundrope, positive otterboard effect 10 m, negative effect 5 m, haddock.