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Analysis of the 1996 Comparative Fishing Trial between the *Alfred Needler* with the Engel 145 trawl and the *Wilfred Templeman* with the Campelen 1800 trawl.

by

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Introduction

Warren (1997) reported the results of the 1995 comparative fishing trial between the *Gadus Atlantica* using the Engel 145 High Lift otter trawl and the new research vessel, the *Teleost*, using the Campelen 1800 shrimp trawl. While the fall groundfish survey in NAFO Divisions 2J and 3K was traditionally carried out by the *Gadus Atlantica*, the survey in Division 3L was carried out by the *Wilfred Templeman*. Because of the differences between the *Gadus Atlantica* and the *Wilfred Templeman* , including differences in the Engel trawl used by each vessel, it was thought questionable whether the factors developed for converting Engel catches to Campelen equivalents in the *Gadus Atlantica - Teleost* comparison would be applicable to the *Wilfred Templeman*. (McCallum and Walsh 1996). Accordingly, another comparative fishing trial was done in early 1996 between the *Wilfred Templeman* with the Campelen net and its sister ship, the *Alfred Needler* with the Engel net. It was assumed that there was no difference between vessels - only differences between the fishing gear. In addition to the five species studied in the 1995 trial, namely Atlantic cod (*Gadus morhua*), American plaice (*Hippoglossoides platessoides*), Greenland halibut (*Reinhardtius hippoglossoides*), witch flounder (*Glyptocephalus cynoglossus*) and beaked redfish (*Sebastes mentella* and *S. fasciatus* combined), yellowtail flounder (*Limanda ferruginea*) was included in the 1996 comparisons. The results of the 1996 trial are here reported.

Methodology

The trial was conducted in the same manner as the *Gadus Atlantica - Teleost* study in 1995. During February and March, 1996, paired tows were conducted in a number of areas and depths around Newfoundland, mainly Divs. 3NOP. Sets were chosen in areas where the target species were thought to occur. The ships fished at the same time and direction on each station, as close as safely possible. Where the depth contours allowed, fishing was done side-by-side, and where this was not possible because of depth, the vessels fished one in front of the other, so that the endpoint of the tow on the trailing vessel was at the starting point of the tow on the leading vessel. Gear performance was monitored on each ship with SCANMAR, and each vessel towed using the standard protocols (30 minutes at 3.5 knots for the AN/Engel, and 15 minutes at 3.0 knots for the WT/Campelen. Catch numbers and weights, as well as length measurements, were collected from the 6 target species in every set in which they occurred.

Analysis of the data was carried out in two steps. First, conversion factors were developed for Atlantic cod in exactly the same manner as in the 1995 study (Warren 1997). Specifically, the function $\log(y) = a + bx + c\log(x)$ was fitted by weighted least squares, where x denotes fish length (1 cm. length class) and y the ratio of the number caught by the Campelen (*Wilfred Templeman*) to the number caught by the Engel (*Alfred Needler*). The weights were taken as the number of trawls going into the estimate of the ratio for a given length class.

One disadvantage of this functional form is that it has a turning point at $x=-c/b$ which, since c, in general turns out to be negative, implies that the ratio decreases with length up to a certain point and then increases, contrary to what is known or believed about the relative catchability of the two nets. For lengths less than that of the turning point, the fitted functions track the data remarkably well. [The situation is somewhat analogous to fitting a quadratic to data which flattens off after an initial curvilinear increase; if the flattened section is too long the fitted curve will then decrease within the range of the data]. This does not appear to be a problem if the turning point is outside the range of the data, as turned out to be the case for cod, plaice, witch flounder and redfish in the *Gadus Atlantica - Teleost* trial (Warren 1997). For G.halibut, a turning point occurred within the range of the data, albeit not far below the maximum length used in fitting, and flattening the curve at the turning point seemed a satisfactory resolution to the problem, i.e. the above function was fitted (by weighted least squares) and applied for lengths $<= -c/b$. For longer lengths $\log(y)$ was estimated as $a+c[1+\log(c/b)]$.

The results of the 1996 study (below) demonstrate the need for a strategy when the turning point occurs more within the range of the data. To accomodate this, the fitting procedure was slightly modified. We begin by assuming the value of x ($=x_0$) (length) for the turning point. This implies $c=-bx_o$. Accordingly for $x<x_o$ we have $\log(y)= a+b[x-x_o\log(x)]$, while for $x >= x_o$, $\log(y)= a+bx_o[1-\log(x_o)]$. Given x_o we may estimate a and b by weighted least squares applied to the first component, obtain the weighted residual sum of squares and then add to it the weighted residual sum of squares for the second component. By varying x_o we can find, fairly rapidly, the value that minimizes the total weighted sum of squares. Note that this differs from the simple approach in that fitting is done by segmenting the range of lengths, whereas the simple approach fitted the original function over the full range and flattened the outcome at the turning point. The modified approach gives the actual weighted least squares fit of a two-piece model. In the cases where the turning point is close to the upper limit of lengths used in fitting the relationships, the difference between the results obtained from simple approach i.e. that used for G.halibut from the *Gadus Atlantica - Teleost* trial, and and the segmented fit should be minor.

In all cases, outliers were identified using the method described in Warren (1997), which employed a mixed Delta-Poisson distribution.

Results

A total of 180 successful paired tows was completed, spread over three trips by each vessel. This produced somewhat less than desired sample sizes for most species, given that all species did not occur in all sets. By comparison, the *Gadus Atlantica - Teleost* trial consisted of approximately 285 tows. Fig. 1 shows the distribution of catch sizes for each of the six target species. American plaice were found in most of the sets, but many of the paired sets contained no G.halibut, witch, or redfish in either net.

ATLANTIC COD

Relatively few cod were caught. In total the *Alfred Needler* caught 1053 fish (average 6.8 per tow) while the *Wilfred Templeman* caught 3350 (21.75 per tow). Lengths caught ranged from 10 to 126 cm. It is clear that the number of fish within a length class from which to estimate the ratio caught by one vessel to the other for that class will, in general, be much less than desirable.

For cod, no effort has been made to detect possible outlying pairs, i.e. pairs where one ship fished on an aggregation missed by the other. With the relatively small catch sizes, such would be difficult to detect, and could have only minimal impact on the results. Accordingly no pairs have been omitted in the analysis.

Fitting was done between lengths 19 to 85 cm. Within this range there are a few (4) lengths which were not caught by one of the vessels. As before these lengths were omitted. Only one fish of length less than 19 cm. was caught by the *Alfred Needler* whereas the *Wilfred Templeman* caught 49 fish in the range 10 -18 cm. Above 85 cm. the *Alfred Needler* caught 21 fish and the *Wilfred Templeman* 5.

The estimated relationship is

$$log(y) = 17.508391 + 0.0590243x - 5.172189\ log(x)$$

For the most part, this falls slightly below that obtained in the *Gadus Atlantica - Teleost* trial. Given the 49/1 ratio for fish less than 19 cm., the low end of the curve seems quite reasonable. The curve falls to a ratio of 1.0 at 56 cm, and 0.634 at a length of 87.6 cm. This, unfortunately, is within the range of the data, although just above the upper limit of lengths used in fitting the relationship. As with G.halibut in the *Gadus Atlantica - Teleost* trial, it is suggested that the relationship be flattened at 0.634 for lengths greater than 87 cm. The 0.634 ratio is, perhaps, larger than might be expected from the numbers of fish greater than 85 cm. but it must be remembered that these are spead over a 40 cm. length range and are, thus, difficult to interpret. Further, the confidence intervals at the upper end of the relationship are extremely wide (see below). It is, perhaps, also worth noting that the largest fish (126 cm) was caught with the Campelen net.

As would be expected, the individual length class estimates are noticeably more widely scattered about the trend than in the previous study. The 95 % confidence intervals (Fig. 2), obtained by bootstrapping, are, accordingly, somewhat wider than before. The flattening of the upper limits is a consequence of flattening the relationship above the estimated turning point, the position of which varies with each bootstrap sample. The relationship seems reasonably well defined in the length range 30-60 cm, but is poorly defined for the smaller and larger fish.

YELLOWTAIL FLOUNDER

Fitting was carried out over the range 15-51 cm. At lengths less than 15 cm. the *Alfred Needler* caught 1 fish while the *Wilfred Templeman* caught 481. At lengths above 51 cm, the *Alfred Needler* caught 6 (max. length 58 cm) and the *Wilfred Templeman* 0.

In 30 out of the 34 length classes represented in set 1-05 (trip 1, set 5), the *Wilfred Templeman* caught more fish than would be expected on the basis of the other sets. This seems evidence that the *Wilfred Templeman* here fished on an aggregation largely missed by the *Needler*. The opposite, albeit not as extreme, is observed with sets 1-13, 3-19, 3-23 and 3-42. Three fits were calculated, (i) using all sets, (ii) with set 1-05 only omitted, and (iii) with all five sets 1-05, 1-13, 3-19, 3-23 and 3-42 omitted. As indicated above, the initial fit yielded a turning point at length c. 40 cm. Accordingly, the segmented model was fitted with the following results:

Case	x_o	a	b	y at x_o
i	38	38.015836	0.3797705	0.953223
ii	39	39.445386	0.3837445	0.658641
iii	39	38.851584	0.3767125	0.755106

At the smaller lengths the difference between the fits is inconsequential, however there are clear differences at the upper end. The removal of a large number of *Wilfred Templeman* fish (set 1-05) reduces the large-fish ratio from 0.953 to 0.659. Since in sets 1-13, 3-19, 3-23 and 3-42, the numbers of *Alfred Needler* fish are above expectation (for 1/4 - 1/3 of the length classes), the further removal of these sets lifts the long-term ratio somewhat, to 0.755. Set 1-05 seems clearly an outlier and its removal justified. The situation with the other 4 sets is less clear and their removal less easily justified. Notwithstanding, since they are flagged as potential outliers, case iii should, perhaps, be preferred. The data points and fits for this model are given in Fig. 3. The curve falls below 1 after 32 cm.

REDFISH

Fitting was carried out over the range 10 - 47 cm. Below 10 cm. the *Alfred Needler* caught 0 fish, while the *Wilfred Templeman* caught 1016. Above 47 cm the *Alfred Needler* caught 1 fish (49 cm) while the *Wilfred Templeman* caught 4 (max. 55 cm).

As expected with redfish, there is clear evidence of one vessel fishing on a aggregation that was, in effect, missed by the other. The most noticeable is set 3-58 where the *Alfred Needler* is recorded as having caught > 140,000 fish, compared to about 17,000 on the

Templeman. Other sets flagged as outliers are 2-53 and 3-74. In all 3 sets the *Alfred Needler* is recorded as having caught at least an order of magnitude more than the *Wilfred Templeman* in length classes where the Campelen (*Wilfred Templeman*) would be expected to catch more than the Engel (*Alfred Needler*). Omission of all 3 sets is necessary for the relationship of conversion on length to be monotonically decreasing . There is little or no evidence of the *Wilfred Templeman* fishing on aggregations that were missed by the *Alfred Needler*.

The initial fit yielded a turning point at about 32 cm. Accordingly, the segmented model was fitted, with the result

xo	a	b	y at *xo*
28	27.898086	0.4312788	0.767082

The data points and fit are given in Fig. 4, and the curve drops below 1 between 22 and 23 cm.

GREENLAND HALIBUT

Fitting was carried out over the range 11 to 57 cm. Below 11 cm the *Alfred Needler* caught 0 fish while the *Wilfred Templeman* caught 20. Above 57 cm the *Alfred Needler* caught 5 (max 67 cm) and the *Wilfred Templeman* 2 (at 59 cm).

Since the turning point of the one-piece model is 213 cm., i.e. well beyond the range of the data, the estimates are based on the original (non-segmented) model. Sets identified as potential outliers provided the bulk of the data for lengths < 20 cm. It would therefore seem questionable to omit these sets since, rather then being outliers, they may indeed be, in good part, the only valid data for determining the short-length conversion. The estimates that follow are, therefore, based on all sets.

a	b	c
11.026226	0.0149854	-3.189120

The data points and fit are given, along with the bootstrap 95 % confidence intervals, in Fig. 5. The curve has a value less than 1.0 after 38 cm.

WITCH FLOUNDER

Fitting was carried out over the range 13 - 54 cm. Below 13 cm the *Alfred Needler* caught 0 fish while the *Wilfred Templeman* caught 139; below 20 cm the *Alfred Needler* caught only 3 witch while the *Wilfred Templeman* caught 661. Above 54 cm the *Alfred Needler* caught 3 (max 58 cm) and the *Wilfred Templeman* 6 (max 57 cm).

A few sets were identified as potential outliers, notably 2-40 and 3-88. Omission of these two sets has a small but noticeable effect of the fit above 45 cm. The exclusion of other potential outliers has negligible effect.

The turning point of the original model is 84 cm (all sets) or 64 cm (with 2-40 and 3-88 omitted); both fall outside the range of the data. Accordingly, the estimates are based on the original model.

Case	a	b	c
All sets	19.990952	0.0705058	-6.116693
2-40 and 3-88 omitted	23.209213	0.1155900	-7.475675

It is debatable whether sets 2-40 and 3-88 should be omitted, however, since they are flagged as outliers, the fit without them was chosen. The data points and fit are given in Fig. 6, along with bootstrap 95 % confidence intervals. Unity occurs at 44 cm.

AMERICAN PLAICE.

Fitting was carried out over the range 14 to 67 cm. Below 14 cm. the *Alfred Needler* caught 0 fish while the *Wilfred Templeman* caught 1272. Above 67 cm the vessels caught 2 fish each. Upper limits of 60, 55 and even 50 cm were also used but had virtually no effect on the estimates; in other words, observations at lengths greater than 60 cm are consistent with those between 55 and 60 cm and, indeed, with those between 50 and 60 cm. Above 60 cm the *Alfred Needler* caught 15 fish and the *Wilfred Templeman* caught 25. Above 52 cm, catches were 106 and 105 for the *Needler* and *Templeman* respectively.

Several sets were identified as potential outliers, the two most notable being 3-53 and 3-85 with, in both, the *Wilfred Templeman* seemingly catching more fish than would be expected. However, as will be shown, omitting these two sets has a negligible effect on the estimates and the effects of excluding the other potential outliers would be even less.

The initial fit had a turning point at 45 cm. Accordingly, the segmented model was fitted, with the results

Case	*xo*	a	b	y at *xo*
All sets	40	41.729647	0.3858129	1.262973
3-53 and 3-84 omitted	41	39.957925	0.3580765	1.126038

The data points and fits are given in Figs. 7. Note that the conversion levels off at a value > 1 after 41 cm. (Fig. 8). This happens whether we fit over the range 10-67 cm or 10-50 cm. and, thus, does not appear to be an aberration consequent on a few peculiar sets. This does not agree with the results for any other species in this trial or in the previous *Gadus - Teleost* work. However, it must be noted that there is a considerable amount of scatter in the ratios for fish above 45 cm (Fig. 2 in Warren 1997), and that he advocated fitting a second curve for use with fish larger than 40 cm, which would give greater predicted values for that portion of the length range.

Given that no explanations could be found for the differences in the results for American plaice from the 2 comparative fishing trials, data for this species from the last Engel surveys were compared with data from the first Campelen surveys in approprite areas. For the *Gadus - Teleost,* this comparison involved the surveys in Div. 2J in 1994 and 1995, and for the *Wilfred Templeman*, population abundance at length was compared between the 1994 fall (Engel) and 1995 fall (Campelen), and between the 1995 spring (Engel) and 1996 spring (Campelen) surveys in Div. 3LNO. At these sizes, large increases from one year to the next would not be expected unless there is a difference in gear efficiency. The results of these comparisons are shown in Fig. 9 (fall) and Fig. 10 (spring). The population abundance at length, as well as the ratio of the population abundance from the Campelen to the Engel, are shown. In the majority of comparisons the population abundance from the surveys using the Campelen is higher than that from the Engel, in some cases substantially so. This supports the results of the comparative fishing that suggest that the Campelen trawl catches more fish at larger sizes than the Engel. For the *Gadus - Teleost* comparison, there were almost no A.plaice larger than 40 cm caught in either 1994 or 1995. For all fish larger than 36 cm, the ratio of *Teleost* population abundance to *Gadus* was 2.1, agreeing with the *Templeman* results.

On the other hand, Walsh (1992) determined that there was very little difference in the efficiency of the Engel survey trawl for both A.plaice and yellowtail (Fig. 11a). This was based on bag trawl experiments conducted on the Grand Bank in 1988. He found that selectivity of the trawl was size-dependent and never reached 100% for either species. Using the same methodology, work was completed in 1994 on the efficiency of the Campelen trawl (Walsh unpubl. data). For A.plaice, the data suggest no difference in trawl efficiency above 34 cm, with the Campelen trawl being much more efficient at lengths below 34 cm (Fig. 11b).

Discussion

It will be noted that bootstrap confidence intervals have not been generated for yellowtail flounder, redfish and American plaice. This is because, with the segmented model, the parameters have to be estimated iteratively. Not only would this require some careful programming, but c.p.u. time would be significantly increased. There is no reason to believe that, for these three species, the precision of the estimated relationship would differ substantially from that indicated by bootstrapping for the other species.

The conversion factors of the 1995 *Gadus Atlantica -Teleost* study reflect vessel differences as well as difference between nets. Since the *Wilfred Templeman* and *Alfred Needler* are sister ships, the 1996 study should reflect differences between nets, with vessel effects minimized if not eliminated. In addition to potential vessel differences *per se*, the Engel net, as used on the *Gadus Atlantica*, differs from the Engel net, as used on the *Wilfred Templeman* (McCallum and Walsh 1996). Accordingly, there is no reason to suppose that the results from the two studies should be identical although, with the Engel - Campelen differences as the principal factor, one might hope for some similarity. Thus, for cod, with the exception of the upper end of the relationship, which is poorly defined at best, the conversion factors from the present study appear to be somewhat smaller than those obtained from the *Gadus Atlantica - Teleost* trial.

The greatest discrepancy between studies appears to occur with American plaice, where, in the 1995 study, the conversion factor was estimated to progressively decrease to values less than 1.0 at lengths above 42 cm (eg. to around 0.5 at 55 cm) while, in the present study, the conversion factor is estimated to flatten off at a value greater than 1.0 at lengths above 40-41 cm. The plotted points Fig. 2 of Warren (1997) suggest that the latter relationship might in reality also flatten off around 1.0 and lengths greater than 43 cm.; these points, however, carry very little weight. Application of the segmented model to the 1995 data clearly gives a turning point outside the range of the data.

Are the estimated relationships accurate enough to be used? In the mid-length range the answer is probably yes, but problems remain with the shorter and longer lengths. Since, however, the Engel was not effective at catching the very short lengths, the practical solution is to determine a lower bound on length with no attempt at conversion for lengths below this. Improvement for the longer lengths requires adequate numbers of fish of such lengths to be caught. This would be difficult and costly. An alternative is to specify, by some means, a (constant) value of the conversion factor for fish above a certain length (this approach can also be used for fish below a certain length at the other end of the length scale). The nature of the chosen function is such that any realistic choice of these values would have little effect on the main body of the fit.

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Walsh, S.J. 1992. Size-dependent selection at the footgear of a groundfish survey trawl. N. Am. J. Fish. Mgmt. 12:625-633.

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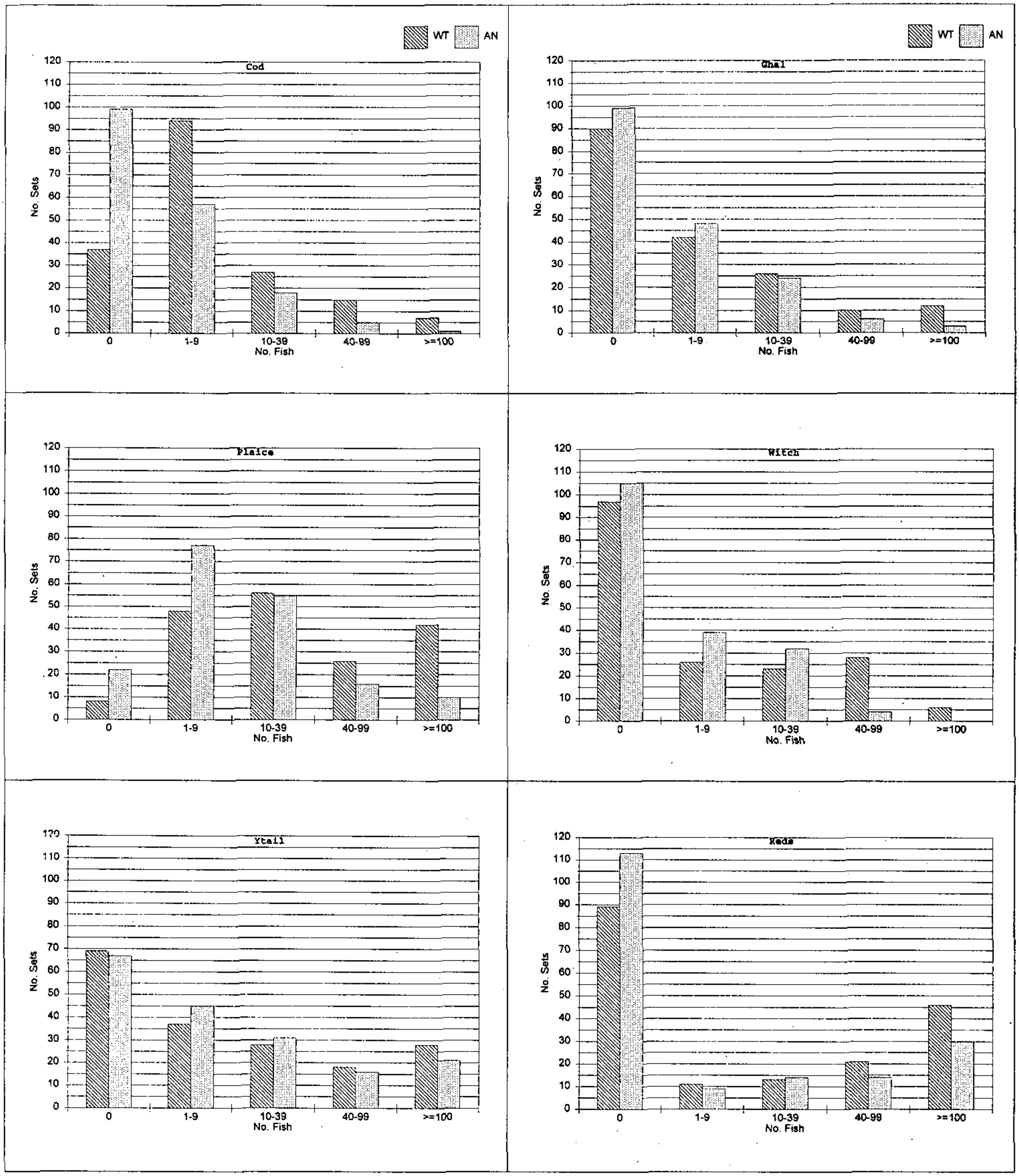

Fig. 1. Range of catch numbers for the six target species in the comparative fishing experiment between *Alfred Needler* and *Wilfred Templeman* in 1996.

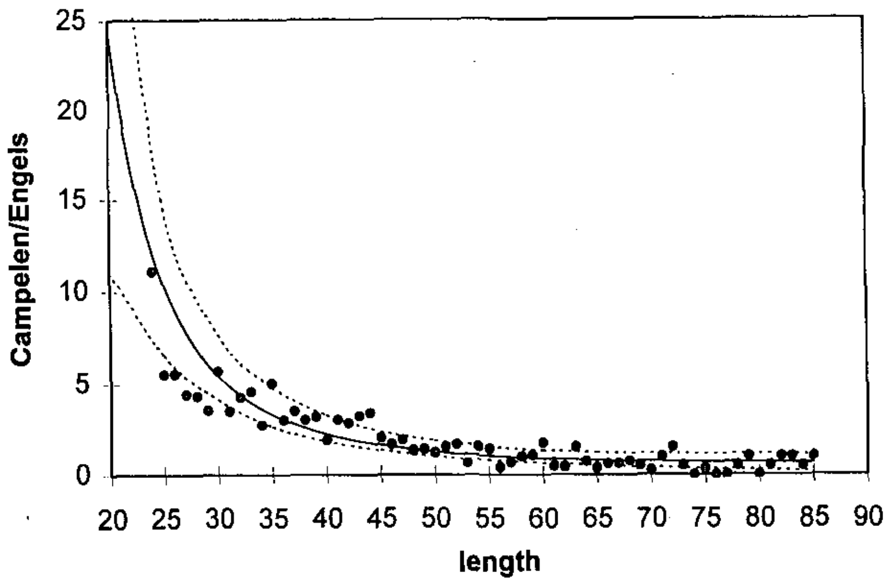

Fig. 2. Ratio of Campelen catches to Engel catches for cod. Solid line shows the fitted model, and the dashed lines indicate the 95% confidence limits.

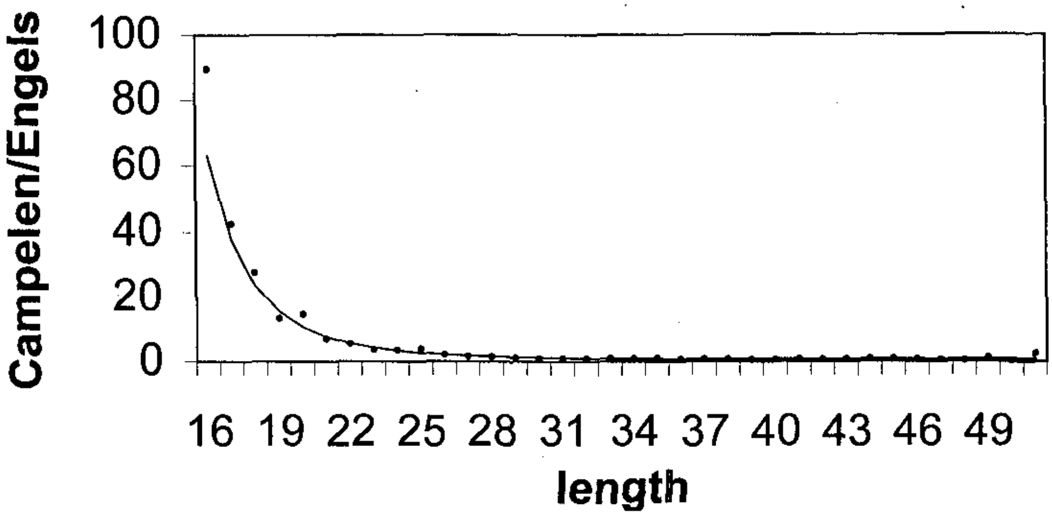

Fig. 3. Ratio of Campelen catches to Engel catches for yellowtail flounder. Solid line shows the fitted model.

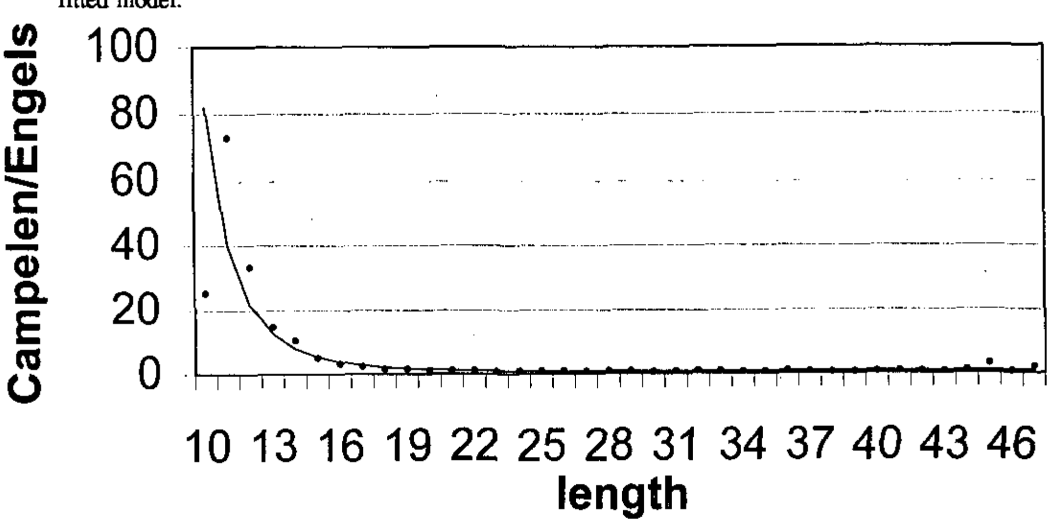

Fig. 4. Ratio of Campelen catches to Engel catches for beaked redfish. Solid line shows the fitted model.

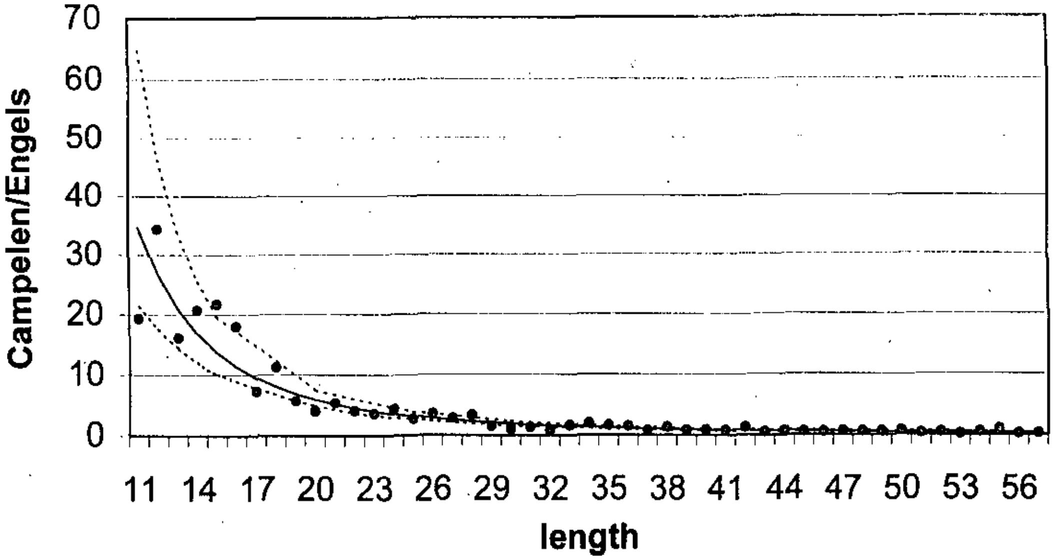

Fig. 5. Ratio of Campelen catches to Engel catches for Greenland halibut. Solid line shows the fitted model, and the dashed lines indicate the 95% confidence limits.

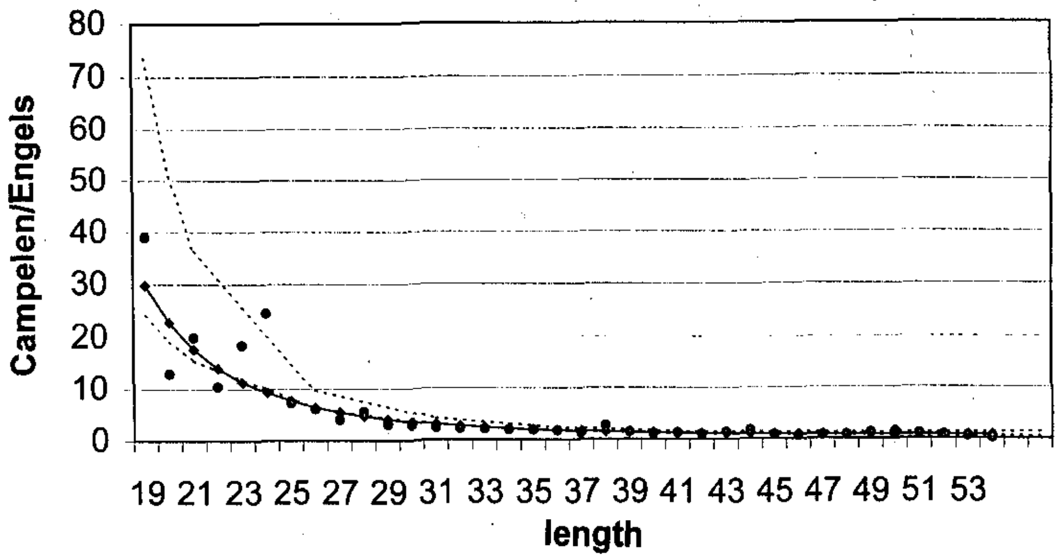

Fig. 6. Ratio of Campelen catches to Engel catches for witch flounder. Solid line shows the fitted model, and the dashed lines indicate the 95% confidence limits.

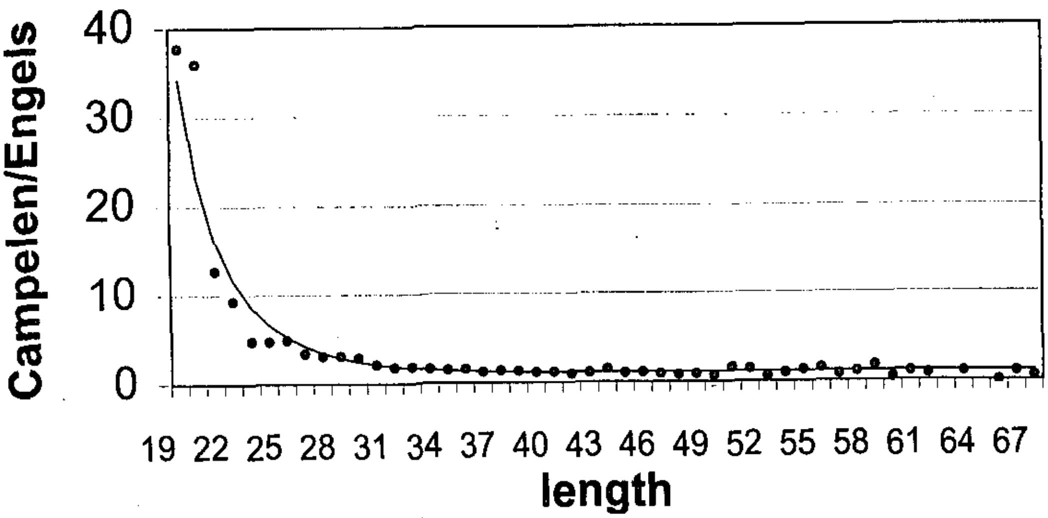

Fig. 7. Ratio of Campelen catches to Engel catches for American plaice. Solid line shows the fitted model.

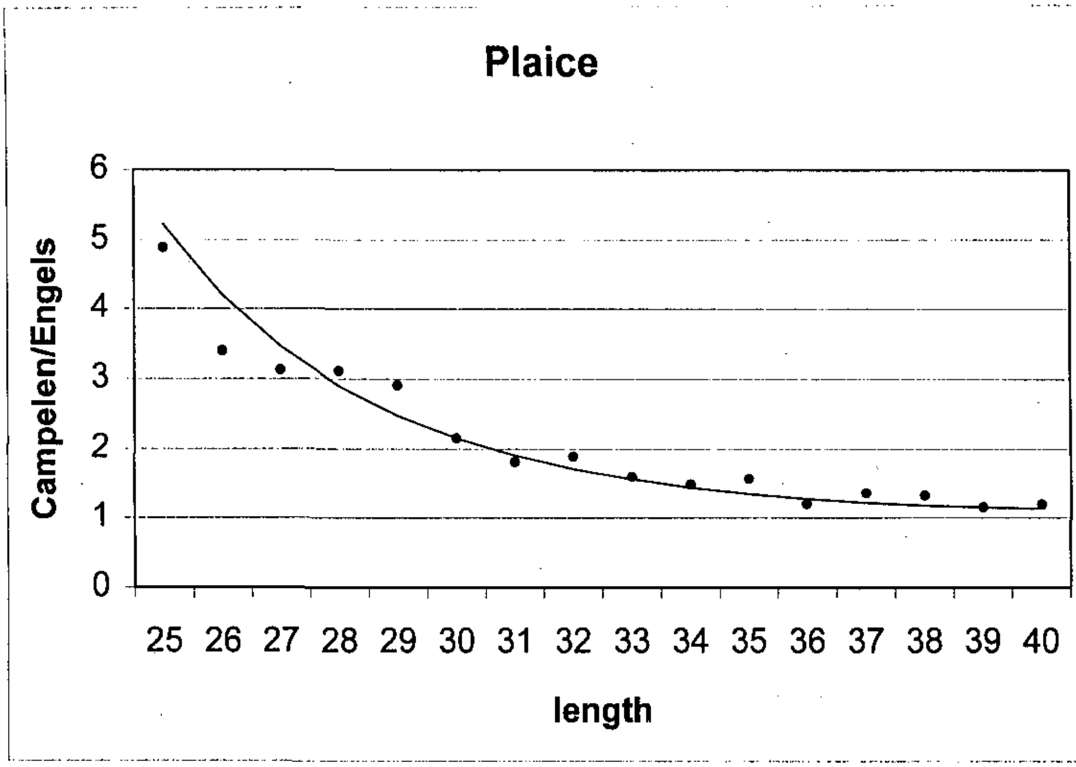

Fig. 8. Ratio of Campelen catches to Engel catches for American plaice, over lengths 35 to 40 cm.. Solid line shows the fitted model.

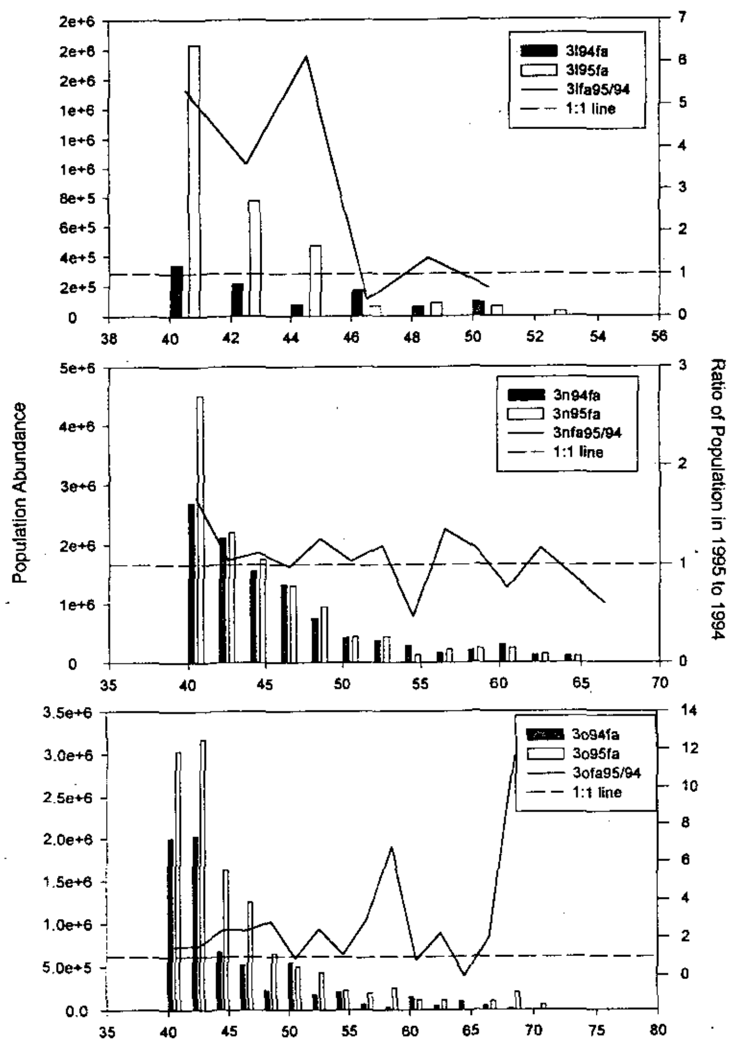

Figure 9 Population abundance for 40 cm and greater American plaice from fall surveys in 1994 (Engels) and 1995 (Campelen).

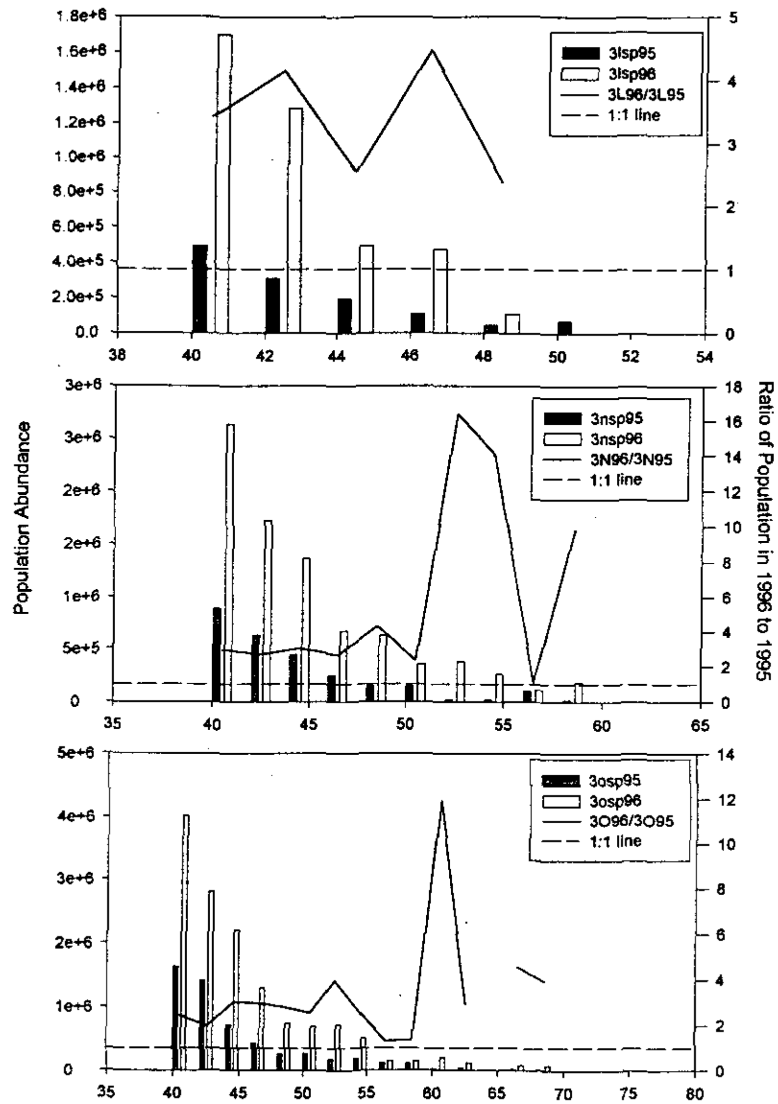

Figure 10 Population abundance for 40 cm and greater American plaice from spring surveys in 1995 (Engels) and 1996 (Campelen).

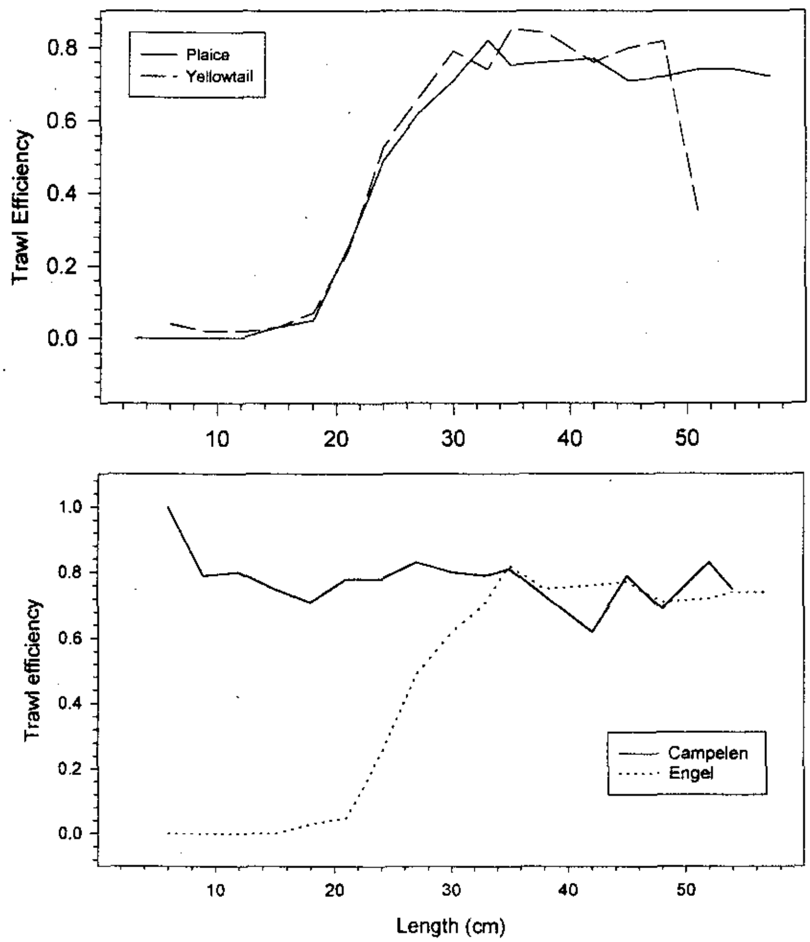

Fig. 11 **A. Trawl efficiency of the Engel 145 high lift otter trawl for American plaice and yellowtail flounder (adapted from Walsh 1992). B. Comparison of trawl efficiency of the Engel High Lift otter trawl (1998 experiments) and the Campelen 1800 shrimp trawl (1994 experiments) for American plaice on the Grand Bank.**