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Prelininney malyeis of A.T. CAMrson - LADY BAYMODD comparative fishins experimenta 1979-81
by

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1 Cette sarie documente les bases scientifiques des conseils de gestion des peches sur la côte atlantique du Canada. Come telle, elle couvre les problemes actuels selon les Echeanciers voulus et les Documents de recherche qu'elle contient ne doiveat pas étre considerfes comat des Enonces finals sur les sujets traités mais plutôt comme des rapports d'Etape sur les Etudes en cours.

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## Introduction

In 1970 the Marine Fish Division, Scotia-Fundy (then Maritimes) Region began a time series of summer (July) stratified randon ground travl gurveys on the Scotian Shelf. These aurveys are an important source of data for species asbessments conducted by CAFSAC. When the A.T. Cameron was retired after the sumer survey of 1981 , the Department vessel which was to carry on the time series in the long term (Alfred Needler) was not yet avilable. A gap between the old and new series, in fact, was anticipated in 1978 when comparative fishing experiment began between A.T. Cameron and Lady Hammond, a chartered vessel which would bridge the gap by comparative fishing with both vessels. Experiments continued in the summers of 1979,1980 and 1981 between A.T. Cameron and Lady Hamond, and begen between Lady Harmond and Alfred Needler in the fall of 1982, With an edditional experiment planned for the summer of 1983. Since neither the A.T. Csmeron nor the Alfred Needler were avallable for the July 1982 groundfieh survey, this crulse was conducted by Lady Hamond using a Western IIA trawl, this being the first time the aurvey was not conducted by the A.T. Cameron-Yankee 36 fishing unit. This report presents some anslyses on the experiments conducted from 1979-81 between A.T. Cameron and Lady Hammond. Because the reactions of Eish to trawling gear is likely to be species specific and even aize specific, and because of the large mount of data ganarated, it is not possible at this time to present anslyses for all species, or even a detailed analysis for one species whose and result is "conversion factor" which can be used to intercalibrate the two tise aeries. Rather, it is the intention of this report to preaent the problems with and linitations of the data preliminary to generation of such conversion factors and to outline a philosophy and stimulate discussion on their use.

## Materials and Methoda

The experiments analyzed in this report wera conducted in July 1979, 1980, and 1981, and involved two vessel-gear units: the A.T. Cameron fishing a standard Yankee 36 survey trawl, and the Lady Hammond fishing a atandard Western IIA survey trawl. During the first experiment conducted in 1978, Lady Hammond used a high-1ift Engel trawl. This gear was aubeequentiy deemed unsuitable as a survey tool and dats from this experimant are not considered here. Differences between the two veasel-gear units used in 1979-81 are mumarized in Table l. In general, the vessel are sinilar in that they are more than powerful enough to drag the gear and have ainilar size and tonnage. Similarly, the overall dimentions of the two trawls are not greatly different, so that great diffarances in their catching power are not expectad. Several differences in vensels and gesr, however, are apparent which may lead to differencea in catch. Side trawling involves different vessel manoeuvres at the beginning and and of a tow which may influence catch at these times. Although the Western IIA (WILA) has a longer footrope, the amount of netting attached to it is less than on the Yankee 36 , i.e. the WIIA has "ilying wing." Although wingspread measured between wing tips is greater on the WIIA, the spread at the end attached to the footrope way be less than the Y36. Thue, the "effective width" of the trawl for some species may be less on the WIIA if fish can escapu over the footrope and to the side, undar the llying wing. The all-rubbar bobbins on the WIIA footrope are reported to make better contact with the botton than
the steel bobbins on the Y 36 , possibly improving the catch of on-bottom fish (i.e. flatfish). The liners of the two trawls are considerably different. The WIIA has a liner in the belly extension which may prevent escape of fish through the meshes in this area caused by buildup of water pressure from the fine meshes in the codend. It also has larger mesh in the codend to decrease this pressure. This larger mesh may, however, also allow greater escape of very small fish that make it back to the codend. The WIIA has a considerably higher headline height which may improve the catches of species distributed slightly off bottom.

The experiments were conducted during the routine July groundfish survey of the A.T. Cameron. Both vessels fished the same randomly selected groundfish survey stations at the same time, side by side. Beginning times of comparative sets were generally within 10 min of each other. Distance between vessels was generally less than 1 naut mi (i.e. both sets were almost always made within the same $2 \frac{3}{2} \times 2$ naut mi standard sampling unit used to select stations), although this varied depending on conditions of visibility, weather, trawlability at the station, and the cooperation of the crew. Beginning and end of set was determined independently on each vessel using Decca, Loran C, or satellite navigation if necessary, but the same navigational method was used on both vessels as much as possible.

Both vessels towed at 3.5 knots as determined independently on each vessel. The A.T. Cameron used a Doppler log (speed over bottom) throughout. The Lady Hammond used a water-inertia type of $\log$ (speed through the water) during the 1979 and 1980 experiment, but switched to a Doppler-type log in 1981. Actual ship speed over the bottom during the set was determined after each survey from begin and end positions recorded on trawl logs and the set duration.

Catches were processed on both vessels according to standard groundfish procedures except that aging material was not collected on the Lady Hammond.

## Results and Discussion

## Speed and tow standardization

Since fish reaction to the trawl and trawl characteristics are likely to change with ship speed, speed is kept constant at 3.5 knots on standard surveys. Similarly, since the amount of catch is not necessarily linearly related to the amount of time the trawl is on the bottom, time of tow is standardized to 30 min . While length of tow is relatively easy to standardize to 30 min on an individual set basis, speed varies considerably from set to set and generally approaches 3.5 knots only on the average. Slow speeds are difficult to maintain because of imprecise throttle settings (actually propellor pitch adjustment) and changes in surface water currents. The closeness of ship speed to the standard on an individual set is therefore dependent on the diligence of the operator in constantly adjusting the propellor pitch, and to some extent, on how quickly the vessel decreases to survey speed after shooting the trawl.

The question of speed is particularly important for the Scotian Shelf survey because catches are adjusted to a standard distance of 1.75 naut mi , i.e. catch is multiplied by the ratio of 1.75 to the actual distance traveled during the set, as determined by the begin and end positions. Since the distance of 1.75 naut mi (i.e. speed of 3.5 ) is achieved only on the average, this means that most catches are adjusted, an adjustment made on the dubious assumption that the amount of catch is linearly related to the distance traveled, at all speeds. This standardization can have a strong effect on the catch ratios of comparative sets if distances traveled are other than 1.75, especially if one set is at one end of the range of distances traveled and the other set is on the other end of the range. The effect of standardization on haddock catch ratios is shown in Fig. 1. Note that a significant correlation between ratios and differences in distance traveled appears after standardization. This problem is further compounded by a speed bias which occurred on the Lady Hammond during the 1979 and 1980 experiments due to growth of a mussel in the sensor outlet. Figure 2 shows that actual speed over bottom was increasingly underestimated beginning in 1978 until the problem was resolved in 1981. The actual distribution of speeds during each survey is given in Fig. 3. Since the effect of trawl speed on fish catch and trawl behavior is unknown, some of the analyses performed were conducted on raw catches rather than apply an adjustment made on dubious assumptions.

Before decisions can be made as to how conversion factors might be calculated and how they should be applied, or even if they are necessary, the data must be explored and several hypotheses tested. The most obvious and important is: are there significant differences in species catches between vessels? Other questions to be answered, in no particular order of importance include: within a species, are there significant or consistent differences in the catches between length groups?; are any differences observed consistent between years?; are catch ratios influenced by other factors besides differences in the vessel trawl unit, in particular, speed, speed differences between vessels, time of day, depth, depth differences, and distance between vessels?; is the relationship of catches on Lady Hammond vs A.T. Cameron linear for all sizes of catch or is the relationship more complex?; finally, is the inherent variation of the data small enough to allow these questions to be answered and to produce meaningful conversion factors? Only some of these questions can be addressed at this time.

## Differences in species catch between vessels

The Wilcoxin matched pairs ranked sign test and the paired t-test were used to test the hypothesis that numbers caught differed significantly between vessel gear units (Table 2, 3). Wilcoxin tests were applied to all comparative sets in which one vessel caught at least one fish while t-tests were done only on non-zero sets for both vessels. All catches were standardized to 1.75 naut mi. The $\log _{10}(x+1)$ transformation was applied to the data for t-tests only. For cod the t-test was not significant for all three years, while the Wilcoxin test gave a significant difference at $\mathrm{p}<.05$ for 1980 . For haddock, t-tests were marginally insignificant in all three years, while Wilcoxin was significant for both 1980 and 1981. Plaice was insignificant for both tests in all years. Differences in redfish catches were significant in 1980 and 1981 for both tests. For pooled data (1979-81), the t-test was significant for all species tested except cod,
while Wilcoxin was significant for all species except plaice. Note that the differences between vessels were almost always consistent within species and between years with regard to which vessel caught more on the average. In fact, Lady Hammond caught more during all experiments of all four species except for cod in 1979 and 1980. For some species, then, it appears that catches differ significantly, although not greatly, between vessels. These differences require further investigation.

Catch ratios and data exploration
Catch ratios of retransformed means (Table 3) were relatively consistent within species between years, particularly for haddock, where ratios for all years differed only by $5 \%$. For plaice, cod, and redfish the ratios for 2 yr were within $5 \%$ of each other, with the third year still relatively close. For these species, the highest ratio for all years was obtained for redfish, an off-bottom fish which one would expect to catch in greater amounts with a net having a higher headline height. It is particularly noteworthy that the two "off-bottom" species (redfish and silver hake) had the two highest catch ratios of all species examined (Tables 3 and 4).

Simple catch ratios ( $\Sigma L H / \Sigma A T C$ ) and their standard errors (untransformed, all non-zero values) were calculated for 10 species to see if there were some consistency in ratios from year to year on the linear scale, but also to simply obtain some initial impression of the magnitude of differences in catch between vessels and species (Table 4). Catch ratios varied considerably from year to year and from species to species, although the ratio was generally greater than 1 for all, or the majority of years, for all species.

For cod and haddock, an attempt was made to subjectively identify sets where one vessel caught a much greater amount than the other and which greatly influenced the ratios and standard errors. Two such sets, both in 1979, were identified for haddock and three for cod, one in each year. Removal of two anomalous sets for haddock in 1979 resulted in relatively similar ratios between years of between 1.0 and 1.3 , and a marked decrease in the S.E. for 1979. For cod, removal of out-liers gave relatively similar ratios for 1979 and 1981, close to 1 , and greatly decreased standard errors, but it also reduced the ratio of 1980 well below 1 . It is apparent that these ratios are greatly influenced by individual comparative sets and that further exploration of the data is required to understand the inherent variability present, its sources, and the kinds of assumptions that may be required.

Two approaches were investigated: 1) ratio of numbers caught, and 2) linear model building. Attention was focused on numbers caught, keeping in mind that working only with numbers or only with weight as a variable may be misleading due to the varying size composition of the catch; we felt that an understanding of the behavior of numbers caught could precede and lead to an understanding of weight as a variable.

For the ratio approach, the Jackknife estimator was used in order to estimate the precision of the ratio estimate. As discussed previously, the speeds of the two vessels were highly variable and catches had been adjusted to a $3.5-\mathrm{knot}$, $\frac{1}{2}$-hour tow standard. In addition, it was found that large
differences in bottom depth also occurred. In order to investigate the potential effects of these differences, Jackenife ratios and coefficients of variation were calculated for various combinations of speed and depth difference criteria. The criteria for speed chose those observations for which the speed of both vessels was within the range of $3.5 \mathrm{knots} \pm 30 \%, 20 \%$ and $10 \%$. The depth criteria was simply set to increments of the absolute difference between the recorded depths for the two vessels. Unstandardized haddock catches were used in this analysis. The results are presented in Table 5. The results for the coefficient of variation showed an interesting pattern with respect to the criteria used. The most precise estimates of the ratio of catches were obtained for +1 fath for $1981,+3$ fath for 1980 , and +5 fath for 1979. Results were less consistent for the speed criteria within these depth ranges. In order to understand this pattern, a component of the Jackknife formula $\frac{L H_{i}}{A T C-i_{1}}$, where " $-i$ " indicates that the
ith pair of points has been removed, was plotted against the difference in depth. These plots are presented in Fig. 4. The important point to note here with regards to these plots is that in each case there are a few points which seem to be driving the ratio estimates. These points are large catches for which there were substantial differences in the sizes of the catch between the two vessels. In addition, there was no consistent relationship between difference in depth and these points. The ratio approach appears to be highly sensitive to a few large catches. Some of these catches could be eliminated by restricting the depth or speed range. A closer examination was made of the distribution of size classes present in the catches (see below) and, again, for some cases, this information can be used to eliminate sets where there were extreme differences in the sizes of fish caught. However, all of these criteria remain ad hoc in nature until more is understood about the spatial distribution of the fish and the interaction of the nets with the size distribution of the fish.

For the linear model approach we assumed a simple model of catch $(\mathrm{LH})=$ catch (ATC). Attention was directed on exploratory analysis of the distribution of the resultant residuals. Transformations were applied in order to symetrize the residuals. Square root transformations seemed to be adequate enough for the data from 1980 and 1981, whereas a fourth root transformation was required for 1979 . Sets identified by the ratio approach as being outliers naturally showed up again with large residuals, but some of the smaller sets, especially those with few or no fish caught by one vessel, also showed up with large residuals. Plots of residuals vs the Cameron catches (appropriately transformed) (Fig. 5) indicated that a weighted regression may be necessary for 1980, but these patterns were less clear for the other 2 years.

Logarithmic transformations were also considered and assessed. These proved to be more appropriate for making the residuals symmetric but zeros presented a problem. For now, one was added to zero catches in order to use the logarithms. The residuals for 1980 still tended to show the need for some sort of weighting. As before, small catches, especially those where few or no fish were caught by at least one of the vessels, had large residuals and were extremely variable in nature.

Therefore, both ratio and linear model approaches may run into serious problems with extreme values, with the latter being sensitive to both large and small catches. In the case of the log transform, the residuals are simply the $\log$ of the ratios of the individual catches. For small catches, a small amount of variation in the numbers caught would change these ratios a great deal and, therefore, residuals in this range would naturally be highly variable. It may be, that due to the variation present, small catches may need to be weighted in order to diminish their effect due to the limited amount of information that they can offer. Again, determining how small is small seems to be an ad hoc matter at this point.

## Catches by length groups

Comparison of catches between vessels based on total numbers or weights caught would be misleading if catches between length groups differ within species. To examine the possibility of consistent differences in catches between length groups, the total catch per length group and relative length frequencies of measured fish were plotted (Fig. 6). Note that length groups in these plots do not represent centimeters.

For 1979 cod (Fig. 6a), there was relatively good correspondence in modes between vessels, although there appeared to be differences in both total numbers and relative proportions caught in these modes, particularly those at length groups 8 and 13-14. Sample size in 1979 was relatively small and these patterns may be due to the inherent variation of the data, since plots of the percent caught in these modes on Lady Hammond vs A.T. Cameron showed no particular pattern (not shown). Total cod caught in 1980 (Fig. 6b) within each length group appeared to differ considerably between modes, but these differences were not consistent with those observed in 1979. Moreover, the differences between vessels largely disappeared when only measured fish were considered, and agreement was better still after removal of the outlier previously identified. Thus, the large differences in total catch of length groups in 1980 can be attributed to differences in the length frequencies of a few large subsampled sets. This may be due to unrepresentative subsampling, or to changes in catchability of length groups with size of catch, or other factors. The agreement of catches for length groups in 1981 is good for both total catches and percent frequency of measured fish (Fig. 6c).

For 1979 haddock (Fig. 6d), catches appeared to be considerably higher on Lady Hammond above length group 20, but relatively similar below. Again, these differences were reconciled by plotting only measured fish, with better agreement still after elimination of the two outliers previously identified. On further investigation, the slight indication of higher catches below length group 7 and lower catches in group 10-12 on A.T. Cameron did not prove to be consistent between sets, and appeared to be caused by only several sets. Catches by length in 1980 (Fig. 6e) were very similar between vessels but with some indication of lower catches on ATC around length group 10, as in 1979, and a slightly higher proportion of the catch between length groups 23 and 28. Again, these differences did not appear to be very consistent from set to set. In 1981 (Fig. 6f) the modes for haddock generally correspond, but there also appeared to be relatively large differences in both total numbers and proportions of fish caught in these modes. These differences are somewhat consistent with previous years
for haddock in that proportionally more fish were caught on A.T. Cameron below 7 as in 1979, and less around length group 10 as in 1979 and 1980, but it is the opposite of what was seen for approximately the same size groups of cod in 1979. Small haddock appeared to be particularly abundant in 1981. Larger catches of very small fish may be expected on A.T. Cameron because of the smaller liner in the codend, while the larger catches on Lady Hamond around length group 10 may be due to the aft belly liner which may prevent escape of somewhat larger juveniles. In any case, these observations warranted further investigation. This was done by plotting the percent of the total set catch in the suspect length groups ( $1-7$ and $8-12$ for all years) on Lady Hammond vs A.T. Cameron for all catches greater than 50 fish. No trends were apparent except for 1981 where most sets in this category on A.T. Cameron generally had a greater percentage of the catch below length group 7 and a lesser percentage between 8-12 (Fig. 7). This pattern persisted when catches greater than 10 fish were plotted (not shown).

It is apparent that there is generally a good correspondence in the relative proportions of length groups caught for cod and haddock after eliminating variations due to subsampling or otherwise. There is, however, also some evidence suggesting that in years when small fish are abundant catch ratios for these fish may differ from other length groups in ways that appear to be consistent with differences in trawl construction.

Total catches within length groups were also plotted for yellowtail, plaice, pollock, redfish, and silver hake (Fig. 8), but these were not subjected to further analysis. Pollock and redfish catches are particularly variable, as might be expected for species with a highly contagious distribution which may be localized within the path of the two vessels. It is noteworthy that silver hake catches are consistently much higher for most length groups in all years, which is consistent with the species' off-bottom distribution as mentioned above.

## Comparison of stratified catch rates

We have compared and examined catches at various levels, i.e. total catches per species, and catches of length groups within species. The highest level of comparison would be of an entire cruise result as produced by the STRAT program. This is possible since both vessels completed an entire cruise of the same stations at the same time. It is of interest to determine whether differences in the STRAT runs produced for the two vessels are within the usual variations one might expect for these statistics. Stratified means were calculated for both vessels for the usual strata groups as well as all strata combined for cod and haddock (Table 6). The data were standardized in the usual way and the five outliers mentioned above were excluded. Catch ratios of stratified means between strata groups varied considerably. This might be expected since differences in catch between vessels, which are themselves variable, will be exaggerated or reconciled more or less at random by the allocation of comparative sets within strata and by the strata weighting factor. The overall stratified means, however, are remarkably similar between vessels with the 1979 and 1981 ratios of means close to 1 , and certainly well within the variations one might expect from such surveys. It is unlikely, for example, that two identical fishing units fishing a different set of random stations at the same time would produce estimates as close. The 1980 survey estimates were
relatively different for both species, but still within the usual survey variations. Because of the strong influence individual sets have on these estimates, comparisons made at this level require further investigation.

Conversion factors and their application to survey data
Before considering how to calculate and apply conversion factors, one should ask if they are necessary, i.e. if they can reduce the uncertainty associated with the present gear change. In order to answer this question, one must consider the inherent variation of both the conversion factor and the survey to which they are to be applied. Intuitively, we can draw the conclusion that the conversion factors (e.g. the ratios or models presented above) are more accurate and precise than the surveys themselves if we assume, probably correctly, that large-scale spacial variation within the survey area and changing catch size with time of day are the greatest source of variation for survey data. Variation due to macro patches, diel rhythms and other factors affecting catch (e.g. tide, depth, etc.) are essentially eliminated with side-by-side trawling. It is very likely that exactly the same gear working on two different sets of random stations on the average will produce results more different from each other than two slightly different gears fishing the same stations side by side. Preliminary analysis seems to support this view. Initially at least, we have more confidence in the conversion factors than in the surveys themselves. Although we are in doubt as to the exact figure, we are reasonably confident which direction the conversion factors take and their approximate order of magnitude, i.e. for many species Lady Hammond catches more, but not much more.

A conversion factor of, for example, 1.2 or 1.3 for haddock is meaningful only in the long term when comparing trends, much as the surveys themselves. To take a year out of the context of the time series and apply a conversion factor to it is dangerous since it will reconcile or accentuate differences between the experimental and parametric mean more or less at random, depending on where the mean happens to fall that year. In this context, confidence in a conversion factor will be maximum only after many years when the trend lines from the two series can be put end to end to see if a break in the time series is apparent. This is the ultimate level of comparison, but it comes only when comparisons are no longer required.

Theoretically, how conversion factors were obtained should determine how they are applied to survey data. Ratios such as presented above are obtained from many sets made under a large variety of conditions and represent a mean conversion factor that should not be applied to individual sets but only to overall results from a survey which encountered a similar variety of conditions. Practically, of course, it makes no difference whether a catch factor is applied at the individual set level, or to the biomass estimate or the stratified mean. The answer is the same, although the former requires more computation time. There is some evidence to suggest that the relative fishing power of the two vessels is dependent on prevailing conditions at the time the set was made, in particular, time of day. However, while in some cases these differences may prove significant, upon further investigation it is unlikely that factor-specific conversions other than vessel-trawl type can be applied with confidence on an individual set basis.

The use of conversion factors for length groups within a species should be approached with extreme caution. The experiments were conducted on a limited range of size compositions. The dynamics of fish reaction to trawls is poorly understood, but it is likely that size and swimming power as well as instinctive schooling and avoidance behavior inmediately prior to capture are key factors. It is quite conceivable that a group of fish between, for example, 25 and 30 cm in length, will have differing pre-capture microdistributions and reaction to the trawl, depending on whether they are smaller or larger than the average fish available for capture, i.e. whether they are on the ascending or descending limb of the length frequency. Even more important may be the effect of total catch weight on the catch of very small fish on Lady Hammond. A larger amount of fish in the codend of the WIIA will open the meshes of the liner near the wall of fish allowing more small fish to escape than when the codend is empty and the mesh is stretched closed along its diagonal. This effect is well known from underwater photography.

The application of conversion factors to biomass estimates and catch per tow statistics needs consideration. Biomass estimates are the product of the standardized mean stratum catch per tow and the number of trawlable units in the stratum. A trawlable unit is the area swept by a trawl during a standard tow and is itself the product of the measured or theoretical wing spread of the trawl and 1.75 naut mi. If one switches to a trawl with a different wing spread and we calculate biomass using this new wing spread, we are essentially applying a conversion factor based on the assumption that the difference in catch between the two vessels is proportional to the difference in wing spread. Actually, this assumption may not be too outrageous for some species. The data for haddock, which are the best we have, suggest a catch ratio not much different from the ratio of nominal wing spreads (i.e. $41 / 35=1.17$ ). For other species, especially off-bottom types like redfish and silver hake, it is apparent that more than the difference in wing spread is involved, in which case any empirically derived catch ratio must be applied to the catch per tow, while the biomass, by definition, would still be calculated using wing spread. The use of two conversion factors on the same set of data is difficult to justify theoretically and the problem needs clarification.

## Further investigations

In July of this year, a comparative fishing experiment will be carried out between the Alfred Needler and Lady Hammond. An attempt will be made to exercise more control over speeds, depth and distance between vessels than in previous experiments.

Further analysis will include an attempt to model the variance according to the effects of small and extreme catches and differences in speed and depth. In addition, possible effects of time of day, variations due to size composition, and multispecies interaction will also be considered.

Table 1. Summary of vessel and trawl characteristics of the two vessel-gear units used in comparative fishing experiments from 1979-81.


Table 2. Wilcoxin matched-pairs ranked-sine test. Standardized numbers caught where one vessel caught at least one fish. Means represent the means of positive differences. ( $\mathrm{LH}=\mathrm{Lady}$ Hamand, ATC=A.T. Cameron)

|  | 1979 |  | 1980 |  | 1981 |  | 1979-81 |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | LH | ATC | LH | ATC | LH | ATC | LH | ATC |
| Cod |  |  |  |  |  |  |  |  |
| Mean (of diff.) | 20.22 | 24.85 | 46.81 | 56.51 | 49.24 | 45.90 | 117.07 | 125.00 |
| - Ranks |  | 27 |  | 61 |  | 49 |  | 137 |
| + Ranks | 18 |  | 43 |  | 45 |  | 106 |  |
| Ties |  |  | 1 |  |  |  | 3 |  |
| z |  | 733 | -2. | 325 |  | 062 | -2. |  |
| P |  | 083 |  | 020 |  | 950 |  |  |
| Cases | 47 |  | 105 |  | 94 |  | 302 |  |
| Haddock |  |  |  |  |  |  |  |  |
| Mean (of diff.) | 29.21 | 23.00 | 49.14 | 43.76 | 42.82 | 39.32 | 120.2 | 105.76 |
| - Ranks |  | 22 |  | 37 |  | 31 |  | 90 |
| + Ranks | 31 |  | 56 |  | 51 |  | 138 |  |
| Ties |  | 0 |  | 1 |  | 0 |  |  |
| z |  | . 682 |  | . 171 |  | . 231 |  | 545 |
| P |  | . 093 |  | . 030 |  | . 026 |  | 000 |
| Cases |  |  |  |  |  | 2 | 22 |  |
| Redfish |  |  |  |  |  |  |  |  |
| Mean (of diff.) | 18.07 | 16.58 | 33.53 | 35.38 | 26.82 | 25.64 | 77.20 | 76.51 |
| - Ranks |  | 13 |  | 17 |  | 14 |  | 44 |
| + Ranks | 21 |  | 50 |  | 38 |  | 109 |  |
| Ties |  | 0 |  | 0 |  | 0 |  |  |
| 2 |  | 1.402 |  | 3.358 |  | 3.005 |  | . 597 |
| P |  | 0.161 |  | 0.001 |  | 0.003 |  | . 000 |
| Cases |  |  |  |  |  | 2 | 15 |  |
| Plaice |  |  |  |  |  |  |  |  |
| Mean (of diff.) | 22.59 | 20.18 | 56.64 | 55.19 | 44.59 | 46.59 | 122.62 | 121.23 |
| - Ranks |  | 19 |  | 49 |  | 41 |  | 109 |
| + Ranks | 23 |  | 62 |  | 49 |  | 134 |  |
| Ties |  | 2 |  | 3 |  | 2 |  | , |
| 2 |  | . 850 |  | 1.187 |  | 0.553 |  | . 466 |
| P |  | 0.395 |  | 0.235 |  | 0.580 |  | . 143 |
| Cases |  |  | 11 |  |  | 2 | 25 |  |



|  | 1979 |  | 1980 |  | 1981 |  | 1919-81 |  | 1979 |  | 1980 |  | 1981 |  | 1979-81 |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 11 | ATC | Lif | Atc | Lif | ATC | 111 | ATC | TH | ATC | $\underline{4}$ | ATC | ui | ATC | IM | ATC |
|  | COD |  |  |  |  |  |  |  | Happori |  |  |  |  |  |  |  |
| Mean | n.ts 3 | 0.924 | 1.076 | 1.128 | 1.281 | 1.260 | 1.111 | 4.137 | 1.420 | 1.326 | 1.466 | 1.365 | 1.435 | 1.354 | 1.446 | 1. 351 |
| 30 | 0.502 | 0.452 | 0.548 | 0.571 | 0.585 | 0.5B6 | 0.576 | 0.569 | 0.703 | 0.639 | 0.647 | 0.658 | 0.784 | 0.755 | 0.706 | 0.684 |
| st. | 0.071 | 0.070 | 0.062 | 0.065 | 0.066 | 0.065 | 0.041 | 0.040 | 0.104 | 0.094 | 0.074 | 0.075 | 0.10 | 0.097 | 0.052 | 0.051 |
| DIff. (mean) | 0.011 |  | 0.050 |  | -0.021 |  | 0.026 |  | -0.093 |  | -0.101 |  | -0.081 |  | -0.093 |  |
| sb | 0.134 |  | 0.484 |  | 0.392 |  | 0.418 |  | 0.372 |  | 0.450 |  | 0. 156 |  | 0.199 |  |
| St. | 0.050 |  | 0.054 |  | 0.044 |  | 0.029 |  | 0.055 |  | 0.052 |  | 0.046 |  | 0.010 |  |
| * | 0.715 |  | 0.631 |  | 0.711 |  | 0.732 |  | 0.850 |  | 0.161 |  | 0.894 |  | 0.835 |  |
| $r$ | 0.000 |  | 0.000 |  | 0.000 |  | 0.000 |  | 0.000 |  | 0.000 |  | $0.00 n$ |  | 0.000 |  |
| T | 1.42 |  | 0.93 |  | $-0.68$ |  | 0.89 |  | -1.12 |  | -1.96 |  | $-1.78$ |  | -3.15 |  |
| p | 0.142 |  | 0.351 |  | 0.610 |  | 0.375 |  | 0.091 |  | 0.051 |  | 0.080 |  | 0.002 |  |
| df | 41 |  | 78 |  | 19 |  | 200 |  | 45 |  | 75 |  | 60 |  | 182 |  |
| enclo (retransformed) | 0.85 |  | 0.89 |  | 1.05 |  | 0.94 |  | 1.24 |  | 1.26 |  | 1.21 |  | 1.21 |  |
|  | REDFISH |  |  |  |  |  |  |  | Platce |  |  |  |  |  |  |  |
| Mann | 1.444 | 1.298 | 1.366 | 1.127 | 1.587 | 1.351 | 1.456 | 1.238 | 0.864 | 0.752 | 1.121 | 1.069 | 1.381 | 1.295 | 1.177 | 1.112 |
| s0 | 0.788 | 0.679 | 0.820 | 0.814 | 0.763 | 0.621 | 0.798 | 0.816 | 0. 501 | 0.357 | 0.573 | 0.622 | 0.517 | 0.580 | 0.387 | 0.601 |
| SE | 0.176 | 0.152 | 0.128 | 0.116 | 0.141 | 0.150 | 0.084 | 0.086 | 0.100 | 0.074 | 0.061 | 0.066 | 0.069 | 0.069 | 0.043 | 0.044 |
| nitf. (eran) |  | 146 |  |  |  | 236 |  | 218 | -0. |  | -0. |  |  | 8\% |  |  |
| sn |  | 466 |  | 535 |  | 621 |  | 549 |  |  |  |  |  | 391 |  |  |
| 58 |  | 104 |  | . 084 |  | 114 |  | 058 |  |  |  |  |  | 34 |  |  |
| \% |  | 808 |  | 802 |  | 696 |  | . 769 |  |  |  |  |  | . 764 |  |  |
| F |  | 000 |  | . 000 |  | 000 |  | D00 |  |  |  |  |  | 000 |  |  |
| 1 |  |  |  |  | -2. |  | -3. |  | -1. |  | -1. |  |  |  | -2. |  |
| \% |  | 176 |  | . 007 |  | 048 |  | 000 |  |  |  |  |  | 169 |  |  |
| $4 t$ | 19 |  | 40 |  | 29 |  | 90 |  | 24 |  | 3 |  | 69 |  | 18) |  |
| cnto (retranntormed) |  |  |  |  |  |  |  |  | 1. |  |  |  |  |  |  |  |

Table 4. Ratios (ELH/EATC) and standard errors for standardized numbers caught, all non-zero values.

| Species | 1979 |  |  | 1980 |  |  | 1981 |  |  | 1979-81 |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Ratio | SE | n | Ratio | SE | n | Ratio | SE | n | Ratio | SE | n |
| Cod | 1.446 | 1.168 | 42 | 1.083 | 1.228 | 79 | 1.013 | 0.214 | 80 | 1.078 | 0.495 | 201 |
| Haddock | 1.939 | 0.426 | 46 | 1.282 | 0.142 | 76 | 1.218 | 0.115 | 61 | 1.352 | 0.111 | 183 |
| Pollock | 1.592 | 0.357 | 13 | 0.343 | 0.357 | 20 | 2.908 | 1.047 | 22 | 1.092 | 0.360 | 55 |
| Redfish | 1.923 | 0.697 | 20 | 1.150 | 0.903 | 41 | 1.376 | 2.734 | 29 | 1.332 | 1.056 | 90 |
| Plaice | 1.978 | 0.660 | 25 | 0.904 | 0.091 | 89 | 1.020 | 0.151 | 70 | 0.985 | 0.087 | 184 |
| S. hake | 1.749 | 0.372 | 33 | 2.915 | 0.347 | 38 | 2.841 | 0.166 | 33 | 2.399 | 0.177 | 104 |
| W. hake | 1.225 | 0.266 | 31 | 0.976 | 0.207 | 38 | 1.356 | 0.165 | 44 | 1.279 | 0.110 | 113 |
| Witch | 0.895 | 0.215 | 11 | 1.006 | 0.261 | 50 | 1.107 | 0.146 | 39 | 1.053 | 0.137 | 100 |
| Yellowt. | 2.570 | 0.537 | 9 | 1.302 | 0.266 | 44 | 1.194 | 0.103 | 31 | 1.271 | 0.132 | 84 |
| Winter fl. | 0.585 | 0.209 | 9 | 1.461 | 0.217 | 13 | 1.286 | 0.311 | 15 | 1.094 | 0.162 | 37 |
| Cod* | 1.112 | 0.115 | 41 | 0.614 | 0.099 | 78 | 0.972 | 0.104 | 79 | 0.839 | 0.064 | 198 |
| Haddock* | 1.014 | 0.122 | 44 | - | - | - | - | - | - | 1.216 | 0.076 | 181 |

*Outliers removed as follows: Cod 1979 , set 18,1980 , set 55,1981 , set 65 ; Haddock 1979, sets 14 and 18.

Table 5. Jackknife estimates of the ratio of numbers caught by Lady Hammond and A.T. Cameron ( $C V=$ coeffient of variation, $n=$ sample size)

| a) 1981 |  | grouping by speed |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Grouping by depth |  | A11 <br> Soeeds | $3.5 \pm 30 \%$ | $3.5 \pm 20 \%$ | $3.5 \pm 10 \%$ |
| All depths | Rj | 1.170 | 1.16 | 1.15 | 2.40 |
|  | CV $n$ | $\begin{gathered} 16.48 \\ 61 \end{gathered}$ | $\begin{gathered} 17.23 \\ 54 \end{gathered}$ | $18.18$ | $\frac{24.32}{15}$ |
| $0^{1} \pm 10 \mathrm{fms}$ | $R_{j}$ | 1.16 | 1.15 | 1.15 | 2.93 |
|  | CV $n$ | $\begin{gathered} 16.56 \\ 59 \end{gathered}$ | $\begin{gathered} 17.32 \\ 52 \end{gathered}$ | $\begin{gathered} 18.28 \\ 41 \end{gathered}$ | $\frac{25.23}{13}$ |
| $0 \pm 5 \mathrm{fms}$ | $R_{j}$ | 1.16 | 1.15 | 1.15 | 2.39 |
|  | CV $n$ | $\begin{gathered} 16.58 \\ 56 \end{gathered}$ | $\begin{array}{r} 17.35 \\ 49 \end{array}$ | $\begin{array}{r} 18.31 \\ 38 \end{array}$ | $\begin{gathered} 25.33 \\ 12 \end{gathered}$ |
| $0 \pm 3 \mathrm{fms}$ | RJ | 1.19 | 1.18 | 1.17 | 2.52 |
|  | ${ }_{\text {cV }}$ | $\begin{array}{r} 16.92 \\ \hline 97 \end{array}$ | $\begin{array}{r} 17.69 \\ 40 \end{array}$ | $\begin{array}{r} 18.63 \\ 30 \end{array}$ | $\begin{gathered} 26.45 \\ 9 \end{gathered}$ |
| $0 \pm 1 \mathrm{fm}$ | $\mathrm{R}_{\mathrm{J}}$ | 1.42 | 1.41 | 1.43 | 2.77 |
|  | CV $n$ | $\begin{array}{r} 12.36 \\ \hline 22 \end{array}$ | $\begin{gathered} 13.26 \\ 27 \end{gathered}$ | $\begin{array}{r} 14.31 \\ 20 \end{array}$ | $\frac{35.02}{6}$ |
| $0 \pm 0 \mathrm{fms}$ | $R_{j}$ | 1.02 | 0.99 | 0.93 | 2.76 |
|  | ${ }_{\text {CV }}$ | $\begin{array}{r} 27.00 \\ 10 \end{array}$ | $\begin{gathered} 27.59 \\ 5 \end{gathered}$ | $\begin{gathered} 38.40 \\ 5 \end{gathered}$ | $i$ |

$1^{1}=$ absolute difference in depth.
b) 1980

GROUPING BY SPEED

| Grouping by depth |  | All <br> Speeds | $3.5 \pm 30 \%$ | $3.5 \pm 20 \%$ | $3.5 \pm 10 \%$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
| All depths | $R_{J}$ | 1.59 | 1.30 | 1.39 | 2.11 |
|  | CV | 17.87 | 18.38 | 22.68 | 39.72 |
|  | n | 76 | 42 | 31 | 11 |
| $0 \pm 10 \mathrm{fms}$ | $\mathrm{R}_{3}$ | 1.60 | 1.30 | 1.37 | 2.11 |
|  | CV. | 18.10 | 18.84 | 22.86 | 39.72 |
|  |  | 73 | 40 | 30 | 11 |
| $0 \pm 5 \mathrm{fms}$ | $R_{J}$ | 1.58 | 1.22 | 1.28 | 1.99 |
|  | Cl | 18.67 | 19.94 | 23.80 | 46.05 |
|  | n | 56 | 34 | 26 | 9 |
| $0 \pm 3 \mathrm{fms}$ | $R_{j}$ | 1.83 | 1.11 | 1.13 | 2.16 |
|  | CV | 16.70 | 35.21 | 55.17 | 81.10 |
|  | n | 46 | 27 | 19 | 6 |
| $0 \pm 1 \mathrm{fm}$ | $\mathrm{R}_{3}$ | 1.16 | 0.66 | 0.55 | 9.95 |
|  | CV | 30.32 | 83.32 | 109.97 | - |
|  | ก | 20 | 13 | 8 | 1 |
| $0 \pm 0$ fms | $R_{J}$ | 0.007 | 1.18 |  |  |
|  | CV | $30922.71$ | - | * | - |
|  | \% | $3$ | 1 |  |  |

Table 5 (cont'a.)
e) 1979

GROUPWGS BY SPEED

| Grouping by Depths |  | A11 Speeds | $3.5 \pm 30 \%$ | $3.5 \pm 20 \%$ | $3.5 \pm 10 \%$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
| All Depths | $\mathrm{R}_{\mathrm{J}}$ | 1.69 | 1.19 | 1.23 | 1.21 |
|  | CV $n$ | $\begin{gathered} 38.95 \\ 46 \end{gathered}$ | $\begin{gathered} 7.54 \\ 32 \end{gathered}$ | $\begin{gathered} 9.07 \\ 22 \end{gathered}$ | $\begin{gathered} 8.32 \\ 11 \end{gathered}$ |
| $0 \pm 10 \mathrm{fms}$ | $\mathrm{R}_{\mathrm{J}}$ | 1.69 | 1.18 | 1.21 | 1.18 |
|  | $\begin{aligned} & \mathrm{CV} \\ & \mathrm{n} \end{aligned}$ | $39.31$ | $\begin{gathered} 7.64 \\ 30 \end{gathered}$ | $\begin{gathered} 9.16 \\ 20 \end{gathered}$ | $\begin{gathered} 8.10 \\ 10 \end{gathered}$ |
| $0 \pm 5 \mathrm{fms}$ | $\mathrm{R}_{\mathrm{J}}$ | 1.10 | 1.19 | 1.23 | 1.18 |
|  | $\begin{aligned} & \mathrm{CV} \end{aligned}$ | $\begin{gathered} 19.23 \\ \hline 7 \end{gathered}$ | $\begin{gathered} 7.23 \end{gathered}$ | $\begin{gathered} 7.34 \\ 18 \end{gathered}$ | $\begin{gathered} 8.10 \\ 10 \end{gathered}$ |
| $0 \pm 3 \mathrm{~ms}$ | $R_{j}$ | 1.04 | 1.19 | 1.27 | 1.22 |
|  | $\begin{aligned} & \mathrm{CV} \\ & \mathrm{n} \end{aligned}$ | $\begin{gathered} 30.87 \\ 27 \end{gathered}$ | $9.98$ | $\begin{gathered} 9.82 \\ 11 \end{gathered}$ | $\underset{6}{5.87}$ |
| $0 \pm 1 \mathrm{fm}$ | $\mathrm{R}_{3}$ | 0.56 | 1.25 | 1.27 | 1.35 |
|  | $\begin{aligned} & \mathrm{CY} \\ & \mathrm{n} \end{aligned}$ | ${ }_{10}^{149.79}$ | ${ }_{6}^{21.05}$ | ${ }_{5}^{21.33}$ | $\stackrel{1}{1}$ |
| $0 \pm 0 \mathrm{mms}$ | $R^{3}$ | 7.5 | 7 | 7 |  |
|  | CV $n$ | 20.0 | - | - | - |

Table 6a. Stratified mean catch for cod, standardized comparative set.

| Strata | 1979 |  |  | 1980 |  |  | 1981 |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | LH | ATC | LH/ATC | LH | ATC | LH/ATC | LH | ATC | LH/ATC |
| 40-42 \# |  |  |  | 67.75 | 67.93 | 1.00 | 83.83 | 110.98 | 0.76 |
| wt. |  |  |  | 110.65 | 91.92 | 1.20 | 150.14 | 161.81 | 0.93 |
| 43-46 \# |  |  |  | 19.50 | 43.62 | 0.45 | 42.17 | 65.36 | 0.65 |
| wt. |  |  |  | 39.81 | 83.71 | 0.48 | 76.54 | 113.27 | 0.68 |
| 47-52 |  |  |  | 5.03 | 32.25 | 0.16 | 70.12 | 54.27 | 1.29 |
| wt. |  |  |  | 8.77 | 70.71 | 0.12 | 64.27 | 56.40 | 1.14 |
| 53-66 \# |  |  |  | 13.22 | 22.85 | 0.58 | 40.35 | 29.13 | 1.39 |
| wt. |  |  |  | 13.43 | 22.33 | 0.60 | 37.43 | 28.34 | 1.32 |
| 70-81 | 3.08 | 4.62 | 0.67 | 5.05 | 5.11 | 0.99 | 8.47 | 5.33 | 1.59 |
| wt. | 9.93 | 15.93 | 0.62 | 17.97 | 16.67 | 1.08 | 14.44 | 13.79 | 1.05 |
| 82-84 \# | 3.39 | 2.68 | 1.26 | 3.38 | 1.10 | 3.07 | 5.04 | 1.35 | 3.73 |
| wt. | 9.97 | 10.21 | 0.98 | 12.19 | 4.75 | 2.57 | 14.73 | 3.77 | 3.91 |
| 85-92 非 | 28.09 | 21.45 | 1.31 | 7.98 | 7.99 | 1.00 | 13.35 | 17.55 | 0.76 |
| wt. | 32.84 | 38.17 | 0.86 | 25.62 | 26.51 | 0.97 | 39.22 | 46.52 | 0.84 |
| 93-95 \# | 22.68 | 17.01 | 1.33 | 6.07 | 3.15 | 1.93 | 4.86 | 13.68 | 0.36 |
| wt. | 33.03 | 21.77 | 1.52 | 21.41 | 10.87 | 1.97 | 15.54 | 35.94 | 0.43 |
| Total \# | 10.10 | 8.83 | 1.14 | 14.10 | 22.73 | 0.62 | 34.84 | 36.33 | 0.96 |
| ( $40-95$ ) wt. | 16.73 | 19.97 | 0.84 | 24.84 | 36.83 | 0.67 | 49.51 | 53.77 | 0.92 |

Table 6b. Stratified mean catch for haddock, standardized comparative set.

| Strata | 1979 |  |  | 1980 |  |  | 1981 |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | LH | ATC | LH/ATC | LH | ATC | LH/ATC | LH | ATC | LH/ATC |
| 40-42 \# |  |  |  | 1.99 | 0.71 | 2.80 | 0.96 | 2.18 | 0.44 |
| wt. |  |  |  | 2.76 | 0.50 | 5.52 | 1.88 | 4.21 | 0.45 |
| 43-46 \# |  |  |  | 3.49 | 0.72 | 4.85 | 0.17 | 3.50 | 0.05 |
| wt. |  |  |  | 3.03 | 0.80 | 3.79 | 0.17 | 1.58 | 0.11 |
| 47-52 \# |  |  |  | 10.50 | 6.64 | 1.58 | 3.10 | 1.57 | 1.97 |
| wt. |  |  |  | 10.47 | 3.06 | 3.42 | 2.28 | 1.33 | 1.71 |
| 53-66 \# |  |  |  | 76.39 | 69.78 | 1.09 | 54.53 | 86.89 | 0.63 |
| wt. |  |  |  | 66.19 | 63.16 | 1.05 | 21.06 | 22.96 | 0.92 |
| 70-81 \# | 51.47 | 35.16 | 1.46 | 97.69 | 53.80 | 1.82 | 118.57 | 62.27 | 1.90 |
| wt. | 41.97 | 32.98 | 1.27 | 64.58 | 42.36 | 1.52 | 53.63 | 42.88 | 1.25 |
| 82-84 \# | 14.85 | 13.23 | 1.12 | 15.57 | 10.57 | 1.47 | 8.75 | 5.64 | 1.55 |
| wt. | 37.14 | 35.00 | 1.06 | 35.75 | 22.44 | 1.59 | 21.58 | 13.43 | 1.61 |
| 85-92 \# | 33.08 | 61.13 | 0.54 | 84.82 | 64.87 | 1.31 | 261.40 | 199.45 | 1.31 |
| wt. | 47.57 | 69.96 | 0.68 | 90.59 | 73.29 | 1.24 | 121.21 | 95.81 | 1.27 |
| 93-95 \# | 1.03 | 4.43 | 0.23 | 2.13 | 0.46 | 4.63 | 6.29 | 4.38 | 1.44 |
| wt. | 4.17 | 8.78 | 0.47 | 2.36 | 0.58 | 4.07 | 8.36 | 7.19 | 1.16 |
| Total \# | 35.81 | 33.62 | 1.07 | 53.80 | 40.67 | 1.32 | 60.11 | 53.64 | 1.12 |
| (40-95) wt. | 39.04 | 39.29 | 0.99 | 46.16 | 37.54 | 1.23 | 28.64 | 24.46 | 1.17 |




Figure $1 A$ - upper. $x$-axis: ratios (LH:ATC) of raw numbers caught (haddock) y-axis: difference in distance travelled between vessels for each set (LH-ATC) in nautical miles. $r=0.12697, p=0.066$.

- lower. same as A except ratios are standardized numbers caught. $r=-0.2805, p=0.0004$.




Figure 2. Mean speed for all groundfish surveys conducted by Lady Hammond and A.T. Cameron from 1978-81.




Fig. 4c:
PSEUDO-VALUE COMPONENT vs. DIFFERENCE IN DEPTH FOR COMPARATIVE SURVEY
Haddock 1981


Fig. 50
RESIDUAL PLOT (fourth root transform) Haddock 1979


Fig.b RESIDUAL PLOT (square root transform) Haddock 1980


Fig. 5c: RESIDUAL PLOT (square root transform) Haddock 1981



Figure 6A. Comparison of length frequencies for cod in 1979: upper total numbers caught; lower - measured fish only.



Figure 6B. Comparison of length frequencies for cod in 1980: upper left - all sets, total numbers caught; upper right - all sets, measured fish only; lower - measured fish only minus set 55 .


COD 198: MEASURED FISH
11* $3460 \times$ - Lady Homnond w = 3as4 o- A $T$ Evmeron


Figure 6C. Comparison of length frequencies for cod in 1981: upper - rotal numbers caught; lower - measured fish only.



Figure 6E. Comparison of length frequencies for haddock in 1980: upper - total numbers caught; lower - measured fish only.



Figure 6F. Comparison of length frequencies for haddock in 1981: upper - total numbers caught; lower - measured fish only.






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Figure 8D. Comparison of length frequencies for yellowtall in 1979, 1980 and 1981 .


