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Canadian Atlantic Fisheries Scientific Advisory Committee

CAFSAC Research Document 85/3

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Comité scientifique consultatif des pêches canadiennes dans l'Atlantique

CSCPCA Document de recherche 85/3

Intercalibration of Research Survey Results Obtained by Different Vessels

by

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Abstract

Data from two series of comparative fishing experiments were analysed to estimate conversion factors for groundfish research survey results. The first comparison, with three years of data, was the A.T. Cameron with the Lady Hammond. The second comparison was the Lady Hammond with the Alfred Needler.

The analysis was based on fitting a beta distribution to the relative catch index defined as I = STD/(STD + TEST) where STD and TEST designate the standard and test vessel, respectively.

Conversion factors were obtained for one or both comparisons for nine species, namely; cod, haddock, white hake, silver hake, redfish, plaice, witch, yellowtail and winter flounder.

It is recommended that the historical catches by research vessels be adjusted to Alfred Needler equivalent catches and so future catches will be accepted without conversion.

Résumé

Des données provenant de deux séries d'expériences de pêche comparatives ont été analysées pour estimer les facteurs de conversion pour les résultats des relevés de recherche portant sur le poisson de fond. La première comparaison, pour laquelle on a utilisé des données portant sur une période de trois ans, a été établie entre le A.T. Cameron et le Lady Hammond. La deuxième comparaison a été établie entre le Lady Hammond et le Alfred Needler.

L'analyse a été fondée sur l'ajustement d'une distribution bêta à l'indice de prise relatif défini comme I = STD/(STD - TEST) où STD signifie le navire standard et TEST signifie le navire-test.

Des facteurs de conversion ont été obtenus pour l'une ou les deux comparaisons dans le cas de neuf espèces: morue, aiglefin, merluche blanche, merlu argenté, sébaste, plie canadienne, plie grise, limande à queue jaune et plie rouge.

Il est recommandé que les prises historiques des navires de recherche soient ajustées en fonction des prises équivalentes du Alfred Needler de sorte que les prises futures puissent être acceptées sans conversion.

Introduction

Since 1970 the Marine Fish Division has conducted a time series of summer (July) stratified random groundfish surveys of the Scotia-Fundy Region. There are also several shorter series of seasonal or species-specific surveys. While the summer survey time series is continuous to the present, there have been three different vessels used to conduct the surveys; A.T. Cameron (ATC), Lady Hammond (LH), and Alfred Needler (AN). The three vessels are all of similar size and tonnage with adequate power to tow the nets (Table 1). The A.T. Cameron used a Yankee 36 survey trawl while the Lady Hammond and the Alfred Needler both use a Western IIA survey trawl.

The survey was conducted by the A.T. Cameron from 1970 to 1981 with comparative surveys conducted by the Lady Hammond in 1978 to 1981. The 1978 survey by the Lady Hammond used an Engel-145 high-lift trawl. This trawl was deemed unsuitable and replaced in 1979 with the Western IIA. The 1978 comparative fishing data has not been analysed to date since use of the particular trawl has been discontinued.

In 1982, the summer survey was conducted by the Lady Hammond alone as the A.T. Cameron had been retired and the Alfred Needler was not yet available.

The 1982 autumn seasonal survey was conducted by the Lady Hammond with the Alfred Needler conducting comparative sets. This survey produced only 49 valid comparative sets.

The 1983 summer survey was conducted by the Alfred Needler with the Lady Hammond conducting comparative sets. As well as the annual survey there were 13 additional comparative fishing sets conducted by both vessels on previously detected concentrations of fish.

A preliminary analysis of 1979 to 1981 data was presented by Koeller and Smith (1983) and for silver hake in the 1983 experiment by Fanning (1984).

The purpose of this paper is to summarize and compare the various results attained with regard to comparative fishing and to suggest conversion factors and guidelines for their use for 10 major species.

Materials and Methods

The aim in all the comparative fishing experiments was to obtain pairs of sets simultaneously from locations as close together as safety permitted. Generally the nearness of the two sets in time and space improved from year to year.

In the 1979 to 1981 comparative fishing between the A.T. Cameron and Lady Hammond (ATC/LH), the start times were generally within 10 minutes of each other and the vessels were less than 1 nautical mile apart. Speed of tow was determined independently on each vessel, A.T. Cameron using a Doppler log throughout while the Lady Hammond used a water-inertia log in 1979 and 1980 but switched to a Doppler log in 1981. Recorded ship's speed was calculated from the distance between start and end positions and the duration of the tow. Catches were processed on board each vessel using standard survey procedures (Koeller 1981) except that ageing material was not routinely collected on the Lady Hammond.

In the 1982 fall survey, (LH/AN), the Lady Hammond was the survey vessel and hence collected ageing material. Catches on the Alfred Needler were processed according to the standard procedures but no ageing material was collected. In the 1983 summer survey, (LH/AN), the Alfred Needler was the survey vessel and collected ageing material. The Lady Hammond processed catches according to standard procedure but collected no ageing material.

The data from both vessels in each comparative survey were processed in the standard groundfish survey data system. Consistency and range checks were performed and the standard survey results were calculated e.g. stratified mean catch per tow and abundance estimates. The data were stored in multicard records according to the groundfish format. All the comparative fishing data sets were transferred by tape from St. Andrews to the BIO Cyber where it was reduced to a single card format by removing redundant data and collapsing the detailed 1, 2, or 3 cm grouping length frequency information down to 5 intervals for each species.

Preliminary investigation was aimed at verification of the data and detection of systematic sources of error. Paired t-tests and stem and leaf plots (Tukey 1977) were used to investigate differences in distances towed and depths recorded. Extreme values on the stem and leaf plots were identified to set and checked manually. If errors were detected but could not be corrected then the associated data for those sets were removed from subsequent analyses. For years in which significant differences in distance towed were detected by t-test the catches were adjusted to 1.75 nautical miles (n mi) standard tows. The standardized catch is the raw catch multiplied by 1.75 divided by distance towed.

There are two indices of stock size calculated from research survey data. The first is the stratified mean catch per tow, $\bar{y}_{st}$. This is the average catch in numbers or weight for each stratum, $\bar{y}_i$, weighted by the stratum areas, w_i, i.e.

$$\bar{y}_{st} = \frac{w_i \bar{y}_i}{w_i}$$

To convert the mean catch per tow to the second index of stock size, population abundance, the actual area sampled by each tow must be known. The standard tow of 1.75 n mi times the nominal wingspread of the trawl gives the area swept by the trawl and defines a standard trawlable unit. The number of trawlable units in a stratum is the stratum expansion factor which multiplied by the stratum mean catch per tow yields the stratum population abundance. For a somewhat more detailed discussion see Halliday and Koeller (1981). The practice of adjusting catches to a standard tow of 1.75 n mi makes the assumption that catch is linearly related to area swept which, given a constant wingspread, is equivalent to distance towed. This assumption is quite robust to non-linearity in the relationship as long as the actual distances are symmetric about a mean of 1.75. Since this is true for most survey data the adjustment to a standard distance towed should not introduce a bias in the resulting estimates of mean catch per tow or population abundance.

In the LH/ATC comparisons the nominal wing spreads are not equal and hence the trawlable units are different. A theoretical conversion factor for mean catch per tow can be computed as the ratio of the two wingspreads. This leads to a conversion factor of LH = 1.17 ATC. This is also based on the assumption that catch is linearly related to area swept. Theoretically this conversion factor should yield the same population abundance estimates and the A.T. Cameron's converted mean catch per tow should equal the Lady Hammond's.

One drawback to this theoretical conversion is that it is not robust to a non-linear relationship. Even if the relationship is linear but the true ratio of wingspreads is not 1.17, a bias will be introduced in the stock size indices.

A further difference between the Yankee 36 net (ATC) and the Western IIA (LH and AN) is headline height. The Yankee 36 had a nominal headline height of 9 feet. The Western IIA on the other hand has a nominal headline height of 15 feet. This 2/3 increase in headline height has obvious implications for the fish less closely associated with the bottom such as redfish and silver hake as well as the younger age groups of several other species.

Since the nominal wingspreads are equal in the LH/AN comparisons the theoretical conversion factor is 1 i.e. no conversion is necessary.

The theoretical conversion factors are the same for all species and all age or size groups for a given pair of trawls.

The alternative to a theoretical conversion factor is to empirically estimate the relative performance of the two pairs of vessels from an experiment. The resulting conversion factors are used to estimate the catch that one vessel would have made based on the catch of the other vessel. Considerations such as the relative sizes of the trawlable units and headline heights, are all included in the estimate based upon observed relative performance. Because the conversion factor incorporates the difference in trawlable unit the estimated catches are in terms of the trawlable unit of the unconverted vessel. For example, if LH = kATC is such an empirical relationship the estimated catches LH would be based on the trawl wingspread and hence trawlable unit of the Lady Hammond even though the actual sets were done by the A.T. Cameron. The stratum expansion factors and hence population abundance estimates in the historical series of the A.T. Cameron would have to be corrected to those of the Western IIA trawl.

Groundfish survey data are typified by large numbers of small or moderate catches and small numbers (1, 2 or 3) of very large catches. The previous analysis of the 1979-1981 comparative surveys by Koeller and Smith (1983) demonstrated the impact of a few such large catches on ratios of catches and estimators for a linear model of catches. The use of a jackknife estimator of the ratio did not remove the sensitivity of the ratio estimate to exceptionally large catches. The linear model approach required different transformations from year to year to yield reasonably symmetric residuals. The same large catches that caused problems with the ratio approach showed up again with large residuals. As well several smaller sets where few or no fish were caught by one vessel also had large residuals.

In an attempt to deal with the problems caused by extreme values described by Koeller and Smith (1983) a relative catch index was devised. It is defined as I = STD/(STD + TEST) where STD is the catch of a particular species by the vessel designated standard and TEST is the catch of the same species by the other vessel. Since the Lady Hammond was common to all 5 years of data she was used as the standard vessel and either A.T. Cameron or Alfred Needler was the test vessel. A few points to note regarding I:

(i) $0 \leq I \leq 1$
(ii) STD = TEST $\rightarrow$ I = 0.5
(iii) STD = 0, TEST $\neq$ 0 $\Rightarrow$ I = 0
(iv) STD $\neq$ 0, TEST = 0 $\Rightarrow$ I = 1
(v) STD = 0, TEsT = 0 $\rightarrow$ I undefined.

The variability of I is much less than that of the original catches or either of the differences or ratio of catches. As well the sampling distribution of I can be modelled with a beta distribution.

The Beta Distribution

The beta distribution is a flexible, 2 parameter distribution defined on the interval [0,1]. The parameters of the distribution are usually denoted by α and β and the probability density function is given by Mood *et al*. 1974; p. 115):

$$f(X;\alpha,\beta) = \frac{1}{B(\alpha,\beta)} X^{\alpha-1}(1-X)^{\beta-1} I_{0,1}(X);\ \alpha,\beta > 0$$

where $B(\alpha,\beta)$ is the complete beta integral

$$B(\alpha,\beta) = \int_0^1 X^{\alpha-1}(1-X)^{\beta-1}\,dx;\ \alpha,\beta > 0.$$

The first two moments of the beta distribution are (Mood et al. 1974; p. 116):

$$E(X) = \mu = \frac{\alpha}{\alpha+\beta} \tag{1}$$

and

$$V(X) = \sigma^2 = \frac{\alpha\beta}{(\alpha+\beta+1)(\alpha+\beta)^2} \tag{2}$$

Assume that the I are independently, identically distributed beta random variables. The sample moments, $\bar{X}$ and S^2, can be used to estimate the beta distribution parameters by the method of moments. This is done by equating the first two sample moments with the first two moments of the distribution i.e. equations (1) and (2). Simultaneously solving for the values of α and β in terms of $\bar{X}$ and S^2 yields the estimators.

$$a = \frac{((1-\bar{X})\,\bar{X} - S^2)\,\bar{X}}{S^2}$$

and

$$b = \frac{(1-\bar{X})^2\,\bar{X} - (1-\bar{X})S^2}{S^2}$$

While the method of moment estimators are consistent, i.e they approach the true value of the parameter as the sample size approaches infinity, they are not minimum variance and are assumably unbiased only when based solely on the first moment (Bickel and Doksum 1977; p. 135).

Least squares estimation also yields consistent estimators which cannot be assumed to be unbiased. Since neither estimator is necessarily unbiased the Cramer-Rao inequality cannot be used to determine if they are minimum variance. The recommended statistics for comparing biased estimators are the mean squared errors, the ratio of which estimates the relative efficiency of the two estimators (Freund and Walpole 1980; p. 316).

The least squares estimates of α and β , a and b respectively, were obtained by iteratively minimizing the residual sum of squares using the Newton-Raphson algorithm. The necessary derivatives were approximated using finite differences (Kennedy and Gentle 1983; p. 442). The distribution function of the beta distribution was replaced with an high-order polynomial approximation (Wheeler 1983). The method of moments estimates were used as initial values in the procedure. Converged estimates of α and β were substituted into equations (1) and (2) to estimate the mean and variance. Approximate 95% confidence intervals were constructed from the mean $\pm$ 2 standard deviations. Trial calculations of exact 95% confidence intervals from beta tables showed that the approximate intervals were more conservative, i.e. wider, than the exact confidence intervals.

The validity of conversion factors between survey vessels depends, for the most part, on the assumptions that the expected difference in catches between the vessels is due solely to differences in fishing power and that variation in the difference is due to random noise. The side-by-side trawling approach was intended to minimize environmental effects on the differences in the catches such as depth or aggregation. The conversion factor for a particular species will be the multiplicative constant which relates the test vessel catch to that which would have been made by the standard vessel. The estimator K = I/(1-I) gives the estimate of the conversion factor based on the fitted beta distribution of I. It is derived from the definition of I as follows:

$$I = \frac{STD}{STD + TEST}$$

$$STD = (STD + TEST) \cdot I$$
$$STD - I \cdot STD = I \cdot TEST$$
$$STD\,(1-I) = I \cdot TEST$$
$$STD = \frac{I}{1-I} \cdot TEST$$

$$\text{i.e. } K = \frac{I}{1-I}$$

All calculations of I and K as well as comparisons of depth and distance towed used the Lady Hammond as the standard vessel. The choice of standard vessel is arbitrary as both the relative catch index and the conversion factors are symmetric with respect to vessel designations. In usage the conversion factors will be applied to bring both Lady Hammond and A.T. Cameron catches in line with those of the Alfred Needler.

The effect of calculating conversion factors on the basis of weight caught was examined for cod, haddock, silver hake, redfish, plaice and yellowtail.

The effect of length on the relative catch index was also examined for cod, haddock, silver hake, redfish, plaice and yellowtail. Each length-frequency grouping is the sum of 14 length groups of 1, 2 or 3 depending on species. Thus length-frequency group 1 for cod includes fish in the range 0.5 cm to 42.5 cm while for yellowtail it is 0.5 cm to 14.5 cm.

Results

Plots of numbers in catches by the test vessels against the standard vessel are given in Figure 1 for each of the ten species investigated. The prevailing pattern is a cluster of relatively small catches by both vessels and a small number of extremely large catches by one or both vessels.

Comparisons of depth of tow and distance towed between the two vessels involved in each survey were based on the stem and leaf plots in Figures 2 and 3, respectively, and the paired t-test in Tables 2 and 3, respectively. Examination of Figure 2 led to deleting one observation in each of 1979, 1981 and 1982 and 2 observations from 1983. The deleted observations were suspected coding errors in 1979, 1982 and 1983 and missing value codes in 1981 and 1983. Subsequent paired t-tests (Table 2) showed only one year (1979) when differences were highly significant ($\alpha = .05$) and one other year (1980) significant at $\alpha = .1$ level. It is worth noting that in all years the absolute value of the mean difference was less than 2 fathoms.

Examination of Figure 3 revealed 3 missing value codes for distance towed in 1983 which were deleted from the paired t-tests. The t-tests detected highly significant differences in distance towed in the years 1979 and 1980. These correspond to the years when the Lady Hammond had a blocked sensor inlet and so under-estimated her speed resulting in longer distances towed. During the remaining three surveys the mean deviation in distance towed was 0.1 n mi or less. In spite of this, significant differences were detected in 1982 and 1983. These significant differences are explained by the high precision (small variance) of the distances towed and are essentially negligible. The differences in 1979 and 1980, 0.17 and 0.29 n mi respectively, are not, however, negligible and catches in those two years were adjusted for distance towed.

Stem and leaf plots of the relative catch index, I, based on numbers caught are given for each species in Figure 4. Looking at Figure 4a (Cod LH/ATC) the two strings of zeros on the top and bottom lines represent sets where the test vessel and standard vessel respectively failed to catch any fish of the given species when the other vessel did. These observations were not used in subsequent analysis. The column headed depth is the cumulative number of observations from each extreme. The bracketed line near the middle indicates the line containing the median value. The distribution of values between zero and one is relatively smooth and continuous for all species except for winter flounder and pollock, both of which were in relatively few sets.

Table 4 contains the results of least squares fitting of the beta distribution for all ten species for numbers caught. Analyses for individual years showed considerable variation so all appropriate years were combined for each comparison. The two years with the smallest sample sizes for all species except silver hake were 1979 and 1982.

The relative catch index for each of the ten species investigated is plotted on a yearly basis in Figure 7. In the LH/ATC comparisons the ordering of the years varies from species to species which is consistent with random errors. The LH/AN comparisons however show a strong systematic difference between years. In the 1982 fall survey the Alfred Needler caught many more fish relative to the Lady Hammond than she did in the 1983 summer survey. One possible explanation is a seasonal effect since one survey is in the fall and the other in the summer. This does not seem likely since even though the abundance and catchability of the fish change with season there is no reason on this basis to suggest that such changes would affect the two vessels differently i.e. change their relative fishing power. Another, more probable, explanation may lie in a change in fishing procedures on one or both vessels. In particular, the Alfred Needler was on only her first groundfish survey during the 1982 fall survey. Combining the two years of data puts more weight on 1983 because of its larger sample size.

Combining 1979-1981 into a single A.T. Cameron versus Lady Hammond comparison and 1982 and 1983 into an Alfred Needler versus Lady Hammond comparison ensured adequate sample sized for almost all comparisons. The one exception was winter flounder which was not caught at all in 1982 and only in 11 sets in 1983. The relative efficiency of the least squares estimators is given in Table 5. The ratio of mean squared errors (MSE) from the method of moments estimates to the MSE from the least squares estimates is the relative efficiency i.e. the improvement in fit due to least squares fitting. The relative efficiency ranges from 1.0 for witch in 1982 to 5.67 for redfish in 1979. The majority of values lie between 1.5 and 3.0. The relative efficiency values in Table 5 are based on catches unadjusted for distance towed.

The effect on the conversion factors of adjusting the catch by the distance towed is shown in Figure 5. The bias caused by the problems with the Lady Hammond's speed sensor is clearly shown in Figures 5a and 5b, 1979 and 1980 respectively. In Figure 5c (1981) the speed problem had been identified and reparied with the result that adjusting for distance towed had negligible impact on the conversion factors.

Results of calculation of conversion factors by weight of catch rather than number caught for cod, haddock, silver hake, redfish, plaice and yellowtial are summarised in Table 6 along with the conversion factors given in Table 4, calculated from numbers caught, for comparison. For cod and haddock, it is apparent that whether analysis is by weight or by number is irrelevent, the conversion factors are nearly identicial. The relative error in all four cod and haddock comparisons is less than 3%. For yellowtail the relative error is less than 10%. For silver hake the two comparisons are quite different. In LH/ATC the relative error is large, 17%, but in LH/AN the relative error is small, 5%.

Figure 6 gives the results of calculating I for each length group. For both sets of comparative experiments, the confidence intervals around I at each length group overlap extensively for cod, haddock, redfish and yellowtail, indicating there are no significant differences due to length. Silver hake shows overlap in the 1982-83 comparisons but the 1979-81 comparisons indicate a significant decline in I with increasing length. In this comparison the Lady Hammond with a Western IIA was fishing with a nominal headline height of 15 feet while the A.T. Cameron's Yankee 36 had a 9 foot headline height. The younger and hence shorter silver hake are believed to be distributed higher off the bottom and hence are more available to the Western IIA then the Yankee 36. The older fish are closer to the bottom and hence more equally available to the two gears.

Plaice also showed a significant decline in I with increasing length in LH/ATC but no change in I in LH/AN. For comparision with Gavaris and

Brodie (1984) both plaice and yellowtail were re-analysed by length using groupings of ≤ 28 cm and > 28 cm (Table 7). Similar results were obtained, the confidence intervals between ≤ 28 cm and > 28 cm length groups did not overlap for plaice but did for yellowtail.

By comparison of the results by weight with those by length, it is apparent that they are related. Presumably the differences in I calculated by number and by weight are due to differences in I at length.

Recommendations

All recommendations are based on results presented in Table 4. If the 95% confidence interval for I includes 0.5 then no conversion is recommended i.e. K = 1.0. When conversion factors are appropriate the value of K from Table 4 is recommended. For all species the recommendation is to bring A.T. Cameron surveys and Lady Hammond surveys into line with Alfred Needler surveys. This will allow conversion of historical data now and future survey data can be accepted without conversion. The procedure for conversion is:

$$AN = \frac{1}{K_2} (LH) = \frac{K_1}{K_2} (ATC)$$

where K_1 and K_2 are the recommended conversion factors for A.T. Cameron - Lady Hammond (79-81) comparisons and Alfred Needler - Lady Hammond (82-83) comparisons respectively and the catches by each vessel are designated by the vessels initials.

1. Cod	AN = .8 LH = .8 ATC
2. Haddock	AN = LH = 1.2 ATC
3. White Hake	AN = LH = ATC
4. Silver Hake	AN = LH
5. Redfish	AN = LH
6. Plaice ≤ 28 cm	AN = LH = .7 ATC
≶ 28 cm	AN = LH = ATC
7. Witch	AN = .8 LH = .8 ATC
8. Yellowtail	AN = .8 LH = .8 ATC
9. Winter flounder	LH = ATC

Recognizing that the wingspread of the Yankee 36 trawl is smaller than that of the Western IIA it is also recommended that after all mean catches per tow are converted to Alfred Needler equivalents, the number or trawlable units used to compute population sizes be computed using the wingspread of the Western IIA trawl.

While conversion factors for both pairs of comparisons for all 10 species were calculated, small sample sizes and/or badly distributed data make several of them unreliable. These are:

Pollock	AN/LH and LH/ATC
Silver hake	LH/ATC
Redfish	LH/ATC
Winter flounder	AN/LH

Because of the apparent year effects in the LH/AN comparison the conversion factors for these two vessels are also suspect. Another comparative fishing experiment is planned for October 1985 using the Alfred Needler and the Lady Hammond. This will be a dedicated experiment and not a piggy-back on a regular survey. This will allow further examination of a systematic difference in relative catch index detected between 1982 and 1983. In Figure 7a the relative catch index is plotted for each year from LH/ATC for 10 species. While the pattern is generally similar for each year the line cross repeatedly indicating relatively random ordering of years. In Figure 7b (LH/AN) it is apparent that the ordering of years is not random but in fact 1983 had a higher relative catch index than 1982 for all 10 species. Note that winter flounder results are missing for 1982 (no data) and unreliable in other years (little data). Also worth noting is that 1982 data was from a fall survey while all other data came from summer surveys.

The second front for future work will be the statistical properties of the estimates, with particular reference to bias. A simulation study will be used for this purpose.

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Table 1. Summary of vessel and trawl characteristics of the three vessel-gear units used in comparative fishing experiments from 1979 to 1983.

	A.T. Cameron	Lady Hammond	Alfred Needler
Vessel type	Side trawler	Stern trawler	Stern trawler
B.H.P.	1000	2500	2000
Tonnage	753	897	925
Length	53 m	58 m	50 m
Trawl	Yankee 36	Western IIA	
Footrope	7" (outer sections) and 14" (inner sections) rubber disc spacers + 17 lb iron spacers	18" (inner) and 21" (outer) bobbins and 6 ¾" diameter 7" long spacers, all rubber	
Liner			
Belly extension	n/a	1¼"	
Lengthening piece	1¼"	1¼"	
Codend	¼"	¾"	
Headline length (ft)	60	75	
Footrope length (ft)			
overall	80	106	
with netting	80	68	
Netting panel lengths (ft)			
top wings	25	27	
square & bunt	14	21	
bellies & 1' piece	30	41	
codend	47	38	
total	116	127	
Door type	Steel bound wood	Portugese (all steel)	
weight	1000 lb	1800 lb	
area	31 ft^2	47 ft^2	
Mouth opening (ft)			
headline height	9	15	
wing spread	35	41	

Table 2. Paired t-tests for differences in depth of tow between the indicated vessels outliers have been deleted as discussed in the text.

	A.T. Cameron - Lady Hammond			Alfred Needler - Lady Hammond	
Year	1979	1980	1981	1982	1983
Sample size	52	94	81	49	85
Number deleted	1	0	1	1	2
Mean difference	-1.96	-0.98	1.23	0.45	0.45
Standard deviation	4.19	5.68	8.27	2.81	6.11
t-statistic	-3.37	-1.67	1.34	1.12	0.67
P (T ≥ | t |)	<0.001	0.098	0.18	0.27	0.50

Table 3. Paired t-tests for differences in distance towed between the indicated vessels. Outliers have been deleted as discussed in the text.

	A.T. Cameron - Lady Hammond			Alfred Needler - Lady Hammond	
Year	1979	1980	1981	1982	1983
Sample size	53	94	82	50	84
number deleted	0	0	0	0	3
mean difference	-0.17	-0.29	0.01	0.10	-0.03
standard deviation	0.52	0.46	0.32	0.23	0.13
t-statistic	-2.43	-6.16	0.24	3.13	-1.94
P (T ≥ | t |)	0.019	<0.001	0.81	0.003	0.060

Table 4. Least-squares estimates and confidence intervals for relative catch index, I, and corresponding conversion factors, K, for each species (based on numbers caught). Catches in 1979 and 1980 are adjusted for distance towed.

Species	Year	N	I	Confidence Limits L	U	K
Cod	79-81	201	0.479	0.451	0.507	0.918
	82-83	102	0.555	0.522	0.588	1.247
Haddock	79-81	183	0.549	0.519	0.578	1.215
	82-83	116	0.500	0.470	0.530	1.000
White Hake	79-81	113	0.518	0.481	0.554	1.073
	82-83	55	0.496	0.456	0.535	0.982
Silver Hake	79-81	104	0.699	0.668	0.730	2.322
	82-83	92	0.471	0.439	0.502	0.889
Pollock	79-81	55	0.571	0.509	0.633	1.332
	82-83	27	0.541	0.446	0.635	1.177
Redfish	79-81	91	0.608	0.562	0.654	1.553
	82-83	53	0.460	0.414	0.506	0.851
Plaice	79-81	184	0.528	0.497	0.559	1.119
	82-83	96	0.507	0.477	0.537	1.028
Witch	79-81	100	0.521	0.482	0.560	1.086
	82-83	56	0.547	0.505	0.590	1.209
Yellowtail	79-81	84	0.524	0.487	0.562	1.101
	82-83	55	0.551	0.515	0.587	1.227
Winter Flounder	79-81	37	0.528	0.465	0.591	1.117
	83*	11	0.594	0.523	0.666	1.464

* No valid comparative sets for Winter Flounder were obtained in 1982 and the sample size makes the resulting estimates unreliable.

Table 5. Relative efficiency of least squares estimators with respect to method of moments estimators based on mean squared error.

Species	Year	Mean Squared Error (10^4) M. of M.	Mean Squared Error (10^4) Least Squares	Relative Efficiency
Cod	79	9	7	1.29
	80	13	4	3.25
	81	10	5	2.00
	79-81	8	2	4.00
	82	21	18	1.17
	83	13	10	1.30
	82-83	13	10	1.30
Haddock	79	6	3	2.00
	80	17	8	2.13
	81	13	9	1.44
	79-81	9	4	2.25
	82	13	12	1.08
	83	17	13	1.31
	82-83	16	13	1.23
Pollock	79	9	5	1.80
	80	50	32	1.56
	81	35	12	2.92
	79-81	23	11	2.09
	82	78	24	3.25
	83	27	9	3.00
	82-83	31	9	3.44
Redfish	79	17	3	5.67
	80	23	9	2.44
	81	34	19	1.78
	79-81	19	6	3.17
	82	18	15	1.20
	83	11	9	1.22
	82-83	10	8	1.25
Plaice	79	24	7	3.43
	80	12	6	2.00
	81	9	2	4.50
	79-81	10	2	5.00
	82	8	7	1.14
	83	4	2	2.00
	82-83	3	1	3.00
White hake	79	10	7	1.43
	80	36	27	1.33
	81	5	3	1.67
	79-81	11	7	1.57
	82	14	11	1.27
	83	3	2	1.50
	82-83	5	3	1.67

Table 5. Continued

Species	Year	Mean Squared Error (10^4) M. of M.	Mean Squared Error (10^4) Least Squares	Efficiency
Silver hake	79	11	9	1.22
	80	32	29	1.10
	81	8	5	1.60
	79-81	9	6	1.50
	82	18	16	1.12
	83	8	7	1.14
	82-83	10	8	1.25
Witch	79	10	7	1.43
	80	16	9	1.78
	81	14	9	1.56
	79-81	8	2	4.00
	82	7	7	1.00
	83	4	1	4.00
	82-83	4	2	2.00
Yellowtail	79	15	12	1.25
	80	13	9	1.44
	81	30	29	1.03
	79-81	13	10	1.30
	82	23	22	1.04
	83	18	17	1.06
	82-83	23	22	1.04
Winter flounder	79	8	6	1.33
	80	17	10	1.70
	81	26	22	1.18
	79-81	12	6	2.00
	82	-	-	-
	83	6	5	1.20
	82-83	-	-	-

Table 6. Least squares estimates and confidence intervals for I and corresponding K based on weight caught. Conversion factors from table 4 (K^1) are included with the percent relative absolute difference from K.

Species	Year	N	I	L	U	K	K^1	% relative Difference
Cod	79-81	197	0.4811	0.4498	0.5124	0.9272	0.9179	1.0
	82-83	101	0.5619	0.5259	0.5979	1.2824	1.2465	2.8
Haddock	79-81	169	0.5448	0.5167	0.5729	1.1969	1.2153	1.5
	82-83	113	0.5060	0.4770	0.5370	1.0283	0.9998	2.8
Silver hake	79-81	76	0.6648	0.6298	0.6997	1.9830	2.3221	17.1
	82-83	81	0.4832	0.4573	0.5091	0.9349	0.8886	5.0
Redfish	79-81	137	0.5594	0.5195	0.5993	1.2697	1.5532	22.3
	82-83	45	0.5101	0.4621	0.5581	1.0412	0.8572	18.3
Plaice	79-81	266	0.5027	0.4785	0.5269	1.0110	1.1187	10.7
	82-83	104	0.5306	0.5052	0.5560	1.1306	1.0281	9.1
Yellowtail	79-81	78	0.5014	0.4533	0.5374	1.-055	1.1011	9.5
	82-83	50	0.5715	0.5379	0.6051	1.3338	1.2270	8.0

Table 7. Comparison of plaice and yellowtail relative catch indices for fish less than or equal to 28 cm and fish greater than 28 cm.

	N	I	L	U	K
Plaice (79-81)					
≤ 28	152	0.5795	0.5460	0.6130	1.3782*
≥ 28	221	0.5017	0.4751	0.5284	1.0070
(82-83)					
≤ 28	110	0.4977	0.4672	0.5281	0.9907
≥ 28	106	0.5402	0.5081	0.5723	1.1748
Yellowtail (79-81)					
≤ 28	47	0.5629	0.5131	0.6127	1.2878
≥ 28	99	0.5144	0.4810	0.5479	1.0595
(82-83)					
≤ 28	46	0.5999	0.5636	0.6361	1.4991
≥ 28	57	0.5539	0.5236	0.5841	1.2414

* No overlap between 95% confidence intervals.

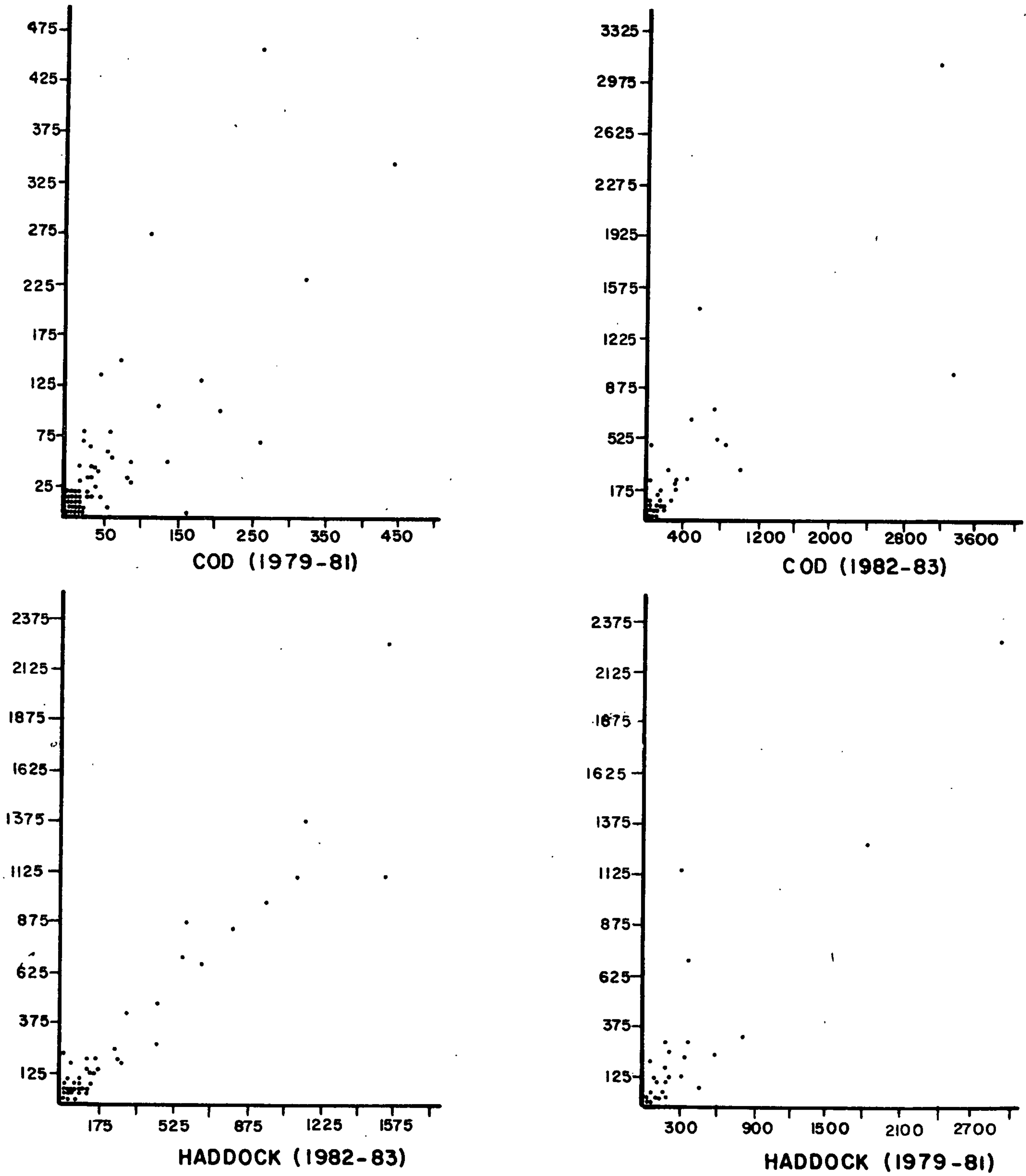


Figure 1. Plots for each species of numbers caught by the test vessels (79-81, A.T. Cameron; 82-83, Alfred Needler) against Lady Hammond numbers caught

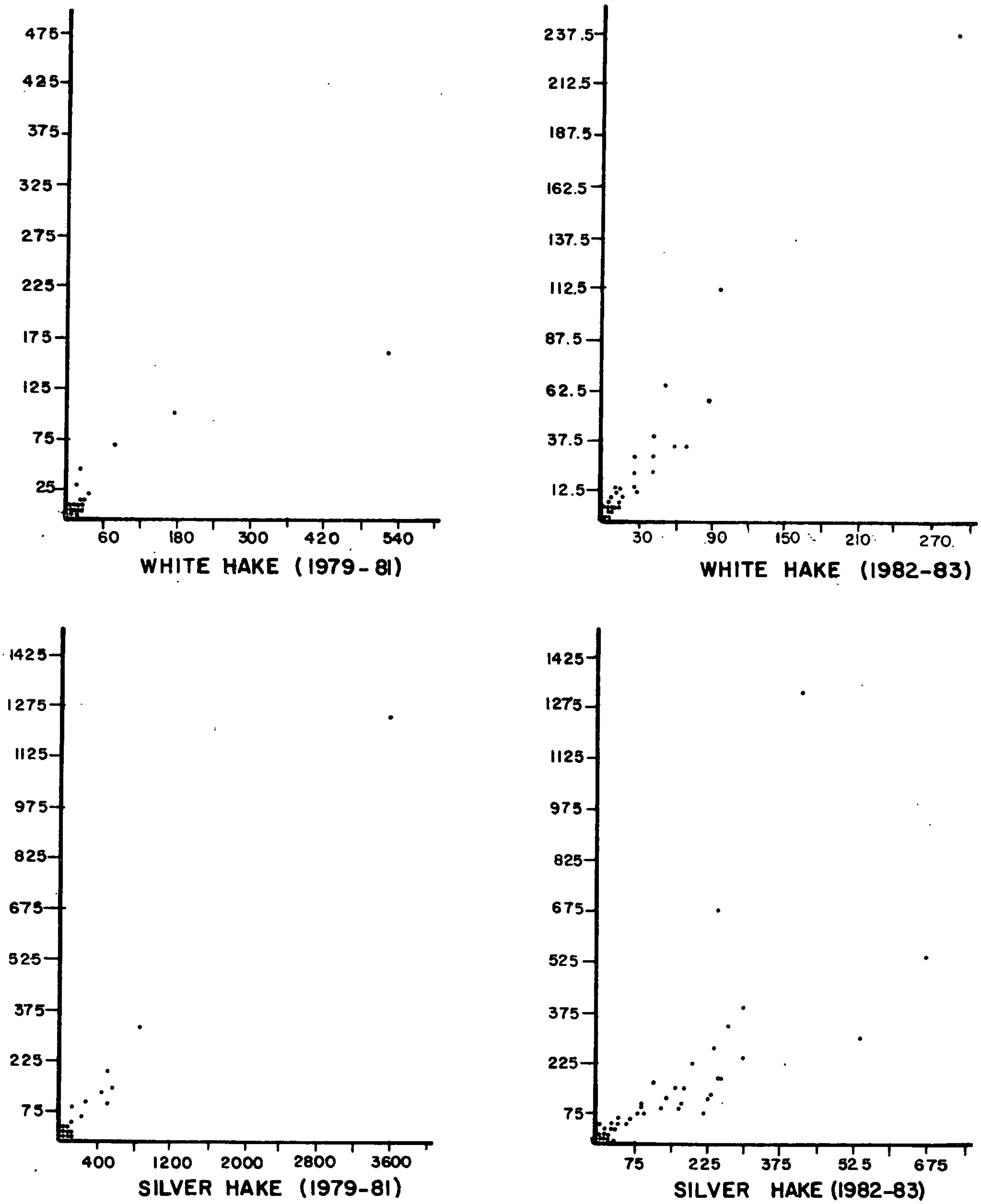


Figure 1. Continued

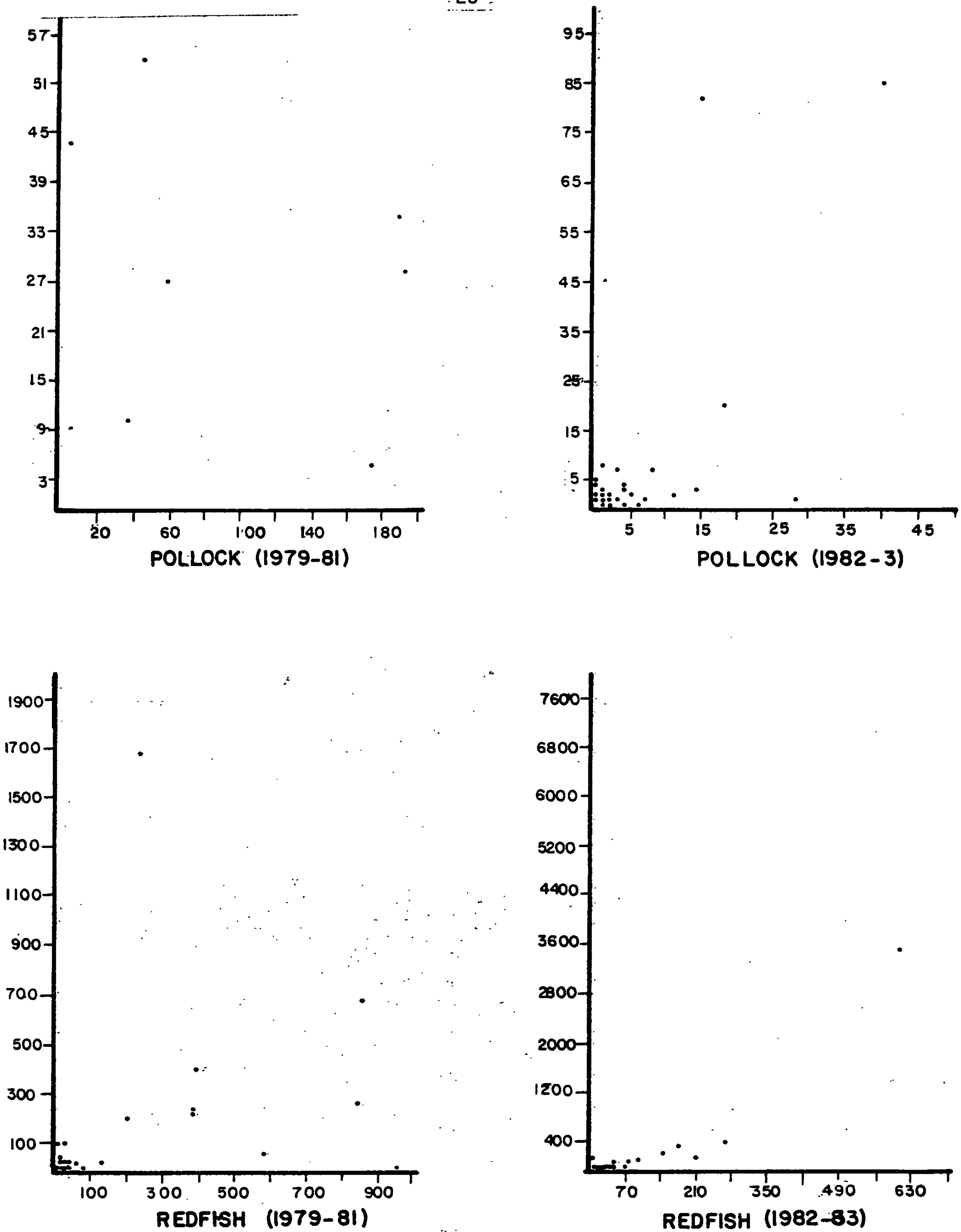


Figure 1. Continued

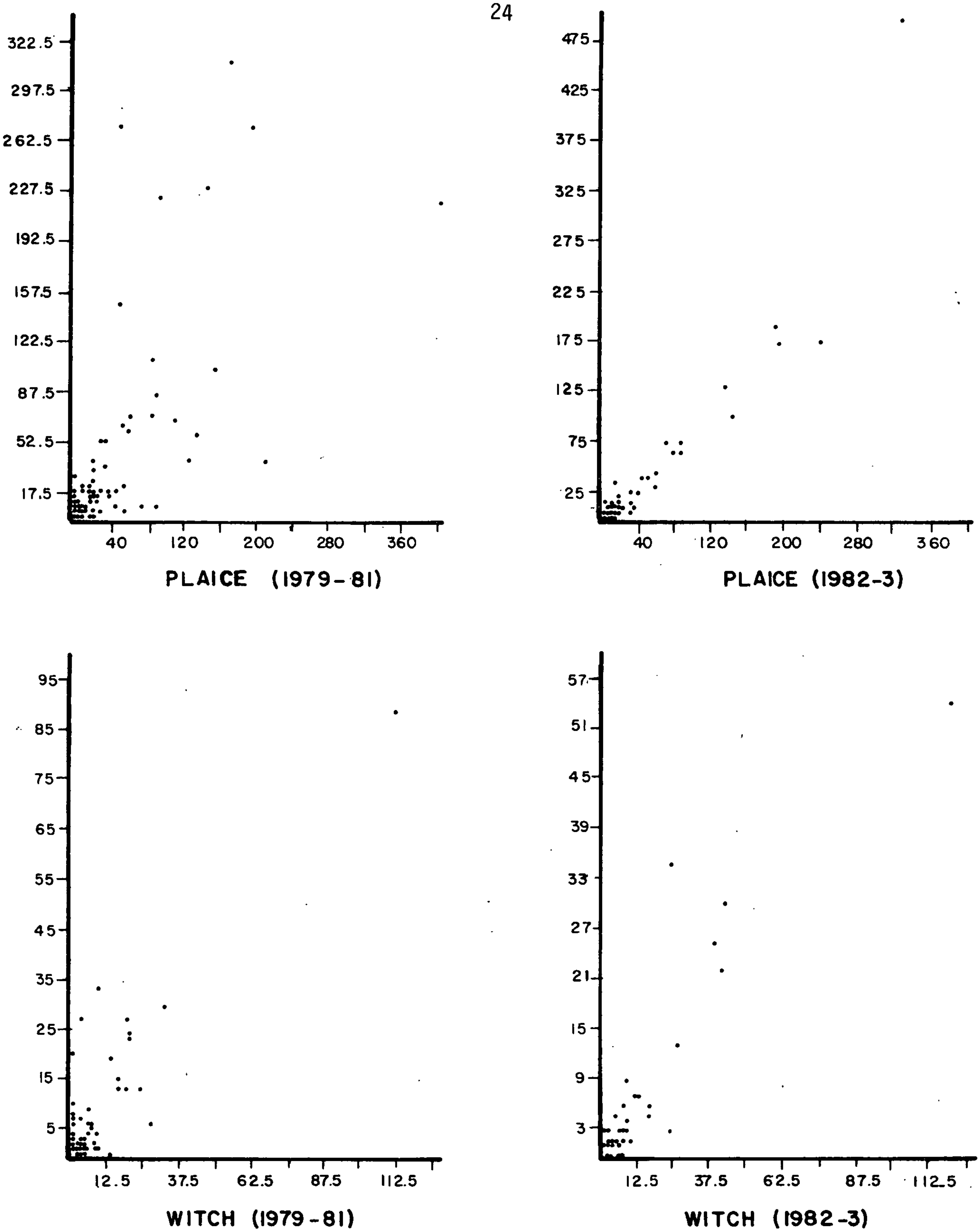


Figure 1. Continued

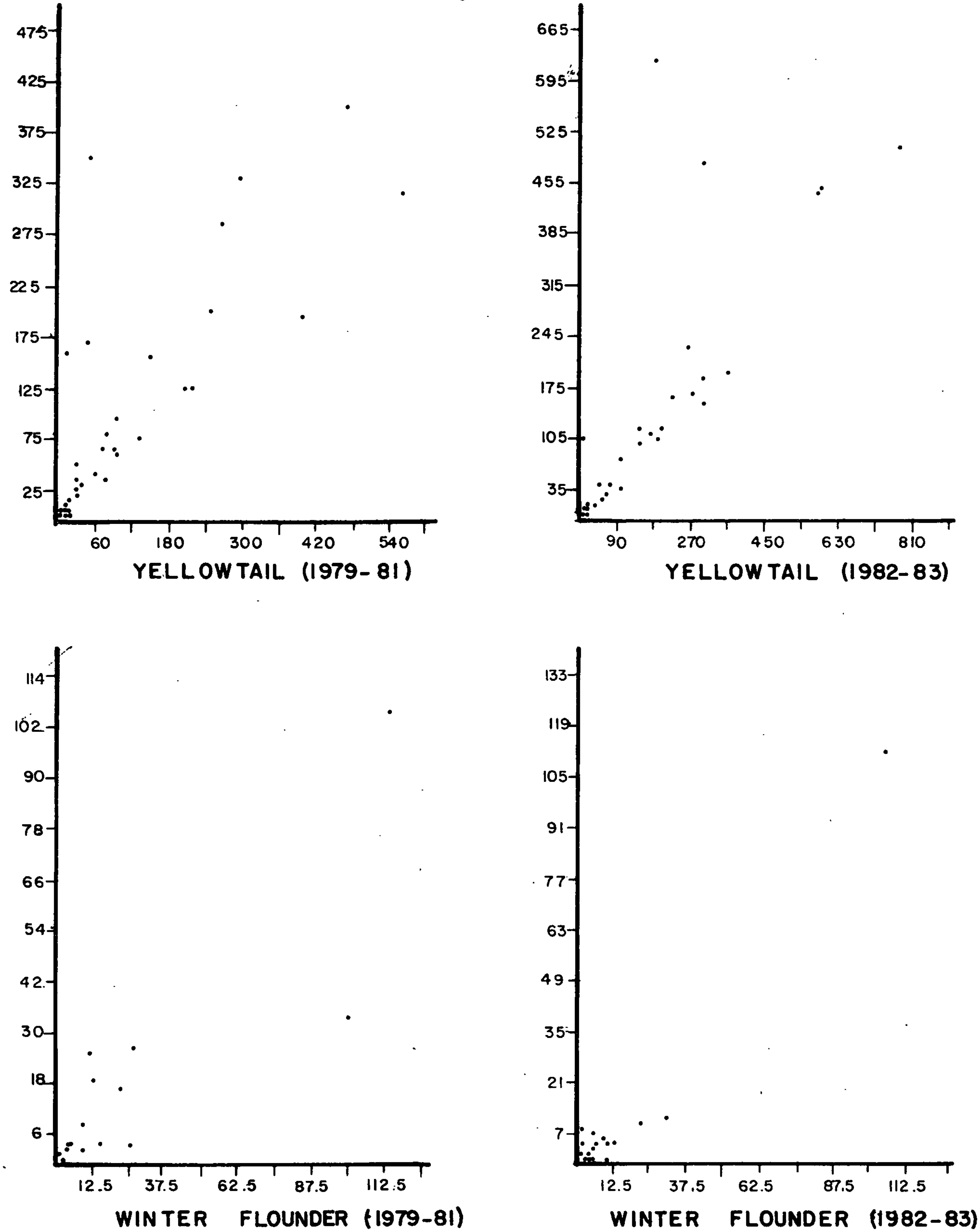


Figure 1. Continued

a) 1979

```
            n = 53
            Unit = 1
 Depth      1|2 rep 12
   1        F| 4
            T|
   2     +1 *| 1
            .|
   3        S| 6
   4        F| 4
   6        T| 3 3
   8     +0 *| 0 1
  17     -0 *| 1 1 1 1 1 1 1 0 0
 (18)       T| 3 3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2
  18        F| 5 5 5 5 5 4 4 4 4 4 4 4
   6        S| 6
   5        .| 9 9 8
   2     -1 *| 0
             |
             |
             |
   1       low| -111
```

b) 1980

```
            n = 94
            Unit = 1
 Depth      1|2 rep 12
   1       Hi| 29
             |
   2        T| 3
   3     +1 *| 1
   5        .| 9 8
   6        S| 7
  12        F| 5 5 5 5 4 4
  22        T| 3 3 3 3 3 3 2 2 2 2
  33     +0 *| 0 0 1 1 1 1 1 1 1 1 1
  45     -0 *| 0 0 1 1 1 1 1 1 1 1 1 1
 (23)       T| 2 2 2 2 2 2 2 2 2 2 2 2 2 2 3 3 3 3 3 3 3 3 3
  26        F| 4 4 4 4 4 4 4 4 4 4 4 5 5 5
  12        S| 6 6 6 7 7
   7        .| 8 8 8 9 9
         -1 *|
            T|
   2        F| 4
            S|
            .|
   1     -2 *| 0
```

Figure 2. Stem and leaf plot of differences in depth between test and standard vessels for each year.

c) 1981

```
          n = 82
          Unit = 1
Depth     1|2 rep 12
             |
           . |
  1    3   * |4
           . |
  2    2   * |5
  4        . |8 9
  8    1   * |1 2 2 5
 10        . |7 7
(34)   0   * |1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 3 3 3 3 4 4 5
 38   -0   * |5 5 5 5 5 5 3 2 2 2 2 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  5        . |9 7
      -1   * |
  3        . |6
      -2   * |
           . |
      -3   * |
           . |
  2   -4   * |1
  1      Low |-939
```

d) 1982

```
          n = 40
          Unit = .1
Depth     1|2 rep 1.2

  1    High|241
  2      11|✓
         10|
          9|
          8|
  3       7|✓
          6|
          5|
  4       4|✓
  5       3|✓
  7       2|✓ ✓
 11       1|✓ ✓ ✓ ✓
(15)      0|✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓
 24      -1|✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓
 14      -2|✓ ✓ ✓ ✓ ✓ ✓
  8      -3|✓ ✓ ✓ ✓
  4      -4|✓
  3      -5|✓
  2      -6|✓ ✓
```

Figure 2. Continued.

e) 1983

```
          N = 87
          Unit = 1
Depth     1|2 rep 12

  1   High|241
  2      F|4
         T|
  4   1  *|0 1
         .|
  5      S|7
  7      F|4 5
 13      T|2 2 2 3 3 3
 40  +0  *|0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1
(33) -0  *|0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 14      T|2 2 2 2 2 2 3 3
  6      F|4 4
  4      S|7
         .|
     -1  *|
  3      T|2
  2    Low|-929, -48
```

Figure 2. Continued.

a) 1979

n = 53
Unit = .01
1|2 rep .12

Depth		
1	-17	✓
	-16	
	-15	
2	-14	✓
	-13	
	-12	
	-11	
	-10	
5	-9	✓ ✓ ✓
	-8	
6	-7	✓
7	-6	✓
13	-5	✓ ✓ ✓ ✓ ✓ ✓
21	-4	✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓
24	-3	✓ ✓ ✓
(8)	-2	✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓
21	-1	✓ ✓
19	0	✓ ✓ ✓
16	1	✓ ✓ ✓
13	2	✓ ✓ ✓ ✓
	3	
9	4	✓ ✓
7	5	✓ ✓
5	6	✓
4	7	✓ ✓
2	8	✓
	9	
	10	
1	11	✓

b) 1980

n = 94
Unit = .01
1|2 rep .12

Depth		
1	12	✓
	11	
	10	
	9	
	8	
	7	
3	6	✓ ✓
4	5	✓
5	4	✓
6	3	✓
14	2	✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓
19	1	✓ ✓ ✓ ✓ ✓
29	0	✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓
38	-1	✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓
43	-2	✓ ✓ ✓ ✓ ✓
(10)	-3	✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓
41	-4	✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓
28	-5	✓ ✓ ✓ ✓
24	-6	✓ ✓ ✓ ✓ ✓ ✓
18	-7	✓ ✓ ✓ ✓
14	-8	✓
13	-9	✓ ✓ ✓ ✓
9	-10	✓ ✓ ✓ ✓ ✓ ✓
3	-11	✓
2	-12	✓
1	Low	-1.9

Figure 3. Stem and leaf plot of differences in distance towed between test and standard vessels in each year.

c) 1981

n = 82
Unit = .01
1|2 rep .12

Depth		
1	9	✓
	8	
	7	
4	6	✓ ✓ ✓
5	5	✓
10	4	✓ ✓ ✓ ✓ ✓
18	3	✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓
28	2	✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓
(13)	1	✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓
41	0	✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓
32	-1	✓ ✓ ✓ ✓ ✓ ✓ ✓
25	-2	✓ ✓ ✓ ✓
21	-3	✓ ✓ ✓ ✓ ✓ ✓
15	-4	✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓
5	-5	✓ ✓ ✓
	-6	
2	-7	✓ ✓

d) 1982

n = 50
Unit = .01
1|2 rep .12

Depth		
1	9	✓
2	8	✓
	7	
	6	
3	5	✓
4	4	✓
11	3	✓ ✓ ✓ ✓ ✓ ✓ ✓
18	2	✓ ✓ ✓ ✓ ✓ ✓ ✓
(10)	1	✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓
22	0	✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓
12	-1	✓ ✓ ✓ ✓ ✓ ✓ ✓
5	-2	✓ ✓ ✓
2	-3	✓ ✓

Figure 3. Continued.

e) 1983

```
        n = 87
        Unit = .01
Depth   1|2 rep .12
  5       2|✓ ✓ ✓ ✓ ✓
 21       1|✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓
(33)      0|✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓
 33      -1|✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓
 14      -2|✓ ✓ ✓ ✓ ✓
  9      -3|✓ ✓ ✓ ✓ ✓
         -4|
  4      -5|✓
  3     Low|-8.9, -8.6, -8.3
```

Figure 3. Continued.

COD 79-81 (Number)

```
          Unit = .01
Depth     1|2 rep .12
  7  10  .|0 0 0 0 0 0 0
  9      *|5 8
 10   9  .|2
 11      *|6
 12   8  .|0
 15      *|5 5 7
 19   7  .|1 1 3 4
 25      *|5 6 6 6 6 8
 30   6  .|0 1 1 2 2
 41      *|5 5 6 7 7 8 8 8 9 9 9
(9)   5  .|0 0 0 0 0 1 2 3 4
 45      *|5 8
 43   4  .|0 0 1 1 2 2 2 3 3 4 4 4
 31      *|5 6 6 8 9
 26   3  .|0 2 2
 23      *|5 5 7 7 8 8 8 9 9
 14   2  .|0 3 3
 11      *|5 8
  9   1  .|4
         *|
  8   0  .|0 0 0 0 0 0 0 0
```

COD 82-83 (Number)

```
          Unit = .01
Depth     1|2 rep .12
  6  10  .|0 0 0 0 0 0
         *|
  8   9  .|2 3
         *|
 11   8  .|0 2 3
 15      *|5 5 7 8
 22   7  .|0 1 1 2 2 4 4
 29      *|5 5 6 6 6 6 7
 40   6  .|0 0 0 0 1 1 2 2 3 4 4
(8)      *|5 5 5 5 7 7 7 9
 35   5  .|0 0 0 0 1 2 3 4 4
 26      *|7 7 8 8 9
 21   4  .|0 0 1 1 4
 16      *|6 8
 14   3  .|4
 13      *|6
 12   2  .|0
         *|
 11   1  .|0
 10      *|8
  9   0  .|0 0 0 0 0 0 0 0 0
```

HADDOCK 79-81 (Number)

```
          Unit = .01
Depth     1|2 rep .12
 13  10  .|0 0 0 0 0 0 0 0 0 0 0 0 0
         *|
      9  .|
 15      *|5 9
 16   8  .|4
 21      *|5 5 5 6 9
 26   7  .|1 1 1 1 3
 34      *|6 6 6 6 6 6 7 8
 40   6  .|0 0 1 1 1 2
(5)      *|5 6 7 8 8
 37   5  .|0 0 1 2 3 3 3 4
 29      *|5 7 7 7 8 8
 23   4  .|0 4
 21      *|9
 20   3  .|3
 19      *|5 8 8 9 9
 14   2  .|0 0
 12      *|5 6 6 8
      1  .|
         *|
  8   0  .|0 0 0 0 0 0 0 0
```

HADDOCK 82-83 (Number)

```
          Unit = .01
Depth     1|2 rep .12
  4  10  .|0 0 0 0
         *|
  6   9  .|2 4
         *|
 11   8  .|0 1 3 4 6
 13      *|5 6
 16   7  .|0 0 1
 20      *|5 5 7 9
 26   6  .|0 0 0 0 0 2
 34      *|5 5 5 6 7 8 9 9
(10)  5  .|0 0 0 0 0 1 1 1 2 3
 43      *|5 7 8 8 8 9 9 9
 35   4  .|0 1 2 2 2 3 3 3 3 4
 25      *|7 8 9 9
 21   3  .|2 3
 19      *|5
 18   2  .|0 0
         *|
 16   1  .|0 3
         *|
 14   0  .|0 0 0 0 0 0 0 0 0 0 0 0 0 4
```

Figure 4. Stem and leaf plots of relative catch index for the two vessel comparisons for 10 species.

WHITE HAKE 79-81 (Number)

```
          Unit = .01
Depth     1|2 rep .12
  8   10  .|0 0 0 0 0 0 0 0
          *|
       9  .|
          *|
 10    8  .|0 4
 14       *|5 5 6 6
 17    7  .|0 0 3
 19       *|6 6
 25    6  .|0 0 0 2 2 3
(6)       *|5 5 6 6 7 8
 29    5  .|0 0 0 0 0 3
 23       *|5 6 8 8 9
 18    4  .|0 0 2 4
 14       *|6 7
       3  .|
 12       *|5 6 7
       2  .|
  9       *|8
       1  .|
          *|
  8    0  .|0 0 0 0 0 0 0 0
```

WHITE HAKE 82-83 (Number)

```
          Unit = .01
Depth     1|2 rep .12
  7   10  .|0 0 0 0 0 0 0
          *|
       9  .|
          *|
       8  .|
  9       *|5 5
 10    7  .|1
 12       *|5 8
 20    6  .|0 0 1 1 1 1 2 3
(5)       *|7 7 7 8 9
 22    5  .|0 0 0 0 0 4
 16       *|5
 15    4  .|0 2 2 2 4 4
  9       *|6 6
  7    3  .|0 3 3
          *|
       2  .|
          *|
       1  .|
          *|
  4    0  .|0 0 0 0
```

SILVER HAKE 79-81 (Number)

```
          Unit = .01
Depth     1|2 rep .12
 20   10  .|0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 21       *|6
       9  .|
 22       *|9
 27    8  .|0 0 1 2 2
(5)       *|6 7 7 8 8
 24    7  .|0 0 0 1 3 3 4
 17       *|5 6
 15    6  .|0 1
 13       *|6 8
 11    5  .|0 1 1 3
  7       *|7
  6    4  .|2
  5       *|7
  4    3  .|1
          *|
       2  .|
          *|
       1  .|
          *|
  1    0  .|0 0 0
```

SILVER HAKE 82-83 (Number)

```
          Unit = .01
Depth     1|2 rep .12
  7   10  .|0 0 0 0 0 0 0
          *|
       9  .|
  8       *|5
 10    8  .|3 4
          *|
 11    7  .|2
 12       *|8
 18    6  .|0 2 3 3 4 4
 25       *|5 5 6 6 6 7 7
 31    5  .|0 1 2 2 4 4
(10)      *|5 5 6 6 7 7 8 8 9 9
 29    4  .|0 1 2 2 3 4 4 4 4
 20       *|5 5 7 7 7
 15    3  .|1 2
 13       *|6
 12    2  .|3 3 4
  9       *|7
       1  .|
          *|
  8    0  .|0 0 0 0 0 0 0 0
```

Figure 4. Continued.

POLLOCK 79-81 (Number)

```
          Unit = .01
Depth     1|2 rep .12
 15  10   .|0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 16       *|7
      9   .|
 18       *|5 7
 (3)  8   .|0 3 4
 18       *|5 7
 16   7   .|3
 15       *|6 6 6 7
      6   .|
          *|
 11   5   .|0
          *|
 10   4   .|4 4
  8       *|7
  7   3   .|3 3
  5       *|5 5
      2   .|
          *|
      1   .|
  3       *|6
  2   0   .|0 0
```

POLLOCK 82-83 (Number)

```
          Unit = .01
Depth     1|2 rep .12
 13  10   .|0 0 0 0 0 0 0 0 0 0 0 0 0
 14       *|6
      9   .|
 15       *|7
 17   8   .|2 4
 19       *|5 5
 20   7   .|1
 21       *|6
      6   .|
 (1)      *|7
 21   5   .|0 0 0 3
 17       *|7
      4   .|
          *|
 16   3   .|0 2 3 3
 12       *|5
      2   .|
          *|
 11   1   .|1
          *|
 10   0   .|0 0 0 0 0 0 0 0 0 0
```

REDFISH 79-81 (Number)

```
          Unit = .01
Depth     1|2 rep .12
 13  10   .|0 0 0 0 0 0 0 0 0 0 0 0 0
 14       *|9
 16   9   .|0 0
 17       *|8
 20   8   .|0 0 3
 22       *|5 5
 24   7   .|2 2
 26       *|6 6
 26   6   .|0 3 3
 23       *|5 5
 21   5   .|0 3 3 4
 17       *|6 8 9
 14   4   .|4
          *|
      3   .|
          *|
 13   2   .|2
 12       *|6
 11   1   .|1 3
          *|
  9   0   .|0 0 0 0 0 0 0 0 0
```

REDFISH 82-83 (Number)

```
          Unit = .01
Depth     1|2 rep .12
  5  10   .|0 0 0 0 0
          *|
      9   .|
  6       *|7
      8   .|
          *|
  7   7   .|1
  8       *|6
 10   6   .|0 3
 14       *|6 6 7 9
 17   5   .|0 1 2
 (5)      *|6 7 8 8 9
 20   4   .|0 1 1
 17       *|7 8 9
 14   3   .|2
 13       *|5
 12   2   .|0
          *|
 11   1   .|4
          *|
 10   0   .|0 0 0 0 0 0 0 0 0 0
```

Figure 4. Continued.

PLAICE 79-81 (Number)

```
         Unit = .01
Depth    1|2 rep .12
 10  10  .|0 0 0 0 0 0 0 0 0 0
         *|
 13   9  .|1 2 3
 15      *|5 6
 18   8  .|0 3 4
 20      *|5 6
 29   7  .|1 2 2 3
 31      *|5 6 6 6 6 9 9
 37   6  .|0 1 1 1 2 4
 43      *|5 5 5 5 8 9
 (7)  5  .|0 0 0 0 1 2 4
 42      *|5 5 6 7
 38   4  .|0 0 1 1 2 3 4 4
 30      *|5 6 8 8 9
 25   3  .|0 1 2 4
 21      *|5 5 9
 18   2  .|0 2 3 4
 14      *|5
 13   1  .|1
         *|
 12   0  .|0 0 0 0 0 0 0 0 0 0 0 0
```

PLAICE 82-83 (Number)

```
         Unit = .01
Depth    1|2 rep .12
  9  10  .|0 0 0 0 0 0 0 0 0
         *|
      9  .|
         *|
 11   8  .|2 4
 15      *|5 5 5 5
 16   7  .|1
 21      *|5 6 6 6 6
 28   6  .|0 1 2 2 3 4 4
 34      *|5 6 7 7 7 7
(12)  5  .|0 0 0 1 1 2 2 2 3 3 4 4
 35      *|5 6 6 7 7 9
 29   4  .|0 0 2 4
 25      *|6 8 9
 22   3  .|0 3 3
 19      *|5 8
 17   2  .|1 1
         *|
      1  .|
         *|
 15   0  .|0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

WITCH 79-81 (Number)

```
         Unit = .01
Depth    1|2 rep .12
 17  10  .|0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
         *|
 18   9  .|0
 19      *|7
 24   8  .|0 0 0 1 3
         *|
      7  .|
 29      *|6 6 6 6 6
 32   6  .|3 3 3
 36      *|5 5 6 7
 (9)  5  .|0 0 0 0 0 0 1 3 4
 28      *|5 5
 26   4  .|0 4
 24      *|5 8 8
 21   3  .|3
         *|
 20   2  .|1 2
         *|
      1  .|
 18      *|6
 17   0  .|0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

WITCH 82-83 (Number)

```
         Unit = .01
Depth    1|2 rep .12
 11  10  .|0 0 0 0 0 0 0 0 0 0 0
         *|
      9  .|
 12      *|8
 14   8  .|1 3
 19      *|5 5 5 5 5
 21   7  .|0 1
 27      *|5 6 6 6 6 8
 (4)  6  .|0 1 2 4
 28      *|7 8
 26   5  .|0 0 0 0 0 0 0 0 0
         *|
 17   4  .|3 4
 15      *|9
 14   3  .|3 3 3
 11      *|5 5
      2  .|
         *|
      1  .|
         *|
  9   0  .|0 0 0 0 0 0 0 0 0
```

Figure 4. Continued.

YELLOWTAIL 79-81 (Number)

```
            Unit = .01
Depth       1|2 rep .12
  6   10  . |0 0 0 0 0 0
          *
       9  .
          *
       8  .
  8       * |5 5
       7  .
 10       * |6 6
 15    6  . |0 1 2 3 3
 19       * |6 8 8 9
 (6)   5  . |0 0 1 2 3 4
 18       * |6 7 7 7 8 8 9
 11    4  . |2
          *
 10    3  . |2
  9       * |5
  8    2  . |0
          *
       1  .
          *
  7    0  . |0 0 0 0 0 0 1
```

YELLOWTAIL 82-83 (Number)

```
            Unit = .01
Depth       1|2 rep .12
  5   10  . |0 0 0 0 0
          *
       9  .
          *
       8  .
  6       * |5
  7    7  . |3
 14       * |5 6 6 6 6 7
(10)   6  . |0 0 0 0 0 1 1 2 4 4
 21       * |5 5 6 6 7 8 9 9
 13    5  . |1 2 3
 10       * |8
       4  .
  9       * |7
  8    3  . |3
          *
  7    2  . |1
          *
       1  .
          *
  6    0  . |0 0 0 0 0 0
```

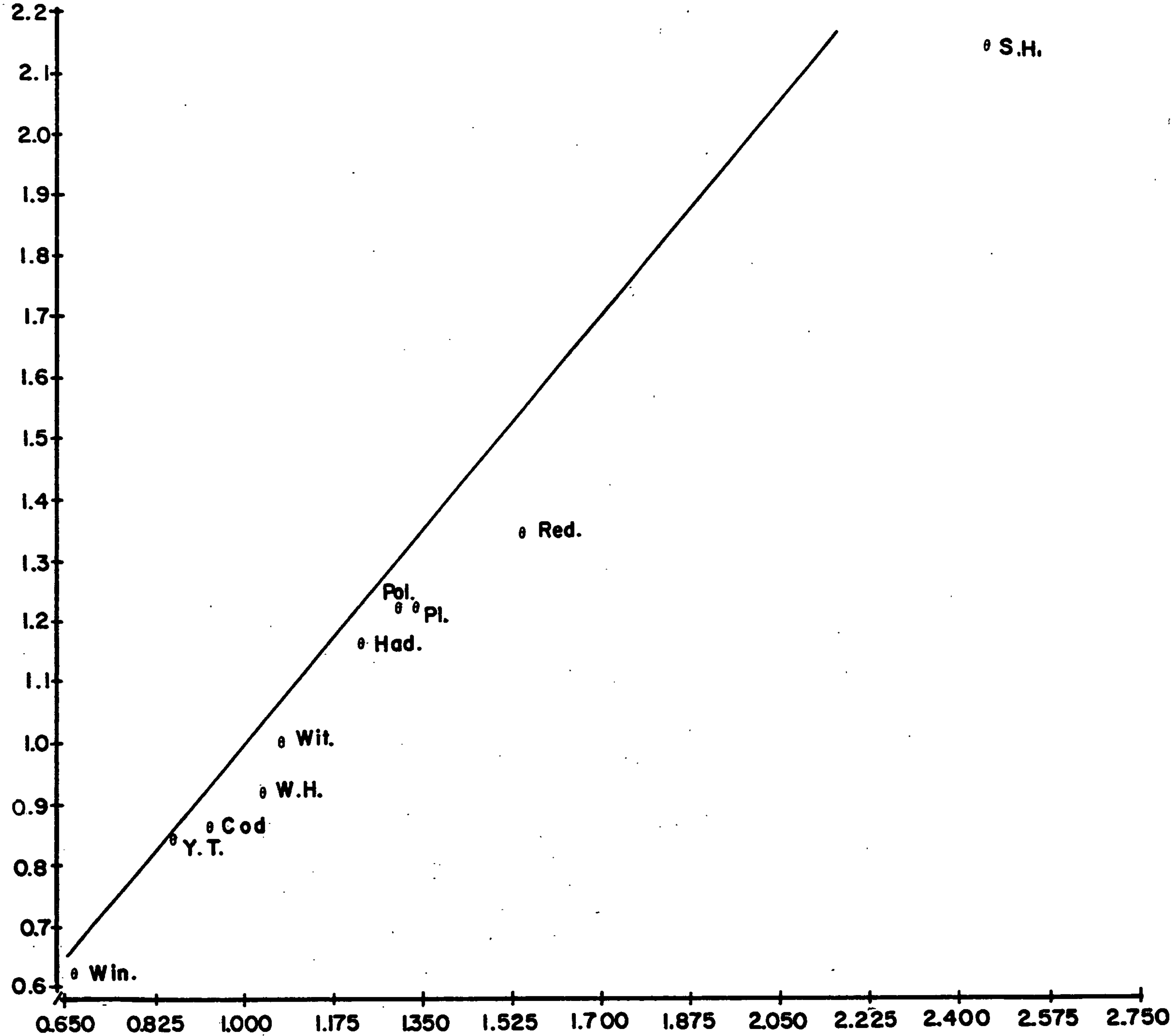
WINTER FLOUNDER 79-81 (Number)

```
            Unit - .01
Depth       1|2 rep .12
  5   10  . |0 0 0 0 0
          *
       9  .
  6       * |5
  7    8  . |0
  8       * |7
  9    7  . |4
          *
       6  .
 10       * |7
 (5)   5  . |0 0 0 1 4
  7       * |6 9
  5    4  . |0
  4       * |6
       3  .
  3       * |8
       2  .
          *
       1  .
          *
  2    0  . |0 0
```

WINTER FLOUNDER 82-83 (Number)

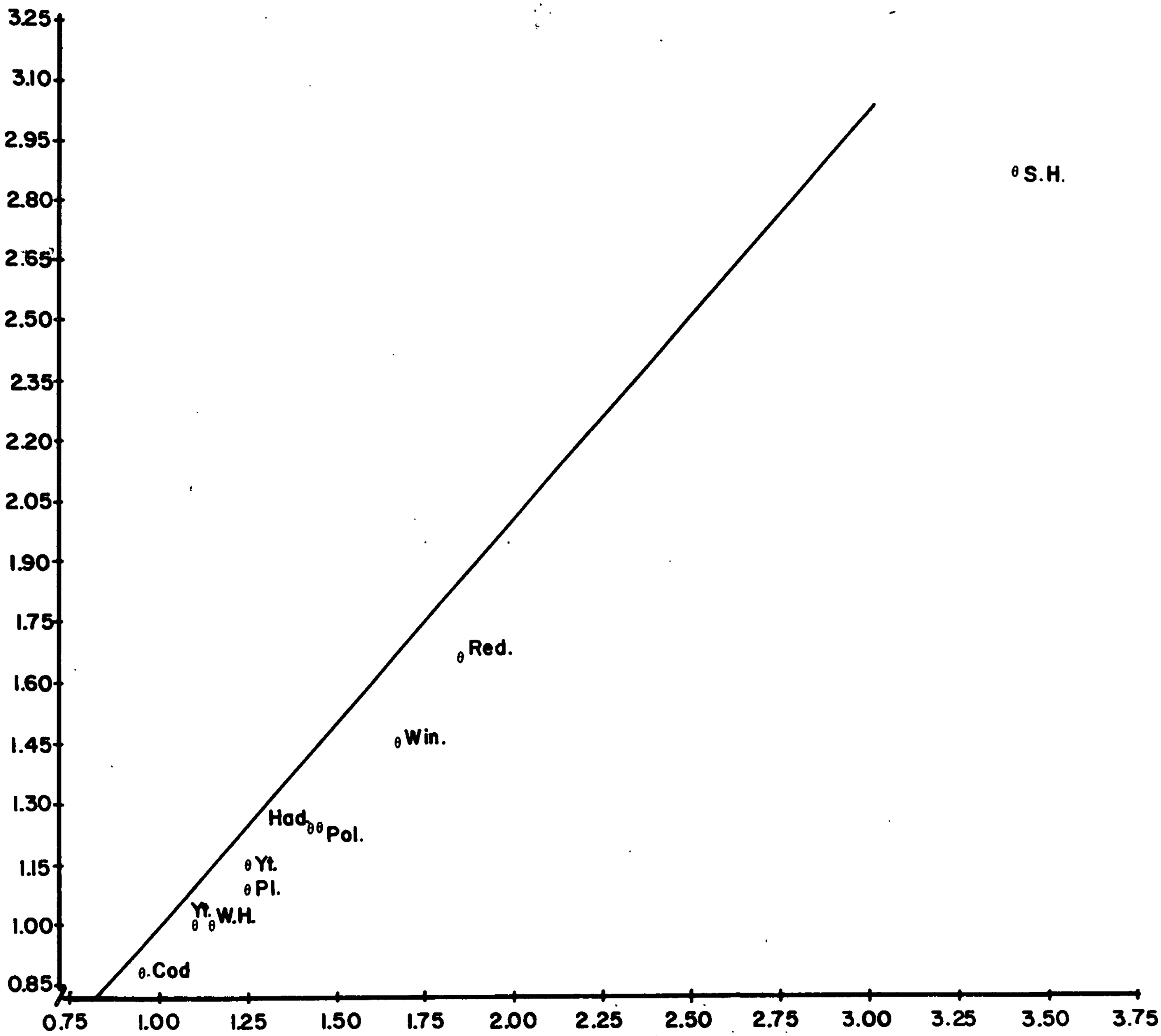
```
            Unit = .01
Depth       1|2 rep .12
  5   10  . |0 0 0 0 0
          *
       9  .
          *
       8  .
          *
  7    7  . |2 3
 10       * |6 6 9
       6  .
 10       * |5 7 8
  7    5  . |0
  6       * |7
       4  .
  5       * |6
       3  .
          *
       2  .
          *
       1  .
          *
  4    0  . |0 0 0 0
```

Figure 4. Continued.



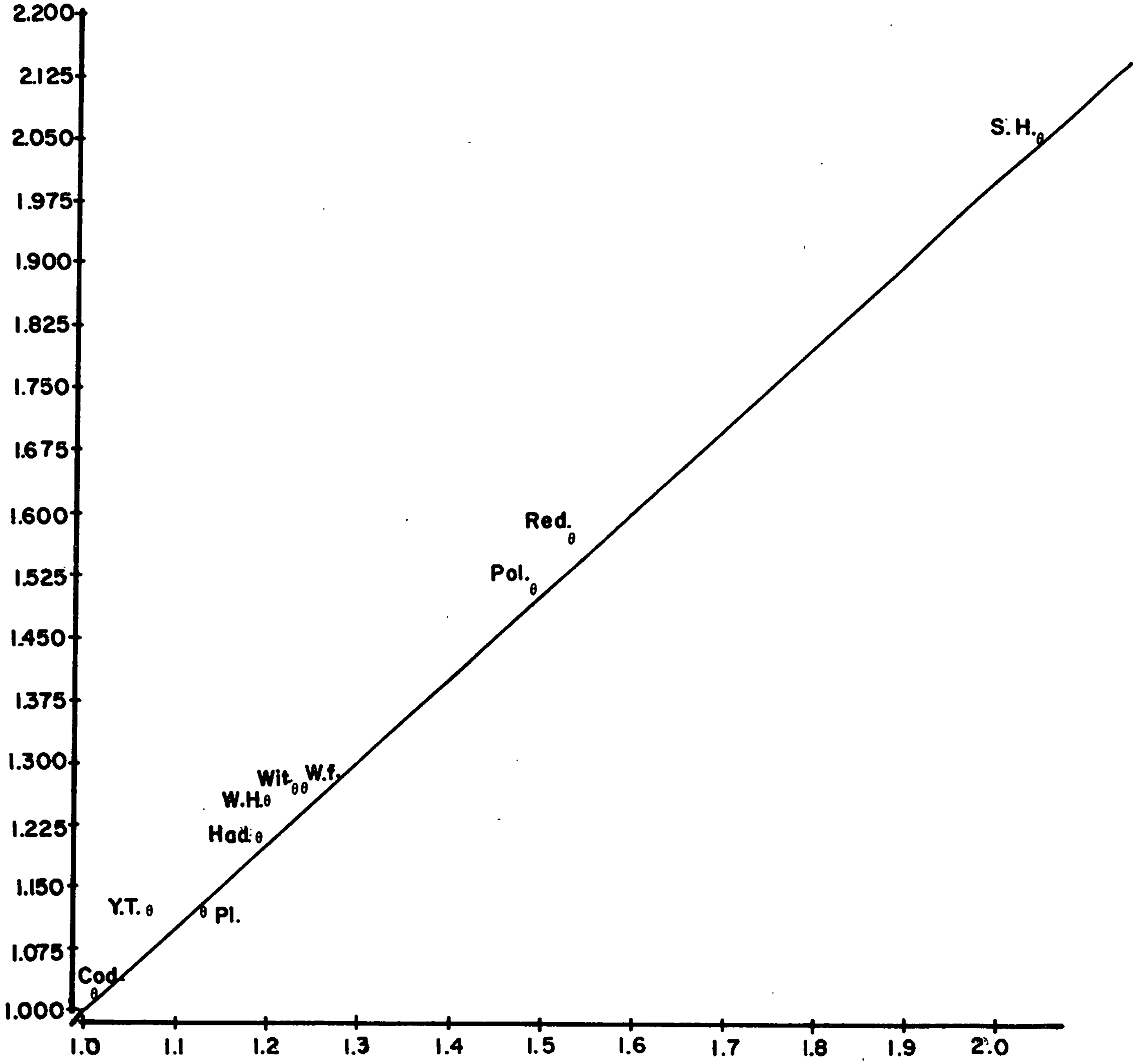
a) 1979

Figure 5. Conversion factors for 10 species based on catches adjusted for distance towed plotted against conversion factors based on raw catches. The solid line indicates equality of conversion factors.



b) 1980

Figure 5. Continued



c) 1981

Figure 5. Continued

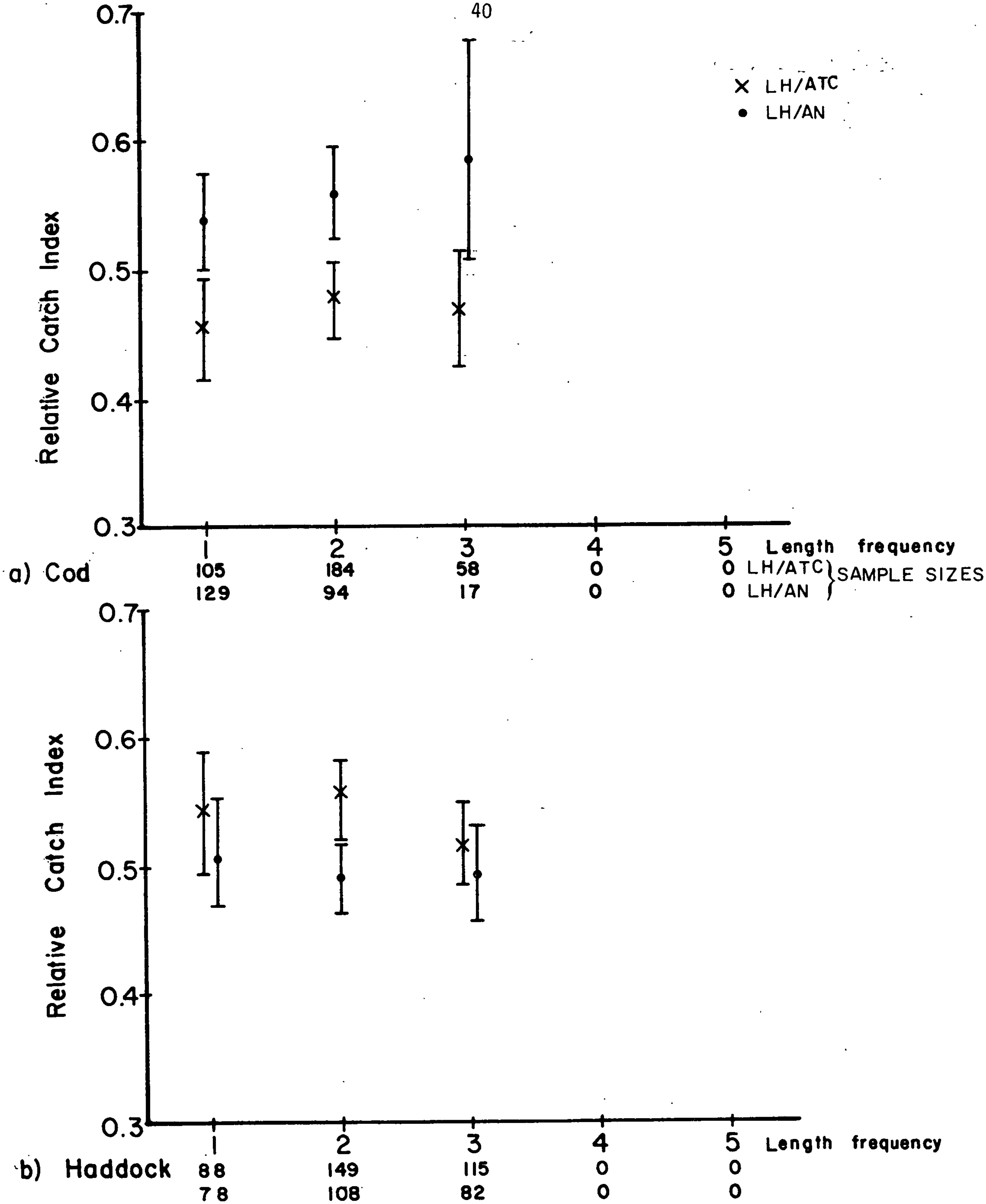


Figure 6. Relative catch index, with confidence intervals, for 6 species. Sample sizes for each group are below the ordinate. Arrow heads indicate error bars that go off scale on the abscissa.

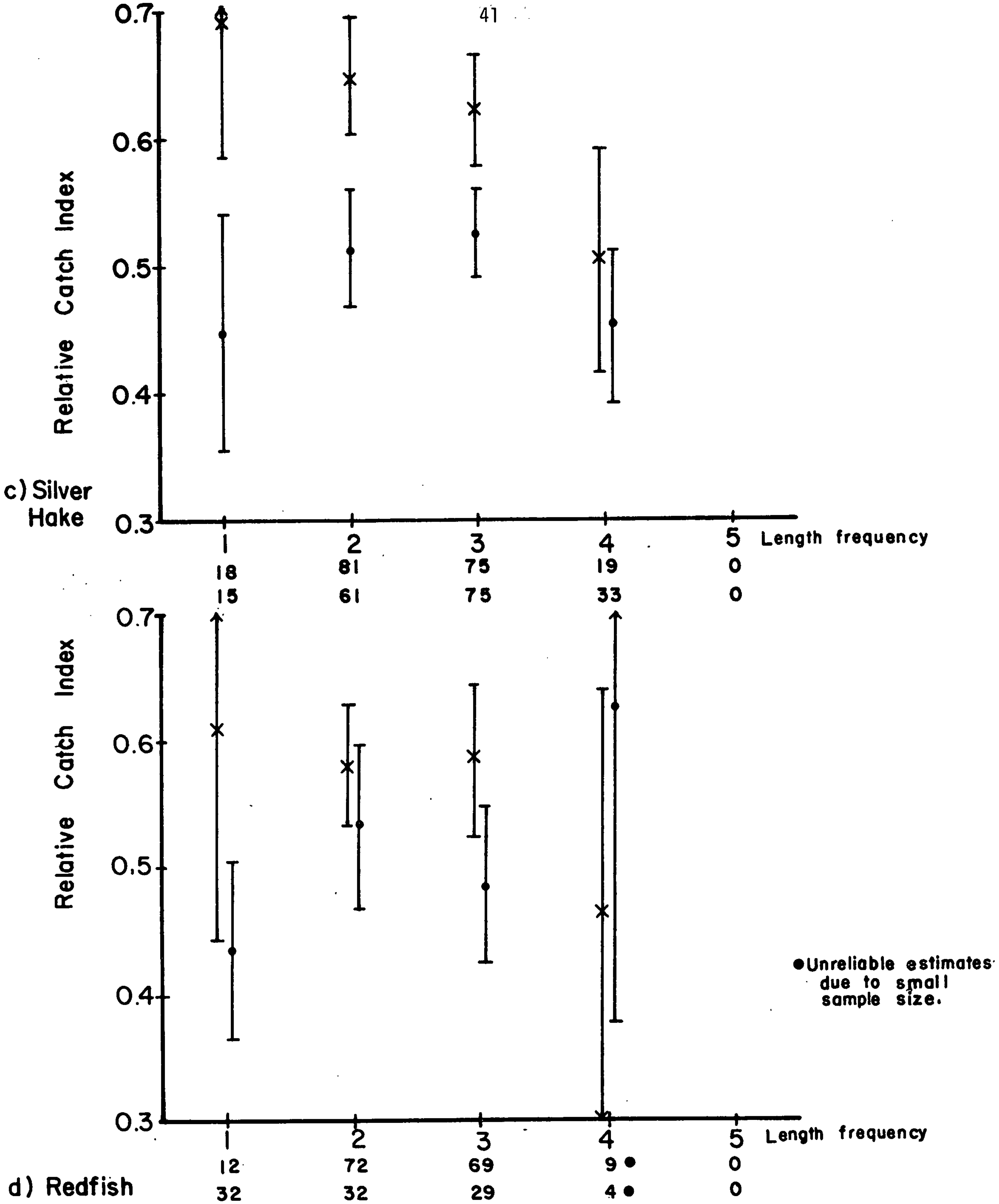
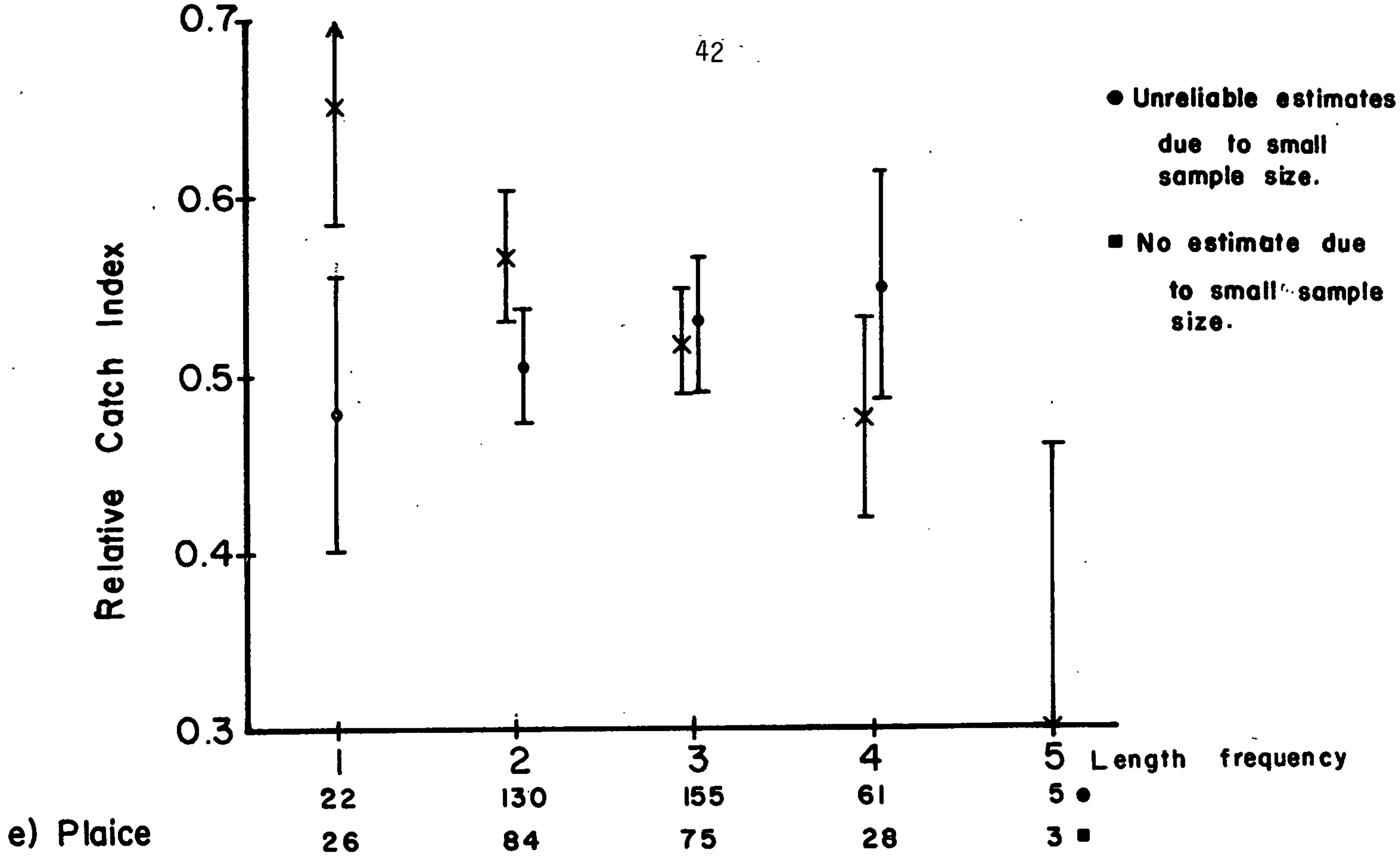


Figure 6. Continued.



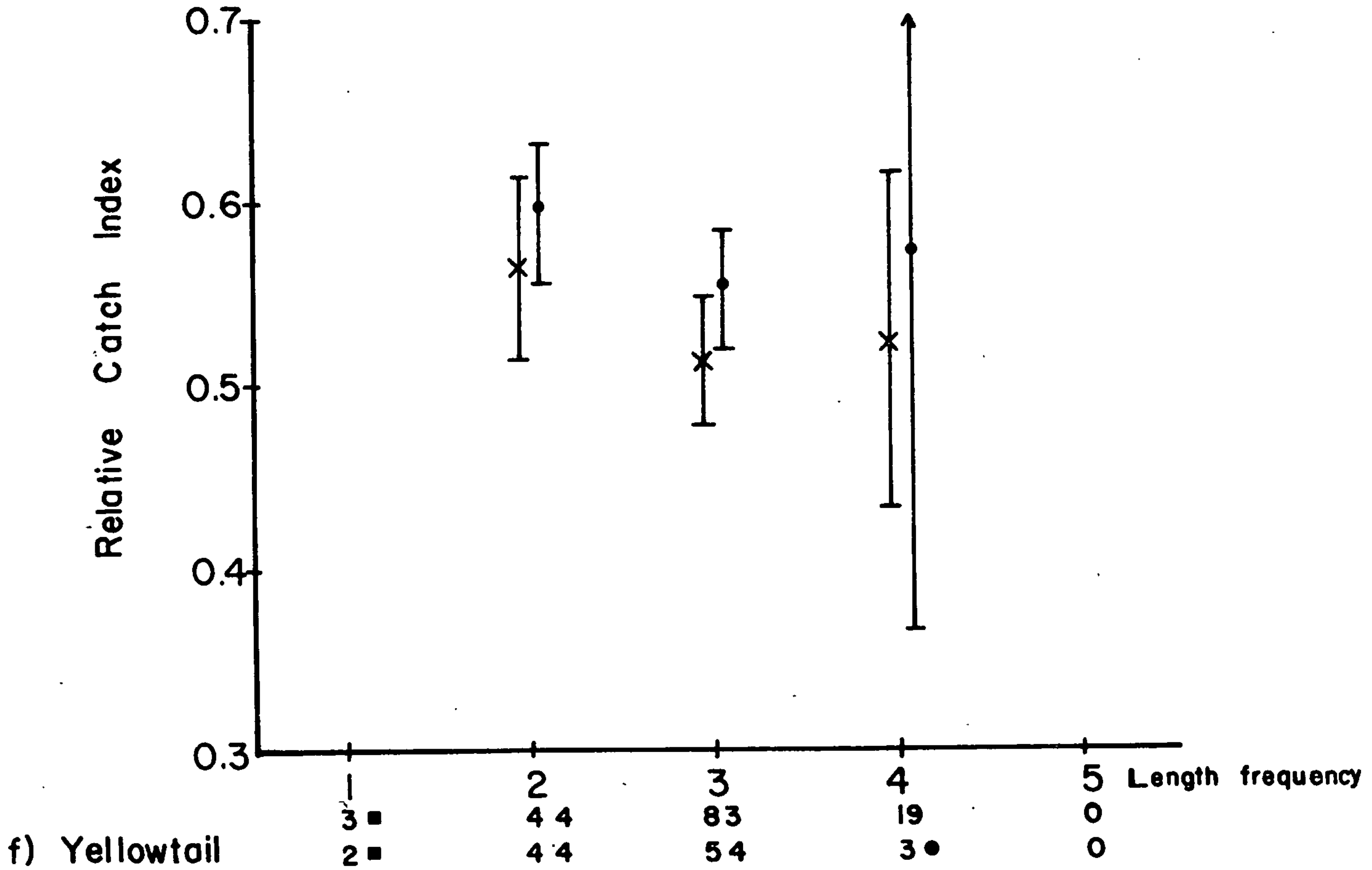
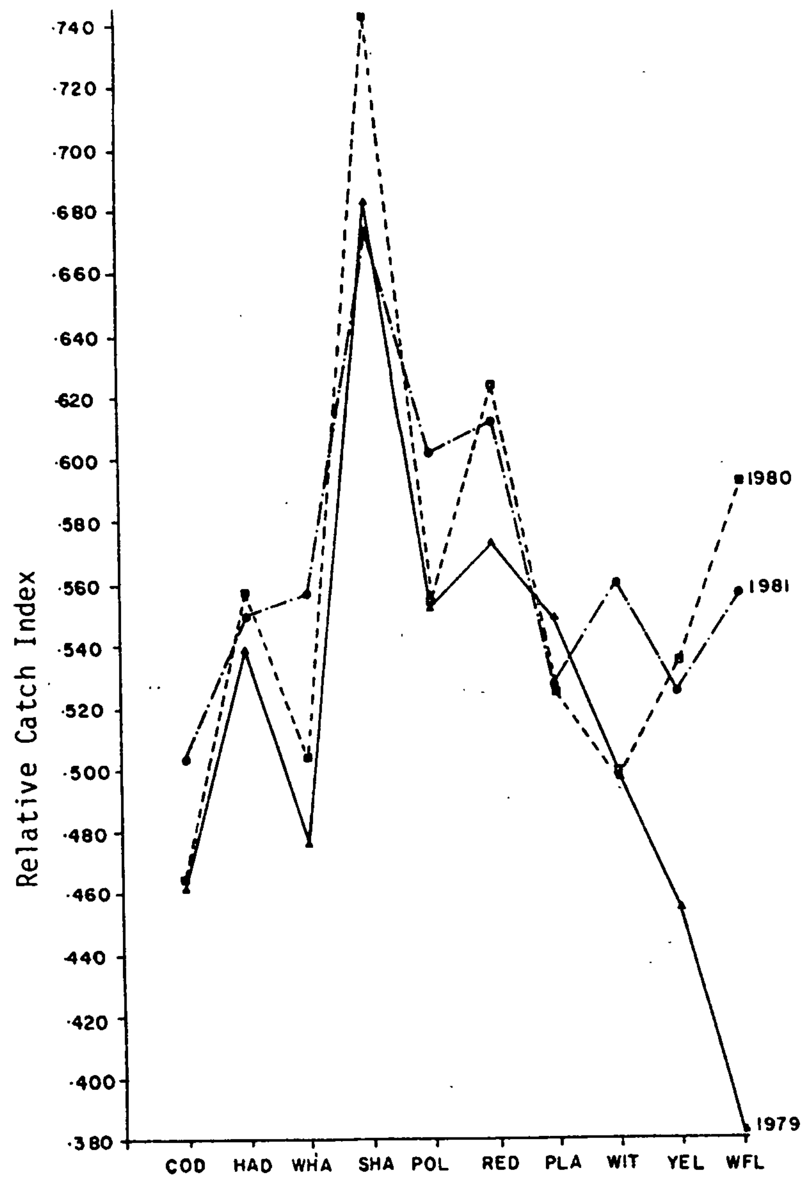
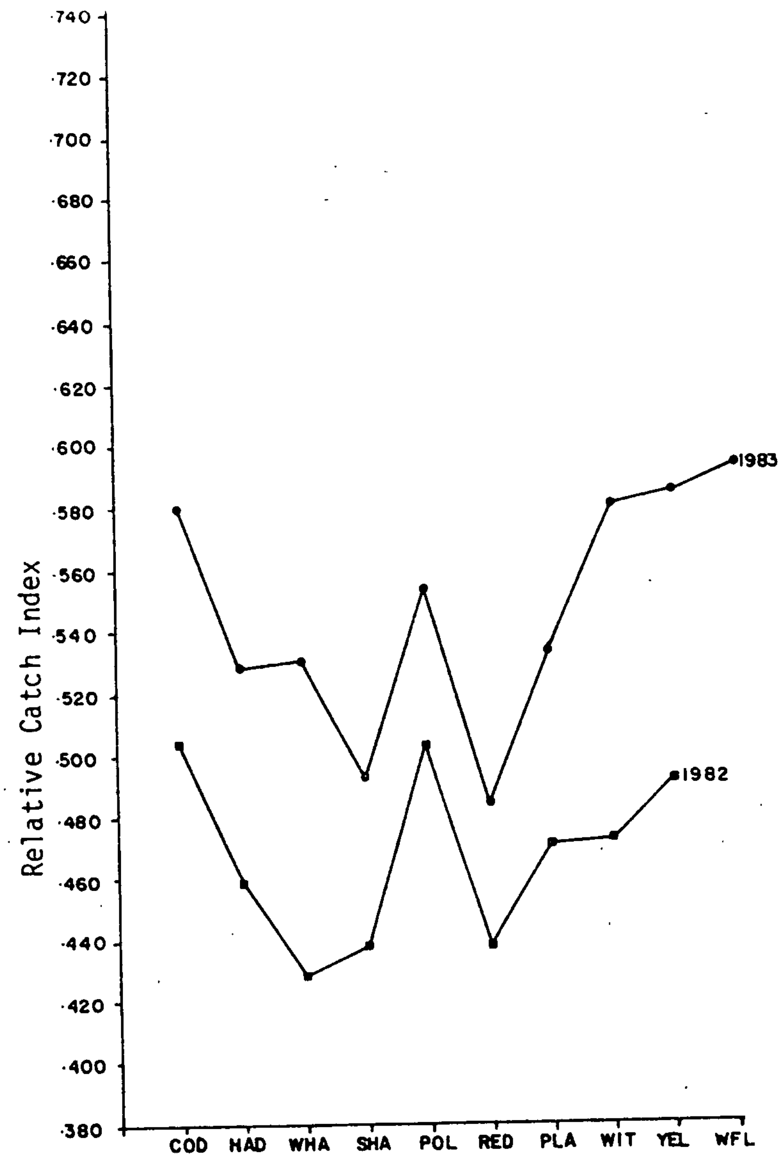


Figure 6. Continued.



a) LH/ATC



b) LH/AN

Figure 7. Relative catch index for each of ten species by year and vessel comparison.