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Comparison of the Fishing Efficiency of Research Vessels used in the Southern Gulf of St. Lawrence Groundfish Surveys from 1971 to 1992

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March 1994

Canadian Technical Report of Fisheries and Aquatic Sciences No. 1952

Fisheries and Oceans
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Canadian Technical Report of Fisheries and Aquatic Sciences

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Cat. No. FS 97-6/1952E ISSN 0706 6457

Correct citation for this publication:

Nielsen, G.A. 1994. Comparison of the Fishing Efficiency of Research Vessels used in the Southern Gulf of St. Lawrence Groundfish Surveys from 1971 to 1992. Can. Tech. Rep. Fish. Aquat. Sci. No. 1952 56pp.

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ABSTRACT

Two comparative experiments between research vessels are analyzed for differences in fishing power especially with respect to cod, white hake, and American plaice. The 1985 experiment found a depth-dependant difference in the relative efficiencies of the two vessels to catch cod, with the *Lady Hammond* catching more than the *E.E.Prince* in deep water and less shallower water. The *Lady Hammond* was more efficient for catching American plaice at all depths than the *E.E.Prince*. The 1992 comparison found a depth-dependant difference in the relative efficiencies of the *Lady Hammond* and the *Alfred Needler* to catch cod, with the *Lady Hammond* catching more in deep water, but less in shallow water. Neither experiment found dissimilarity in the power of the vessels to catch white hake.

INTRODUCTION

Stratified random surveys (Figure 1) are conducted in the southern Gulf of St. Lawrence (NAFO Division 4T) annually in September to estimate the abundance of different species of groundfish. These estimates are used in the assessment of stock abundance for cod, white hake, and American plaice. The research vessels used for the surveys were the *E.E.Prince*, from 1971 to 1985, the *Lady Hammond*, from 1986 to 1991, and, the *Alfred Needler* starting in 1992. Prior to each vessel change, a comparative experiment was conducted to determine the efficiency of the new vessel relative to that of the vessel being replaced. The objective of the experiments was to quantify any differences in fishing power between vessels, and produce factors, if necessary, by which catches by one vessel could be multiplied to ensure consistency with catches by another, resulting in consistent abundance indices over time.

METHODS

In 1985, while the *E.E.Prince* conducted the regular fall survey, the *Lady Hammond* fished alongside the *E.E.Prince* in the same direction, as close as was practicable, to obtain pairs of comparable fishing sets. The *E.E.Prince* fished only during daylight hours, while the *Lady Hammond* fished 24 hours a day; only daylight fishing sets were paired.

Paired fishing sets between the *Lady Hammond* and the *Alfred Needler* were obtained during a comparative survey conducted August 1-8, 1992. Fishing protocols were similar to those used in annual groundfish abundance surveys. That is, the vessels attempted a standard 30 minute tow at 3.5 knots at each station; direction of the tow varied; stations were chosen randomly within strata in the same manner as for an abundance survey. In addition, the vessel fishing on the port or starboard side was chosen randomly at each station. Both vessels fished 24 hours a day, so day and night sets are available for comparison.

The *E.E.Prince* fished with a Yankee 36 otter trawl; both the *Lady Hammond* and the *Alfred Needler* fished with a Western IIA otter trawl. The trawl and vessel specifications are detailed in Table 1. The nominal wing spreads of the two trawls are not equal. Converting the catches of the *Lady Hammond* to those of the *E.E.Prince* by the ratio of the wingspreads before comparison of the paired sets assumes linearity of the relationship between wingspread and catch. If the relationship is not linear, or the actual ratio is not equal to the ratio of the nominal wingspreads (due to fishing behaviour of the trawls, for example), then error would be introduced by such conversion. The alternative used here and in at least some previous analyses (Fanning, 85) is to compare the paired fishing sets directly, incorporating all differences in fishing efficiency in the vessels in the conversion factors.

To ensure the comparability of sets, paired t-tests were made on average depth of tow and distance towed. Distances recorded from ships' logs were used rather than calculations made from latitude and longitude recordings because the latter were found to be inaccurate in several cases.

Analysis of catches focused on results for cod, white hake, and American plaice. Catches were adjusted to a standard tow of 1.75 nautical miles and then log-transformed. Because $\ln(x)<0$ for $x<1$, paired sets in which both vessels caught the species of interest but one caught fewer than one fish (standardized) were not included in the analysis; sets in which both vessels caught fewer than one fish (standardized) were included.

Generalized linear models (SAS GLM) were fit to numbers caught to test for differences in efficiencies of the vessels. The first model tests for a vessel effect in the catches:

1) $\ln(catch_{ij}) = ship_i + set_j + \varepsilon_{ij}$
where i references the vessel
j references the fishing set

The conversion factor is the difference in the means of the log-transformed catches by the two vessels. That is, letting f_{12} =(mean $\ln(catch_1)$)-(mean $\ln(catch_2)$), then $\ln(catch_1) = f_{12} + \ln(catch_2)$.

This model was also carried out on subsets of the data by length groupings if it appeared that there were differences in catches by these subsets (eg all cod >46 cm).

The second model tested for a depth effect in the efficiencies of the vessels. For this, the difference in log-transformed catches was regressed on depth of tow:

2) $diffl = \alpha + \beta \cdot depth + \varepsilon$
where diffl is the difference in log-transformed catches (old vessel - new vessel)
depth is the average depth of tow of the two vessels

In this case, the conversion factor is simply: $f_{12} = (\alpha + \beta \cdot depth)$, and $\ln(catch_1) = (\alpha + \beta \cdot depth) + \ln(catch_2)$.

When analysis of the comparative experiments found no significant difference in the efficiencies of the two vessels for a species of interest, the conversion factor between the historical series of species abundance and the series starting with the vessel change is taken to be 1.0. For the change from the ***E.E.Prince*** to the *Lady Hammond*, it is necessary, however, to use the same trawl width (and resulting number of trawlable units in each stratum) when calculating the abundance indices from the two vessels.

Transformation of the conversion factor from the log scale to the arithmetic scale was made using the results of Bradu and Mundlak (1970):

$$T(e^{f_{12}}) = e^{\hat{f}_{12}} \, g_m\left[-\frac{m+1}{m} \; \frac{\hat{\sigma}_{\hat{f}_{12}}^{2}}{2}\right]$$

where

$T(e^{f_{12}})$ is the estimator of $e^{f_{12}}$
m is the residual degrees of freedom

and, from Ebbeler (1973):

$$\lim_{m \to \infty} g_m(t) = e^{t}$$

Paired t-tests were performed on the numbers of fish and invertebrate species caught in each set by the vessels. Species caught in more than one comparative tow were tested for equality of catches by the vessels. As with cod, hake, and plaice, catches were standardized to a tow of 1.75 nautical miles and then log-transformed. Paired t-tests were made on the differences in the catches. Analyses were performed on both weight and numbers caught, because, while all species were weighed, not all species were counted.

RESULTS

Experiment between the *E.E.Prince* and the *Lady Hammond* - 1985

A total of 62 comparative sets were fished. Estimated distance towed was missing from two sets, which were therefore eliminated from further analysis. For the remaining sets, the *E.E.Prince* towed ,on average, 0.155 nautical miles further than the *Lady Hammond* (P<0.01). There was no significant difference in the depth of paired tows; the difference averaged -0.03 metres, and in all but one case was less than 9 metres. In the one extreme case of 25 metres, there did not appear to be any difference in the catches of the two vessels. Figure 1 shows the locations of the successful sets.

Cod

There were 53 sets in which both the *E.E.Prince* and the *Lady Hammond* caught cod and an additional 5 sets in which one vessel no cod, but the other caught a few (<4). The *Lady Hammond* tended to catch more than the *E.E.Prince* (Figure 2), but the difference was not significant (Table 2). In set 3, the *Lady Hammond* had it second largest catch of cod in the paired sets (>4400 fish) but the *E.E.Prince* caught only 340 cod. Omission of this one influential set reduced the difference from 0.154 to 0.109, and the significance from P=0.107 to P=0.201. There is a preponderance of negative residuals for *E.E.Prince* catches in deep water (>100 metres) (Figure 4). *E.E.Prince* residuals for September 20, 21, and 22 are all negative; 9 of these 12 sets were deeper than 100 metres, 2 were between 90 and 100 metres in depth, and one set was at 69.5 metres depth.

The *E.E.Prince* caught more cod in shallow depths (less than 50 metres), while the *Lady Hammond* caught more in deeper depths (greater than 50 metres, and especially greater than 100 metres) (Figure 3). A linear regression of difference in log-transformed catches against depth of tow results in a linear parameter significant at 0.035 when all data are used, and at 0.040 when set 3 is removed; set 3 is not influential in the regression with depth (Table 3). In both cases the intercept is not significant. A regression without intercept results in a linear parameter significant at 0.010 using all paired sets, and 0.024 omitting set 3. The residuals indicate a possible lack of fit for catches at depths greater than 200 fathoms (Figure 5).

The length distribution of cod caught by the two vessels is shown in Figure 6, and the distribution excluding set 3 in Figure 7. The few fish less than 7 cm or greater than 108 cm were caught by the *E.E.Prince*, but the vessels caught basically the same range of lengths, with the *Lady Hammond* catching more at most lengths. Results of GLM's performed separately on cod less than or equal to 46 cm and on cod greater than 46 cm (Table 4) show that although the catch of large fish was the same by the two vessels, the *Lady Hammond* caught more small fish than the *E.E.Prince* (P<0.05). The residuals exhibit the same pattern as for all fish combined, that is, relatively more positive *E.E.Prince* residuals in shallow depths, and relatively more negative *E.E.Prince* residuals in deeper depths (Figure 8).

White hake

There were 17 sets with substantial (>1) white hake catches by both the *E.E.Prince* and the *Lady Hammond*, 7 sets with small (<2) catches by one vessel and none by the other, and 3 sets with fewer than 3 hake caught by one vessel and fewer than 1 (standardized) by the other. There is no significant difference in log-transformed hake catches by the two vessels (Figure 9, Table 5). Plots of the residuals indicate a possible trend with depth (Figure 11), and the *Lady Hammond* appeared to catch more white hake at depths less than 50 metres while the *E.E.Prince* appeared to catch more at depths greater than 50 metres (Figure 10). There are two deep sets (depths 239 metres, 319 metres) in which the *Lady Hammond* caught 10 and 6.5 times the number of white hake that the *E.E.Prince* caught. Elimination of these two outliers decreases the mean difference in log-transformed catches and reverses its direction.

A regression of the log-transformed catches on depth of tow results in a linear effect significant at 0.036, although the existence of basically two sets of points - one group at depths between 28 and 49 metres and the other at depths between 230 and 319 meters - makes interpretation of a linear depth effect somewhat difficult (Figure 10, Table 6). The residuals against depth show no pattern (Figure 12). When the two outlying deep sets are removed, the significance level of the linear parameter becomes 0.452.

Plots of the length distributions of white hake caught by the two vessels show comparable ranges, with the *E.E.Prince* catching the smallest and largest fish, but the *Lady Hammond* catching more at most length intervals (Figure 13). There is no appropriate length grouping for which to try separate testing of ship effects.

American plaice

There were 51 sets in which more than one American plaice was caught by both the *E.E.Prince* and the *Lady Hammond*, 4 sets with fewer than 4 plaice caught by one vessel and none by the other, and 1 set in which one vessel caught a small number of plaice but the other caught fewer than 1 (standardized). Overall, the *Lady Hammond* caught more than the *E.E.Prince* (Figures 14, 15); the difference in mean log-transformed catches by the two vessels was 0.642 at a significance level of 0.0001 (Table 7). There were two sets in which the *Lady Hammond* caught more than 13 times the amount of plaice as the *E.E.Prince* did (at depths of 31 metres and 121 metres - this latter set was set 3, the set with the disproportionate cod catch). These two extreme sets did not appear to unduly influence the results, and if they are removed from the regression, the mean difference (0.557) is still significant at 0.0001. No pattern is evident in the residuals (all data) from the GLM (Figure 16).

A regression of difference in log-transformed catches against depth of tow results in a significant intercept, but not significant depth effect (Table 8). The regression line and residuals are plotted in Figure 17.

Graphs of the length distribution of the catches (Figure 18) show that the same range of plaice was caught by both the *E.E.Prince* and the *Lady Hammond*, with the *Lady Hammond* catching the smallest fish and the *E.E.Prince* catching the largest, but the *Lady Hammond* catching more plaice at most lengths. Dividing the plaice caught into those less than or equal to 30 cm and those greater than 30 cm and running GLMs on these two groups separately, results in mean differences of 0.303 (significant at 0.009) for large plaice and 0.826 (significant at 0.0001) for small plaice (Table 9, Figure 19).

Other species

Paired t-tests using all 62 paired sets showed no difference in the number of fish species caught in each set by the *Lady Hammond* and the *E.E.Prince* (Prob>|T| = 0.71). The *E.E.Prince*, however, on average caught 2.03 more invertebrate species in a set than the *Lady Hammond* (P=0.0001). This difference was caused by the numbers of species such as whelks, scallops, clams, and various types of sea stars (codes > 4000) and may indicate both a difference in the efficiency of the two vessels catching these species as well as a difference in identification procedures of the crews on the two vessels with respect to some invertebrate species. When only the species with codes in the interval (1000,3999) were included in the t-test, there was no difference in the number of invertebrate species caught by the two vessels.

Examination of catches by set and species shows several differences in the catches of the two vessels. Table 10 summarizes the results of paired-t tests for all the species caught by both vessels in the experiment. Sample size varies among species because sets with catches for a particular species (either in weight or number) of less than 1 by one of the vessels were omitted from analysis for that species.

The *Lady Hammond* caught significantly ($P<=0.01$) more rainbow smelt and winter flounder than the *E.E.Prince*, both by weight and numbers, more yellowtail by weight, and more queen snow crab by numbers. In addition, the *Lady Hammond* caught more ($P<0.05$) redfish by weight, alewife by numbers, and, although only 2 sets are included, more silver hake by numbers.

The *Lady Hammond* caught Arctic eelpout in 20 sets and no Laval's eelpout, while the *E.E.Prince* caught no Arctic eelpout but caught Laval's eelpout in 15 sets. This is presumably a classification problem rather than difference in fishing power for these species. The *Lady Hammond* caught smooth skate in 4 sets and winter skate in 12, while the *E.E.Prince* caught no winter skate, but caught smooth skate in 11 sets. The only other large discrepancy in fish catches of the two vessels is the catch of alligator fish in 13 sets by the *E.E.Prince*, but only 3 sets by the *Lady Hammond*.

Experiment between the *Lady Hammond* and the *Alfred Needler* - 1992

Seventy-four paired sets were attempted in the experiment approximately one month before the annual survey was due to begin; 66 sets were successful. The distance towed on one set by the *Lady Hammond* was incorrectly recorded, and a correction could not be determined; this set was removed from further analysis. The average distance towed for each set was 0.045 nautical miles longer ($P<0.001$) by the *Alfred Needler* than by the *Lady Hammond*. The *Alfred Needler* fished on average 1.8 metres deeper than the *Lady Hammond* ($P<0.001$), but the absolute difference in depth was greater than 10 metres in only 2 sets (once the *Lady Hammond* fishing deeper, once the *Alfred Needler* fishing deeper). Measurements of trawl wing spread were available for the first 21 paired sets. These showed no significant differences between the two vessels (mean=-0.18, $P>|T|=0.80$). Figure 20 shows the location of the comparative sets.

<u>Cod</u>

There were 56 sets in which both vessels caught more than one cod, 5 sets with cod caught by one vessel only, and 1 set with the standardized catch of cod less than 1 by one vessel. The catches of less than one fish were evenly split between the *Lady Hammond* and the *Alfred Needler*. In only one set was the catch of cod extremely large by one vessel (*Alfred Needler*) when the catch of the other was zero (set 58).

Overall, the *Alfred Needler* caught more cod ($P<0.04$) than the *Lady Hammond* (Figure 21, Table 11). Examination of residuals indicates that depth may be a factor in the difference in efficiency of the two vessels (Figure 23). It appears that in shallow water (<50 metres), the *Alfred Needler* caught more than the *Lady Hammond*, but in deep water (>100 metres), the opposite may be true (Figure 22). The regression of difference in log-transformed catch on depth of tow shows the depth effect to be significant at the 0.008 level and the intercept significant at the 0.0009 level (Table 12, Figure 24). No pattern is evident in the residuals from this model (Figure 24). There do not appear to be any trends in the difference by day or time of day (Figure 22).

The two vessels caught the same length range of cod, but it appears that the *Alfred Needler* was particularly more efficient then the *Lady Hammond* in catching small cod (<=36 cm) while the *Lady Hammond* caught the only fish greater than 115 cm (Figure 25). When cod were grouped into those less than or equal to 36 cm and those greater than 36 cm, vessel effects were significant only for those less than or equal to 36 cm (Table 13). Residuals for both the large fish and the small fish are shown in Figure 26.

<u>White hake</u>

There were 22 sets in which both vessels caught more than one white hake, 8 sets in which one vessel caught none but the other caught a few (< 4), and 2 sets in which one vessel caught fewer than one (standardized) white hake but the other caught a few. In two sets, both vessels caught fewer than 1 fish (standardized); these 2 sets were included in the analysis, to give a total of 24 paired sets.

The *Lady Hammond* and the *Alfred Needler* did not differ in fishing efficiency with respect to white hake either overall (P>0.34; P>0.76 when one influential point was removed; Table 14, Figure 27) or with respect to time of day, depth (P=0.97; Table 15), or date (Figure 28). Residuals of these models are plotted in Figures 29 and 30. It is interesting to note that white hake was caught by both vessels in either shallow water (less than 40 metres) or deep water (greater than 150 metres), but in only one set (at 57 metres) in between these two depths (Figure 28).

The length distribution of white hake caught by both vessels was the same, and the frequencies at length were comparable (Figure 31).

American plaice

There were 54 sets in which both the *Lady Hammond* and the *Alfred Needler* caught more than one plaice, and an additional 4 sets in which one vessel caught none while the other caught fewer than 4. In one set, the *Alfred Needler* caught more than 350 American plaice, but the *Lady Hammond* caught fewer than 3. This was the same set (set 58) in which the *Alfred Needler* had its largest cod catch (more than 600 fish), while the *Lady Hammond* caught none. It was not included in the analysis for plaice, leaving 53 paired sets for comparison.

Graphs of the plaice catches do not indicate obvious differences in fishing efficiency for American plaice by the two vessels (Figure 32). However, it does appear from the plots of difference in log-transformed catch (Figure 33) that the *Lady Hammond* may have caught more plaice than the *Alfred Needler*, in general, and especially at depths greater than 100 metres. The GLM testing for vessel effect results in a mean difference of log-transformed catch of 0.133, significant at 0.063, with the *Lady Hammond* more efficient than the *Alfred Needler* (Table 16). Removal of one outlier results in the mean difference decreasing to 0.095, with a significance level of 0.119. With the exception of the residuals at depths greater than 100 metres, there do not appear to be any problems with the model fit (Figure 34).

A regression of difference in log-transformed catches versus depth of tow gives a linear effect significant at 0.042, but a not-significant intercept. The linear effect becomes significant at 0.007 (Table 17) in a no-intercept model. No pattern is evident in the residuals (Figure 35).

Both vessels caught the same length range of American plaice, though the *Lady Hammond* caught the only fish greater than 44 cm. The length frequencies exhibit no differences (Figure 36).

Other species

A paired t-test testing for the number of fish species caught in each set by the *Lady Hammond* and the *Alfred Needler* shows no difference. But the *Lady Hammond* caught on average 1.6 more invertebrate species in each set than the *Alfred Needler* (P<0.001). When species codes greater than 5999 are excluded, however, there is no difference in the number of invertebrate species caught by the two vessels. It is possible that the crews were not consistent in classifying these species which include varieties of starfish, sea urchins, and sand dollars.

Paired t-tests (Table 18) show the *Lady Hammond* caught significantly more (P<0.01) fourbeard rockling and toad crab by numbers than the *Alfred Needler*. The *Lady Hammond* caught Laval's eelpout in 30 sets, and the *Alfred Needler* caught none, but caught Arctic eelpout in 30 sets, while the *Lady Hammond* caught arctic eelpout in only one set. A paired t-test assuming these are actually the same species, shows no significant difference in the numbers caught by the two vessels.

SUMMARY and DISCUSSION

The *Lady Hammond* caught more of all three species of specific interest (cod, white hake and American plaice) than did the *E.E.Prince* in the 1985 experiment. However, the difference in the catches of the two vessels was not significantly different from zero for all species. Regressions against depth of tow resulted in negative slopes, indicating the relative efficiency of the *Lady Hammond* increased with increasing depth, although only for cod is the slope significant once outliers have been removed.

The *Lady Hammond* also caught more white hake and American plaice than the *Alfred Needler* caught in the 1992 comparative experiment. For cod, hake and plaice, the *Lady Hammond* was consistent in catching more than the *Alfred Needler* at depths greater than 100 metres. In the case of cod, there was a linear effect with depth, with the *Alfred Needler* catching more in shallow sets, while with hake and plaice, catches by the two vessels in shallow sets were not different from each other.

Traditionally when comparative surveys result in a conversion factor other than 1, the historical data are converted to be consistent with catches from the current research vessel. This means that conversion is done once, rather than annually.

After the 1992 annual groundfish survey was completed, the *Alfred Needler* was refit. There is no information about the effect modifications to the vessel will have on its fishing power, and its relative efficiency with respect to the *Lady Hammond*. It seems, therefore, that although the 1992 survey estimate of cod abundance should be adjusted for significant differences in the catches of two vessels, conversion factors resulting from the 1992 comparative experiment may not be appropriate for future surveys. Rather than convert historical data to the catches of the *Alfred Needler*, it is recommended that 1992 data be converted to the *Lady Hammond* catches, and catches in future years be analyzed both adjusted and unadjusted. Caution will be required when using an abundance index which includes years both before and after 1993.

Cod

The catches of cod by the *Lady Hammond* were not significantly different from those of the *E.E.Prince*. The *Lady Hammond* did catch more than the *E.E.Prince* in deep water, while the *E.E.Prince* caught more than the *Lady Hammond* in shallow water, and the *E.E.Prince* caught more large fish than the *Lady Hammond*, which caught more small fish, although the significance levels for these differences were greater than .01. For the purpose of a consistent time series of mean catch per tow, or total numbers of cod in the southern Gulf of St. Lawrence, it is not necessary to convert the *E.E.Prince* historical data to be comparable to the catches of *Lady Hammond*.

The linear depth effect, however, was significant at the 0.011 level (all sets included) and 0.024 level (set 3 removed). It has been shown that the spatial distribution of cod in the southern Gulf of St. Lawrence depends on the age (ie size) of the fish (Swain, 1993). Small fish tend to be found in shallower water than where large fish are found. Abundance indices at age, therefore, could be affected by a conversion factor based of depth of tow. Studies of fish distribution both in total and by size would also be affected. Catches of the *E.E.Prince* should be adjusted to catches of the *Lady Hammond* using the depth-dependant conversion factor.

The following equation should be used (data with set 3 removed):

$$Catch_{Prince} = e^{(-.001845depth)} \times Catch_{Hammond}$$

The relative efficiency of the *Alfred Needler* and the *Lady Hammond* was found to vary significantly with depth of tow. The *Alfred Needler* caught more in shallow water, and less in deep water than the *Lady Hammond* caught. In addition, the *Alfred Needler* caught more small cod (<=36 cm P<0.05) than the *Lady Hammond* caught. Therefore, for consistent time series of cod abundance, the catches of the *Alfred Needler* in the 1992 groundfish survey should be converted by a depth-dependant factor to be comparable to the catches of the *Lady Hammond.*

The following equation is appropriate:

$$Catch_{Hammond} = e^{(-.491908+.004609depth)} \times e^{\left[\frac{-55}{108}\,\theta_{\ell_{12}}^{2}\right]} \times Catch_{Needler}$$

where

$$\theta_{\ell_{12}}^{2} = .0190883 - .00038376depth + .00000278depth^{2}$$

White hake

White hake was caught either in very shallow or very deep sets, and not in between in both comparisons; the number of paired sets for comparing white hake catches was not large in either experiment. The *E.E.Prince* caught more in the shallow sets than the *Lady Hammond*, but with the exception of two deep sets with very large *Lady Hammond* catches, catches in the deep sets were the same by both vessels. No significant difference in the catches of white hake by the *Lady Hammond* and the *Alfred Needler* were found. No conversion of white hake catches is indicated by either comparison.

American plaice

The *Lady Hammond* caught significantly more American plaice at all depths than the *E.E.Prince* caught. The removal of two extreme sets reduces the difference, but does not change the level of significance (-.0001). The difference in catches is greater for small plaice (<=30 cm) than for large plaice, but is significant for both groups. Catches of the *E.E.Prince* should be converted to be comparable to catches of the *Lady Hammond.*

The following equation is appropriate for conversion (data with sets 3, 257 removed):

$$Catch_{Prince} = .571 \times Catch_{Hammond}$$

The *Lady Hammond* caught more plaice than the *Alfred Needler*, but the difference in efficiency was not significant. A significant linear depth effect was found, and in deep water (>100 metres), differences in the catches of the two vessels were more pronounced than in shallower water. However, this result seems driven by the few deep water sets, and differences in shallow and intermediate depth sets were not significant. The catches of plaice by the two vessels by depth are as follows:

Depth of set	*Lady Hammond* catch	*Alfred Needler* catch
0-50 metres	2305	1938
50-100 metres	14429	13765
>100 metres	510	404

The catches of plaice in deep sets is a very small percentage of a total survey catch and contributes little to the abundance estimates; a conversion to account for significant difference in fishing efficiencies in deep water does not seem warranted. It is not necessary to convert 1992 catches of American plaice by the *Alfred Needler* to be comparable to catches by the *Lady Hammond*.

ACKNOWLEDGEMENTS

The author thanks J.Allard, G.Chouinard, T.Hurlbut, and D.Swain for their helpful suggestions and advice in the analysis of these comparative experiments.

REFERENCES

Bradu, D, and Y. Mundlak. 1970 Estimation in log-normal models. J. Am. Statist. Assoc. 65: 198-211.

Ebbeler, D.H. 1973 A note on estimation in log-normal linear models. J. Am. Statist. Comput. Simul. 2:225-231.

Fanning, P. 1985 Intercalibration of Research Survey Results Obtained by Different Vessels. CAFSAC Res. Doc. 85/3

Swain, D.P. 1993 Age- and density-dependent bathymetric pattern of Atlantic cod (*Gadus morhua*) in the southern Gulf of St. Lawrence. Can. J. Fish. Aquat. Sci. 50: *1255-1264.*

Table 1. Vessel and trawl parameters for the 3 research vessels used in the southern Gulf of St. Lawrence fall abundance surveys (from Fanning 1985).

	E.E.Prince	*Lady Hammond*	*Alfred Needler*
Vessel type	Stern trawler	Stern trawler	Stern trawler
B.H.P.	600	2500	2000
Tonnage	406	897	925
Length	40 m	58 m	50 m
Trawl	Yankee 36	Western IIA	Western IIA
Footrope	7" (outer sections) and 14" (inner sections) rubber disc spacers + 17 lb iron spacers	21" (outer) and 18" (inner) bobbins and 6.75" diameter 7" long spacers, all rubber	21" (outer) and 18" (inner) bobbins and 6.75" diameter 7" long spacers, all rubber
Liner			
Belly extension	n/a	1.25"	1.25"
Lengthening piece	1.25"	1.25"	1.25"
Codend	0.25"	0.75"	0.75"
Headline length	60'	75'	75'
Footrope length			
Overall	80'	106'	106'
With netting	80'	68'	68'
Netting panel lengths			
Top wings			
Square & bunt	25'	27'	27'
Bellies & 1' piece	14'	21'	21'
Codend	30'	41'	41'
Total	47'	38'	38'
	116'	127'	127'
Door type	Steel bound wood	Portuguese (all steel)	Portuguese (all steel)
Weight	1000 lb	1800 lb	1800 lb
Area	31 ft^2	47 ft^2	47 ft^2
Mouth opening			
Headline height	9'	15'	15'
Wing spread	35'	41'	41'

Table 2. Results of Generalized Linear Models testing for vessel effect 1985 Cod Catches

All paired sets included

Source	DF	SS	MS	F	Pr > F	R^2
Model	53	305.402	5.762	24.39	0.0001	0.961
Ship	1	0.636	0.636	2.69	0.1070	
Setno	52	304.767	5.861	4.81	0.0001	
Error	52	12.283	0.236			
Corrected Total	105	317.685				

Ship	Effect
Prince	4.7596
Hammond	4.9145

Set 3 removed

Source	DF	SS	MS	F	Pr > F	R^2
Model	52	294.431	5.662	30.94	0.0001	0.969
Ship	1	0.307	0.307	1.6	0.2014	
Setno	51	294.125	5.767	31.52	0.0001	
Error	51	9.333	0.183			
Corrected Total	103	303.764				

Ship	Effect
Prince	4.7388
Hammond	4.8474

Table 3. Results of Generalized Linear Models testing for depth effect in 1985 Cod Catches

All paired sets

Source	DF	SS	MS	F	Pr > F	R^2
Model (Depth)	1	2.081	2.081	4.72	0.035	0.085
Error	51	22.485	0.441			
Corrected Total	52	24.566				

Parameter	Estimate	T for H0:Par=0	Pr > |T|	Std Error of Est
Intercept	0.1188	0.76	0.449	0.1555
Depth	-0.0033	-2.17	0.035	0.0015

Set 3 removed

Source	DF	SS	MS	F	Pr > F	R^2
Model (Depth)	1	1.530	1.530	4.46	0.040	0.082
Error	50	17.136	0.343			
Corrected Total	51	18.665				

Parameter	Estimate	T for H0:Par=0	Pr > |T|	Std Error of Est
Intercept	0.1248	0.91	0.367	0.1371
Depth	-0.0028	-2.11	0.040	0.0013

All paired sets, no intercept

Source	DF	SS	MS	F	Pr > F	R^2
Model (Depth)	1	3.095	3.095	7.08	0.010	0.120
Error	52	22.742	0.437			
Corrected Total	53	25.837				

Parameter	Estimate	T for H0:Par=0	Pr > |T|	Std Error of Est
Depth	-0.0023	-2.66	0.010	0.0009

Table 3. **Results of Generalized Linear Models testing for depth effect in 1985 Cod Catches** (cont'd)

Set 3 removed, no intercept

Source	DF	SS	MS	F	Pr > F	R^2
Model (Depth)	1	1.859	1.859	5.44	0.024	0.096
Error	51	17.420	0.342			
Corrected Total	52	19.278				

Parameter	Estimate	T for H0:Par=0	Pr > |T|	Std Error of Est
Depth	-0.0018	-2.33	0.024	0.0008

Table 4. Results of Generalized Linear Models testing for length effect in 1985 Cod Catches

All paired sets, cod <=46 cm

Source	DF	SS	MS	F	Pr > F	R^2
Model	49	210.145	4.289	14.24	0.0001	0.936
Ship	1	1.222	1.222	4.06	0.0496	
Setno	48	208.923	4.435	14.45	0.0001	
Error	48	14.458	0.301			
Corrected Total	97	224.603				

Ship	Effect
Prince	4.6940
Hammond	4.9173

All paired sets, cod >46 cm

Source	DF	SS	MS	F	Pr > F	R^2
Model	50	158.567	3.171	12.81	0.0001	0.929
Ship	1	0.083	0.083	0.33	0.5660	
Setno	49	158.484	3.234	13.06	0.0001	
Error	49	12.133	0.248			
Corrected Total	99	170.700				

Ship	Effect
Prince	3.4955
Hammond	3.4380

Table 5. Results of Generalized Linear Models testing for vessel effect in 1985 White Hake Catches

All paired sets

Source	DF	SS	MS	F	Pr > F	R^2
Model	17	49.708	2.924	7.98	0.0001	0.895
Ship	1	0.313	0.313	0.85	0.3693	
Setno	16	49.395	3.087	8.43	0.0001	
Error	16	5.860	0.366			
Corrected Total	33	55.567				

Ship	Effect
Prince	3.1452
Hammond	3.3370

Table 5. Results of Generalized Linear Models testing for vessel effect in 1985 White Hake Catches (cont'd)

Sets 2, 73 removed

Source	DF	SS	MS	F	Pr > F	R^2
Model	15	48.894	3.260	26.72	0.0001	0.966
Ship	1	0.029	0.029	0.24	0.6342	
Setno	14	48.866	3.490	28.61	0.0001	
Error	14	1.708	0.122			
Corrected Total	29	50.602				

Ship	Effect
Prince	3.3094
Hammond	3.2474

Table 6. Results of Generalized Linear Models testing for depth effect 1985 in White Hake Catches

All paired sets

Source	DF	SS	MS	F	Pr > F	R^2
Model (Depth)	1	3.060	3.060	5.30	0.036	0.261
Error	15	8.660	0.577			
Corrected Total	16	11.720				

Parameter	Estimate	T for H0:Par=0	Pr > |T|	Std Error of Est
Intercept	0.2481	0.94	0.364	0.2655
Depth	-0.0037	-2.30	0.036	0.0016

Sets 2,73 removed

Source	DF	SS	MS	F	Pr > F	R^2
Model (Depth)	1	0.151	0.151	0.60	0.4521	0.044
Error	13	3.265	0.251			
Corrected Total	14	3.415				

Parameter	Estimate	T for H0:Par=0	Pr > |T|	Std Error of Est
Intercept	0.1561	0.88	0.395	0.1774
Depth	-0.0010	-0.78	0.452	0.0012

Table 7. Results of Generalized Linear Models testing for vessel effect in 1985 American Plaice Catches

All paired sets

Source	DF	SS	MS	F	Pr > F	R^2
Model	51	358.805	7.035	25.42	0.0001	0.963
Ship	1	10.523	10.523	38.02	0.0001	
Setno	50	348.282	6.966	25.17	0.0001	
Error	50	18.839	0.277			
Corrected Total	101	372.644				

Ship	Effect
Prince	3.9440
Hammond	4.5864

Table 7. Results of Generalized Linear Models testing for vessel effect in 1985 American Plaice Catches (cont'd)

Sets 3, 257 removed

Source	DF	SS	MS	F	Pr > F	R^2
Model	49	352.162	7.187	37.33	0.0001	0.974
Ship	1	7.598	7.598	39.47	0.0001	
Setno	48	344.564	7.178	37.29	0.0001	
Error	48	9.241	0.193			
Corrected Total	97	361.403				

Ship	Effect
Prince	4.0215
Hammond	4.5784

Table 8. Results of Generalized Linear Models testing for depth effect in 1985 American Plaice Catches

All paired sets

Source	DF	SS	MS	F	Pr > F	R^2
Model (Depth)	1	0.211	0.211	0.38	0.542	0.008
Error	49	27.466	0.561			
Corrected Total	50	27.678				

Parameter	Estimate	T for H0:Par=0	Pr > |T|	Std Error of Est
Intercept	-0.5573	-3.21	0.002	0.1737
Depth	-0.0010	-0.61	0.542	0.0017

Sets 3, 257 removed

Source	DF	SS	MS	F	Pr > F	R^2
Model (Depth)	1	0.246	0.246	0.63	0.430	0.013
Error	47	18.236	0.388			
Corrected Total	48	18.482				

Parameter	Estimate	T for H0:Par=0	Pr > |T|	Std Error of Est
Intercept	-0.4638	-3.16	0.003	0.1469
Depth	-0.0011	-0.80	0.430	0.0014

Table 9. Results of Generalized Linear Models testing for length effect in 1985 American Plaice Catches

All paired sets, plaice <=30 cm

Source	DF	SS	MS	F	Pr > F	R^2
Model	44	295.594	6.718	21.88	0.0001	0.957
Ship	1	15.001	15.001	48.85	0.0001	
Setno	43	280.592	6.525	21.25	0.0001	
Error	43	13.204	0.307			
Corrected Total	87	308.798				

Ship	Effect
Prince	3.8977
Hammond	4.7235

Table 9. Results of Generalized Linear Models testing for length effect in 1985 American Plaice Catches (cont'd)

All paired sets, plaice >30 cm

Source	DF	SS	MS	F	Pr > F	R^2
Model	47	164.295	3.496	11.89	0.0001	0.924
Ship	1	2.151	2.151	7.32	0.0095	
Setno	46	162.144	3.525	11.99	0.0001	
Error	46	13.522	0.294			
Corrected Total	93	177.817				

Ship	Effect
Prince	2.9246
Hammond	3.2271

Table 10. Summary of species information in 1985 comparison

	Species	Number of sets		Paired sets (weight caught)				Paired sets (numbers caught)			
		E.E.Prince	Lady Hammond	n	diffl	t	P>|t|	n	diffl	t	P>|t|
10	Atlantic cod	57	54	50	-0.140	-1.416	0.163	53	-0.153	-1.628	0.110
11	Haddock	8	5	5	-0.229	-0.582	0.592	5	-0.211	-0.597	0.583
12	White hake	24	24	16	-0.088	-0.320	0.753	18	-0.183	-0.936	0.362
14	Silver hake	4	6	0	.	.	.	2	-1.748	-52.581	0.012
16	Pollock	3	4	1	-0.095	.	.	1	-0.095	.	.
23	Redfish	13	17	8	-0.573	-2.969	0.021	11	-0.365	-1.288	0.227
30	Alantic halibut	2	3	1	-0.111	.	.	1	-0.294	.	.
31	Greenland halibut	14	13	6	-0.072	-0.410	0.699	6	-0.218	-0.618	0.564
40	American plaice	55	53	46	-0.427	-3.949	0.000	51	-0.644	-6.180	0.000
41	Witch flounder	15	17	5	0.016	0.036	0.973	8	-0.077	-0.261	0.802
42	Yellowtail flounder	25	17	10	-0.632	-3.833	0.004	15	-0.379	-2.045	0.060
43	Winter flounder	18	17	14	-0.759	-4.945	0.000	16	-0.831	-7.195	0.000
51	Spotted wolffish	1	0	0	.	.	.	0	.	.	.
60	Atlantic Herring	39	46	15	-0.045	-0.123	0.904	29	-0.337	-1.356	0.186
61	Shad	1	2	1	-0.799	.	.	0	.	.	.
62	Alewife	14	12	6	-0.538	-1.990	0.103	11	-0.880	-3.026	0.013
63	Rainbow smelt	14	11	7	-0.900	-4.303	0.005	10	-0.889	-5.652	0.000
64	Capelin	3	7	0	.	.	.	1	-1.735	.	.
70	Atlantic salmon	5	9	1	0.000	.	.	3	-0.325	-1.986	0.185
112	Longfin hake	5	4	0	.	.	.	2	-0.679	-1.184	0.447
114	Fourbeard rockling	4	8	0	.	.	.	2	-0.374	-1.393	0.396
118	Greenland cod	2	0	0	.	.	.	0	.	.	.
122	Cunner	3	2	0	.	.	.	0	.	.	.
143	Brill	9	7	2	0.470	9.163	0.069	7	-0.756	-1.783	0.125
160	Atlantic argentine	1	0	0	.	.	.	0	.	.	.
201	Thorny skate	32	29	5	0.281	1.314	0.259	13	0.024	0.100	0.922
202	Smooth skate	11	4	0	.	.	.	1	-2.151	.	.
203	Little skate	2	0	0	.	.	.	0	.	.	.
204	Winter skate	0	12	0	.	.	.	0	.	.	.
220	Spiny dogfish	8	7	1	-0.057	.	.	1	0.231	.	.
221	Black dogfish	0	2	0	.	.	.	0	.	.	.
241	Northern hagfish	6	3	0	.	.	.	2	-0.376	-1.389	0.397
300	Longhorn sculpin	19	12	6	0.097	0.528	0.620	10	-0.003	-0.014	0.989
301	Shorthorn sculpin	1	1	0	.	.	.	0	.	.	.
304	Mailed sculpin	2	4	0	.	.	.	1	-0.105	.	.
306	Arctic hookear sculpin	0	2	0	.	.	.	0	.	.	.
320	Sea raven	11	10	7	0.299	0.765	0.473	9	0.183	0.608	0.560
340	Alligator fish	13	3	0	.	.	.	3	1.009	2.093	0.171
350	Atlantic sea poacher	0	4	0	.	.	.	0	.	.	.
361	Threespine stickleback	3	4	0	.	.	.	0	.	.	.
400	Monkfish	2	2	1	-0.111	.	.	0	.	.	.
410	Marlin-spike grenadier	6	7	0	.	.	.	6	-0.168	-0.254	0.810
500	Seasnail unidentified	2	1	0	.	.	.	0	.	.	.
501	Lumpfish	3	3	0	.	.	.	0	.	.	.
504	Striped seasnail	1	3	1	-0.100	.	.	1	-1.199	.	.
505	Seasnail, gelatinous	1	5	0	.	.	.	1	-1.081	.	.
560	Bony fishes, unspec.	0	1	0	.	.	.	0	.	.	.
610	Northern sand lance	5	0	0	.	.	.	0	.	.	.
616	Fish doctor	1	0	0	.	.	.	0	.	.	.
620	Laval's eelpout	15	0	0	.	.	.	0	.	.	.
622	Snake blenny	10	4	0	.	.	.	3	0.389	0.814	0.501
625	Radiated shanny	5	1	0	.	.	.	1	-0.693	.	.
626	4-line snake blenny	0	3	0	.	.	.	0	.	.	.
630	Wrymouth	1	3	0	.	.	.	0	.	.	.
640	Common ocean pout	5	4	0	.	.	.	1	0.000	.	.
641	Arctic eelpout	0	20	0	.	.	.	0	.	.	.
646	Atlantic soft pout	0	1	0	.	.	.	0	.	.	.
647	Shorttailed eelpout	3	11	2	-0.168	-1.408	0.393	2	-0.651	-3.311	0.187
674	P. coregonoides	0	2	0	.	.	.	0	.	.	.
701	Butterfish	2	1	0	.	.	.	1	-0.172	.	.

Table 10. Summary of species information in 1985 comparison (cont'd)

	Species	Number of sets E.E.Prince	Lady Hammond	Paired sets (weight caught) n	diffl	t	P>|t|	Paired sets (numbers caught) n	diffl	t	P>|t|
770	Atlantic silverside	5	0	0	.	.	.	0	.	.	.
1510	Mollusc eggs unid.	1	0	0	.	.	.	0	.	.	.
1701	Marine inverts unspec.	0	13	0	.	.	.	0	.	.	.
1810	Tunicata s.p.	6	0	0	.	.	.	0	.	.	.
1827	Sea peach	8	3	0	.	.	.	1	-0.633	.	.
2000	Crustacea c.	0	1	0	.	.	.	0	.	.	.
2200	Pandalidae f.	2	0	0	.	.	.	0	.	.	.
2210	Pandalus sp.	8	0	0	.	.	.	0	.	.	.
2211	Pandalus borealis	0	2	0	.	.	.	0	.	.	.
2511	Jonah crab	0	6	0	.	.	.	0	.	.	.
2513	Atlantic rock crab	6	1	1	-1.099	.	.	0	.	.	.
2520	Toad crab, unid.	19	20	0	.	.	.	12	-0.232	-0.901	0.387
2522	Snow crab unid.	0	1	0	.	.	.	0	.	.	.
2523	Northern snow crab	3	3	0	.	.	.	1	0.582	.	.
2526	Queen snow crab	34	37	20	-0.533	-2.443	0.025	25	-0.566	-2.776	0.010
2550	American lobster	10	9	8	0.050	0.124	0.905	7	0.136	0.329	0.753
2560	Paguroidea s.f.	3	2	0	.	.	.	0	.	.	.
3212	Aphrodita sp.	0	2	0	.	.	.	0	.	.	.
4210	Whelks	0	8	0	.	.	.	0	.	.	.
4235	Dog whelks	17	0	0	.	.	.	0	.	.	.
4300	Bivalvia c.	2	1	0	.	.	.	0	.	.	.
4304	Ocean quahaug	18	0	0	.	.	.	0	.	.	.
4310	Clams, unspec.	3	0	0	.	.	.	0	.	.	.
4320	Scallops	7	0	0	.	.	.	0	.	.	.
4321	Sea scallops	2	8	0	.	.	.	1	-0.747	.	.
4322	Iceland scallops	6	1	0	.	.	.	0	.	.	.
4330	Mussels, unspec.	3	2	0	.	.	.	0	.	.	.
4340	Cockles	10	0	0	.	.	.	0	.	.	.
4511	Short-fin squid	6	3	0	.	.	.	0	.	.	.
4513	Ommastrephes sp.	0	0	0	.	.	.	0	.	.	.
4514	Squid, unspec	2	0	0	.	.	.	0	.	.	.
4521	Octopus	0	3	0	.	.	.	0	.	.	.
6000	Spiny skinned animals	1	14	0	.	.	.	0	.	.	.
6100	Asteroidea s.c.	35	7	2	-0.797	-0.636	0.639	0	.	.	.
6119	Blood star	0	1	0	.	.	.	0	.	.	.
6120	Sunstar	2	3	0	.	.	.	0	.	.	.
6200	Brittle star	14	4	1	-2.639	.	.	0	.	.	.
6300	Basket star	11	0	0	.	.	.	0	.	.	.
6400	Sea urchins	29	13	9	-0.496	-1.716	0.125	0	.	.	.
6500	Sand dollars	4	1	0	.	.	.	0	.	.	.
6600	Sea cucumbers	8	2	1	0.862	.	.	0	.	.	.
8300	Sea anemone	9	3	0	.	.	.	0	.	.	.
8318	Sea pen	2	0	0	.	.	.	0	.	.	.
8500	Jellyfishes	4	1	0	.	.	.	0	.	.	.
8600	Sponges	8	0	0	.	.	.	0	.	.	.
9300	Seaweed,kelp	1	0	0	.	.	.	0	.	.	.
9999		0	9	0	.	.	.	0	.	.	

Table 11. Results of Generalized Linear Models testing for vessel effect in 1992 Cod Catches

All paired sets included

Source	DF	SS	MS	F	Pr > F	R^2
Model	56	154.372	2.767	13.64	0.0001	0.933
Ship	1	0.841	0.841	4.16	0.0461	
Setno	55	154.531	2.791	13.82	0.0001	
Error	55	11.113	0.202			
Corrected Total	111	165.485				

Ship	Effort
Hammond	3.4125
Needler	3.5858

Table 12. Results of Generalized Linear Models testing for depth effect in 1992 Cod Catches

All paired sets

Source	DF	SS	MS	F	Pr > F	R^2
Model (Depth)	1	2.758	2.758	7.65	0.0078	0.124
Error	54	19.469	0.361			
Corrected Total	55	22.226				

Parameter	Estimate	T for H0:Par=0	Pr > |T|	Std Error of Est
Intercept	-0.4919	-3.50	0.0009	0.1404
Depth	0.0046	2.77	0.0078	0.0017

Table 13. Results of Generalized Linear Models testing for length effect in 1992 Cod Catches

Model 1: all paired sets, fish<=36 cm

Source	DF	SS	MS	F	Pr > F	R^2
Model	44	146.395	3.327	14.53	0.0001	0.937
Ship	1	1.315	1.315	5.74	0.0210	
Setno	43	145.080	3.374	14.73	0.0001	
Error	43	9.849	0.229			
Corrected Total	87	156.244				

Ship	Effect
Hammond	2.5045
Needler	2.7491

All paired sets, fish>36 cm

Source	DF	SS	MS	F	Pr > F	R^2
Model	54	110.618	2.048	8.52	0.0001	0.897
Ship	1	0.590	0.590	2.45	0.1232	
Setno	53	110.028	2.076	8.64	0.0001	
Error	53	12.738	0.240			
Corrected Total	107	123.356				

Ship	Effect
Hammond	3.0062
Needler	3.1540

Table 14. Results of Generalized Linear Models testing for vessel effect in 1992 White Hake Catches

All paired sets

Source	DF	SS	MS	F	Pr > F	R^2
Model	24	108.273	4.511	11.90	0.0001	0.925
Ship	1	0.349	0.349	0.92	0.3475	
Setno	23	107.925	4.692	12.38	0.0001	
Error	23	8.721	0.379			
Corrected Total	47	116.994				

Ship	Effect
Hammond	2.6800
Needler	2.5095

Set 67 removed

Source	DF	SS	MS	F	Pr > F	R^2
Model	23	107.901	4.691	26.54	0.0001	0.965
Ship	1	0.017	0.017	0.09	0.7610	
Setno	22	107.884	4.904	27.74	0.0001	
Error	22	3.889	0.177			
Corrected Total	45	111.790				

Ship	Effect
Hammond	2.607
Needler	2.569

Table 15. Results of Generalized Linear Models testing for depth effect in 1992 White Hake Catches

All paired sets

Source	DF	SS	MS	F	Pr > F	R^2
Model (Depth)	1	0.001	0.001	0.00	0.9726	0.000
Error	20	17.395	0.870			
Corrected Total	21	17.396				

Parameter	Estimate	T for H0:Par=0	Pr > |T|	Std Error of Est
Intercept	0.1760	0.60	0.555	0.2930
Depth	0.0001	0.03	0.973	0.0018

Table 16. Results of Generalized Linear Models testing for vessel effect in 1992 American Plaice Catches

All paired sets

Source	DF	SS	MS	F	Pr > F	R^2
Model	53	240.001	4.528	34.72	0.0001	0.973
Ship	1	0.471	0.471	3.61	0.0629	
Setno	52	239.530	4.606	35.32	0.0001	
Error	52	6.782	0.130			
Corrected Total	107	246.783				

Ship	Effect
Hammond	4.9869
Needler	4.8536

Table 16. Results of Generalized Linear Models testing for vessel effect in 1992 American Plaice Catches (cont'd)

Set 51 removed

Source	DF	SS	MS	F	Pr > F	R^2
Model	52	239.760	4.611	49.10	0.0001	0.927
Ship	1	0.236	0.236	2.52	0.1189	
Setno	51	239.524	4.697	50.01	0.0001	
Error	51	4.789	0.094			
Corrected Total	103	244.550				

Ship	Effect
Hammond	4.9669
Needler	4.8716

Table 17. Results of Generalized Linear Models testing for depth effect in 1992 American Plaice Catches

All paired sets

Source	DF	SS	MS	F	Pr > F	R^2
Model (Depth)	1	1.068	1.068	4.36	0.0419	0.079
Error	51	12.496	0.245			
Corrected Total	52	13.564				

Parameter	Estimate	T for H0:Par=0	Pr > |T|	Std Error of Est
Intercept	-0.0623	-0.54	0.593	0.1158
Depth	0.0026	2.09	0.042	0.0012

All paired sets, no intercept

Source	DF	SS	MS	F	Pr > F	R^2
Model (Depth)	1	1.939	1.939	8.02	0.0066	0.134
Error	52	12.567	0.242			
Corrected Total	53	14.506				

Parameter	Estimate	T for H0:Par=0	Pr > |T|	Std Error of Est
Depth	0.0020	2.83	0.007	0.0007

Table 18. Summary of species information for 1985 comparison

	Species	Number of sets		Paired sets (weight caught)				Paired sets (numbers caught)			
		Lady Hammond	Alfred Needler	n	diffl	t	P>|t|	n	diffl	t	P>|t|
10	Atlantic cod	60	58	54	-0.169	-1.538	0.130	56	-0.174	-2.048	0.045
12	White hake	28	32	23	0.067	0.276	0.785	24	0.170	0.959	0.347
14	Silver hake	1	0	0	.	.	.	0	.	.	.
16	Pollock	0	2	0	.	.	.	0	.	.	.
23	Redfish	13	10	9	0.352	2.195	0.059	9	0.263	1.586	0.151
31	Greenland halibut	11	14	9	0.164	0.783	0.456	9	-0.102	-0.897	0.396
40	American plaice	55	55	52	0.127	1.692	0.097	53	0.132	1.884	0.065
41	Witch flounder	15	17	10	-0.248	-1.826	0.101	11	-0.062	-0.519	0.615
42	Yellowtail flounder	23	27	19	-0.146	-0.899	0.380	20	-0.134	-0.658	0.519
43	Winter flounder	15	13	12	0.311	1.358	0.202	12	0.200	0.762	0.462
50	Striped Atl. wolffish	2	2	1	-0.693	.	.	1	0.000	.	.
51	Spotted wolffish	1	0	0	.	.	.	0	.	.	.
60	Atlantic Herring	33	37	22	-0.102	-0.383	0.706	24	-0.054	-0.158	0.876
62	Alewife	5	4	3	-0.312	-0.590	0.615	3	-0.652	-1.961	0.189
63	Rainbow smelt	10	12	6	-0.319	-1.149	0.303	8	-0.445	-1.564	0.162
64	Capelin	5	9	4	-0.580	-1.843	0.163	3	-0.467	-3.437	0.075
70	Atlantic salmon	3	5	1	-0.793	.	.	1	0.054	.	.
112	Longfin hake	1	2	1	0.061	.	.	1	0.061	.	.
114	Fourbeard rockling	10	9	7	0.514	1.797	0.122	7	0.433	4.183	0.006
118	Greenland cod	6	9	4	0.777	2.464	0.091	4	-0.089	-0.435	0.693
122	Cunner	2	3	0	.	.	.	1	-0.916	.	.
201	Thorny skate	37	36	19	0.186	0.963	0.348	23	0.091	0.753	0.460
202	Smooth skate	8	5	3	0.226	0.703	0.555	3	-0.176	-0.415	0.718
204	Winter skate	4	7	0	.	.	.	0	.	.	.
220	Spiny dogfish	10	10	7	-0.670	-1.276	0.249	6	-0.416	-0.855	0.432
221	Black dogfish	1	1	1	0.412	.	.	1	0.265	.	.
300	Longhorn sculpin	17	17	10	-0.181	-0.778	0.457	11	0.129	0.763	0.463
301	Shorthorn sculpin	4	7	0	.	.	.	1	1.386	.	.
304	Mailed sculpin	23	19	10	-0.194	-0.696	0.504	16	-0.028	-0.151	0.882

Table 18. Summary of species information for 1985 comparison

	Species	Number of sets		Paired sets (weight caught)				Paired sets (numbers caught)			
		Lady Hammond	Alfred Needler	n	diffl	t	P>|t|	n	diffl	t	P>|t|
306	Arctic hookear sculpin	0	2	0	.	.	.	0	.	.	.
320	Sea raven	11	8	4	0.014	0.050	0.963	5	0.358	0.950	0.396
340	Alligator fish	16	11	1	-1.609	.	.	5	-0.143	-0.298	0.780
350	Atlantic sea poacher	3	6	3	0.215	1.129	0.376	3	-0.016	-0.033	0.976
410	Marlin-spike grenadier	7	5	5	-0.122	-0.338	0.752	5	0.127	0.507	0.639
500	Seasnail unidentified	3	1	1	-1.731	.	.	1	0.061	.	.
501	Lumpfish	2	1	0	.	.	.	0	.	.	.
502	Atl. spiny lumpsucker	2	3	0	.	.	.	1	0.000	.	.
503	Atlantic seasnail	1	0	0	.	.	.	0	.	.	.
504	Striped seasnail	3	3	1	-0.336	.	.	1	0.693	.	.
505	Seasnail, gelatinous	2	0	0	.	.	.	0	.	.	.
512	Seasnail, dusky	7	8	5	1.005	2.504	0.066	4	0.230	0.999	0.391
513	Gulf seasnail	0	1	0	.	.	.	0	.	.	.
520	Sea tadpole	0	6	0	.	.	.	0	.	.	.
620	Laval's eelpout	30	0	0	.	.	.	0	.	.	.
622	Snake blenny	2	8	0	.	.	.	0	.	.	.
625	Radiated shanny	0	1	0	.	.	.	0	.	.	.
626	4-line snake blenny	5	4	1	0.000	.	.	1	0.223	.	.
630	Wrymouth	2	5	2	0.321	0.386	0.766	1	0.000	.	.
640	Common ocean pout	10	12	8	-0.802	-1.631	0.147	8	-0.188	-1.749	0.124
641	Arctic eelpout	1	30	1	-2.079	.	.	1	-2.773	.	.
643	Vachon's eelpout	0	2	0	.	.	.	0	.	.	.
647	Shorttailed eelpout	9	9	6	-0.198	-1.011	0.358	7	0.098	0.485	0.645
674	P. coregonoides	3	3	0	.	.	.	1	0.000	.	.
1510	Mollusc eggs unid.	4	0	0	.	.	.	0	.	.	.
1810	Tunicata s.p.	0	2	0	.	.	.	0	.	.	.
1827	Sea peach	4	0	0	.	.	.	0	.	.	.
2200	Pandalidae f.	13	2	1	-0.904	.	.	0	.	.	.
2210	Pandalus sp.	3	9	2	-0.918	-1.456	0.383	0	.	.	.
2416	Crangon sp.	0	1	0	.	.	.	0	.	.	.
2511	Jonah crab	5	0	0	.	.	.	0	.	.	.
2513	Atlantic rock crab	8	11	4	-0.090	-0.249	0.820	6	0.301	1.045	0.344
2520	Toad crab, unid.	35	37	22	0.211	0.915	0.371	22	0.384	2.960	0.007
2523	Northern snow crab	3	6	2	1.447	12.285	0.052	2	1.153	2.230	0.268
2526	Queen snow crab	44	47	38	0.154	1.439	0.158	38	-0.075	-0.770	0.446
2550	American lobster	14	8	7	0.251	0.802	0.453	8	0.503	1.435	0.194
3212	Aphrodita sp.	2	4	1	0.847	.	.	2	0.077	0.100	0.937
4000	Mollusca p.	15	0	0	.	.	.	0	.	.	.
4210	Whelks	5	6	0	.	.	.	0	.	.	.
4211	Wave whelk	2	0	0	.	.	.	0	.	.	.
4304	Ocean quahaug	0	3	0	.	.	.	0	.	.	.
4310	Clams, unspec.	0	1	0	.	.	.	0	.	.	.
4321	Sea scallops	1	4	0	.	.	.	1	0.134	.	.
4322	Iceland scallops	3	11	1	-0.582	.	.	0	.	.	.
4330	Mussels, unspec.	1	1	1	0.000	.	.	1	0.288	.	.
4340	Cockles	0	1	0	.	.	.	0	.	.	.
4511	Short-fin squid	7	13	3	0.336	1.202	0.352	2	1.099	2.337	0.257
4512	Long-finned squid	2	0	0	.	.	.	0	.	.	.
4521	Octopus	3	7	2	0.401	0.348	0.787	2	-0.405	-7.094	0.089
4700	Chitons	4	4	2	-0.094	-0.304	0.812	1	-0.588	.	.
6000	Spiny skinned animals	1	4	0	.	.	.	0	.	.	.
6100	Asteroidea s.c.	24	12	4	-0.506	-1.994	0.140	2	-0.670	-0.667	0.626
6115	Mud star	9	4	1	0.916	.	.	1	1.552	.	.
6120	Sunstar	35	16	12	0.142	0.814	0.433	4	0.372	1.720	0.184
6200	Brittle star	5	4	1	-0.811	.	.	0	.	.	.
6300	Basket star	27	8	3	-0.218	-0.450	0.697	1	-0.636	.	.
6400	Sea urchins	27	19	14	0.179	1.163	0.266	0	.	.	.
6500	Sand dollars	6	0	0	.	.	.	0	.	.	.
6600	Sea cucumbers	15	3	2	0.258	0.307	0.810	1	0.111	.	.
8300	Sea anemone	10	2	2	0.130	5.319	0.118	0	.	.	.
8318	Sea pen	2	0	0	.	.	.	0	.	.	.
8500	Jellyfishes	4	5	1	1.310	.	.	0	.	.	.
8600	Sponges	8	2	1	-0.223	.	.	0	.	.	.
8610	Polymastia sp.	0	1	0	.	.	.	0	.	.	.
9000	Unidentified remains	5	27	1	0.336	.	.	0	.	.	.
9003	Unident. fish and eggs	5	0	0	.	.	.	0	.	.	.
9200	Stones and rocks	2	0	0	.	.	.	0	.	.	.
9300	Seaweed,kelp	12	1	0	.	.	.	0	.	.	.
9400	Foreign articles	20	0	0	.	.	.	0	.	.	.

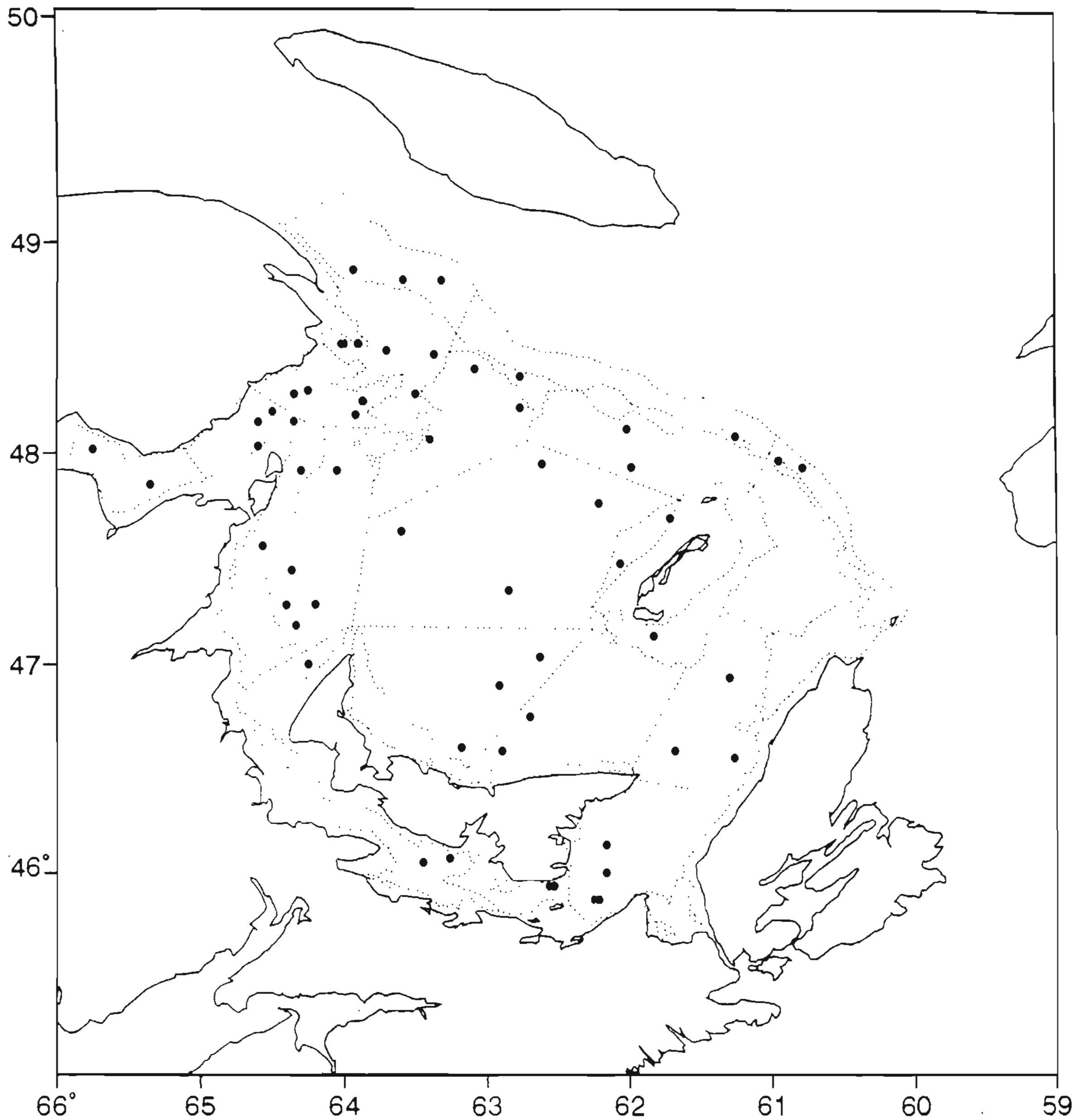


Figure 1. Strata boundaries and location of fishing sets in the 1985 comparative survey

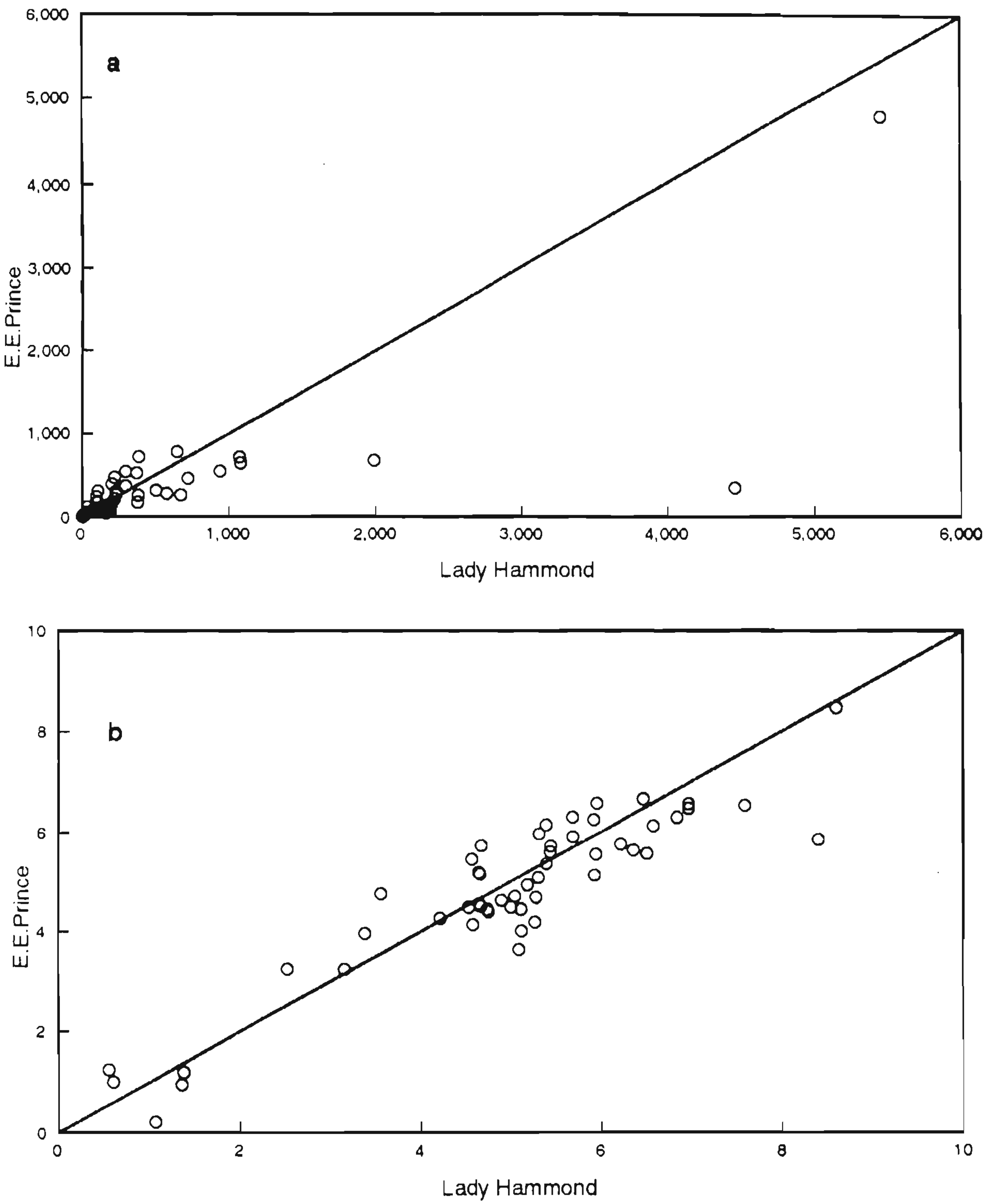


Figure 2. Cod catchses in the 1985 comparative survey
a) numbers caught in the arithmetic scale
b) log-transformed numbers caught

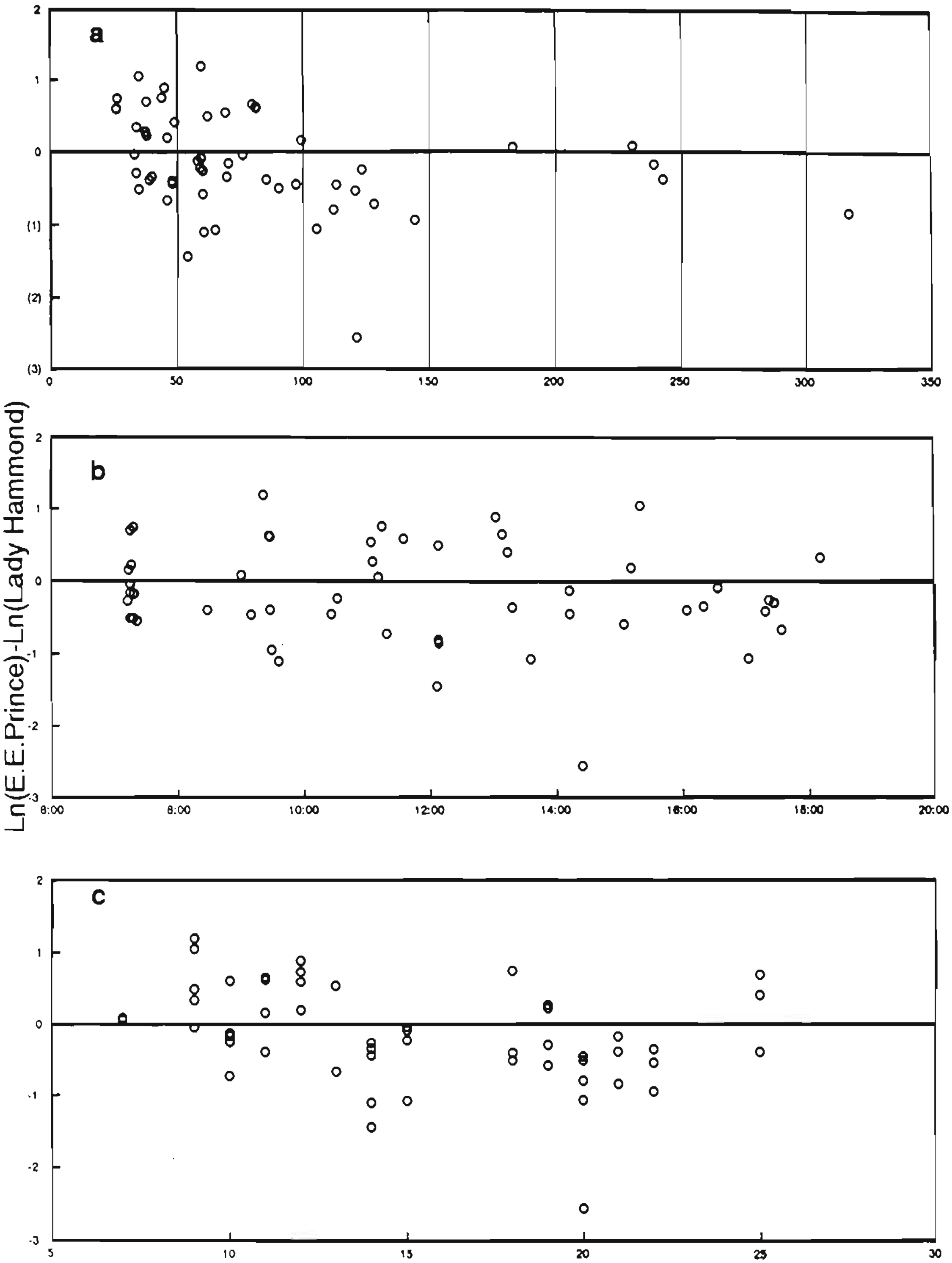


Figure 3. Difference in log-transformed cod catches in the 1985 survey
a) versus depth of tow
b) versus time of day
c) versus day

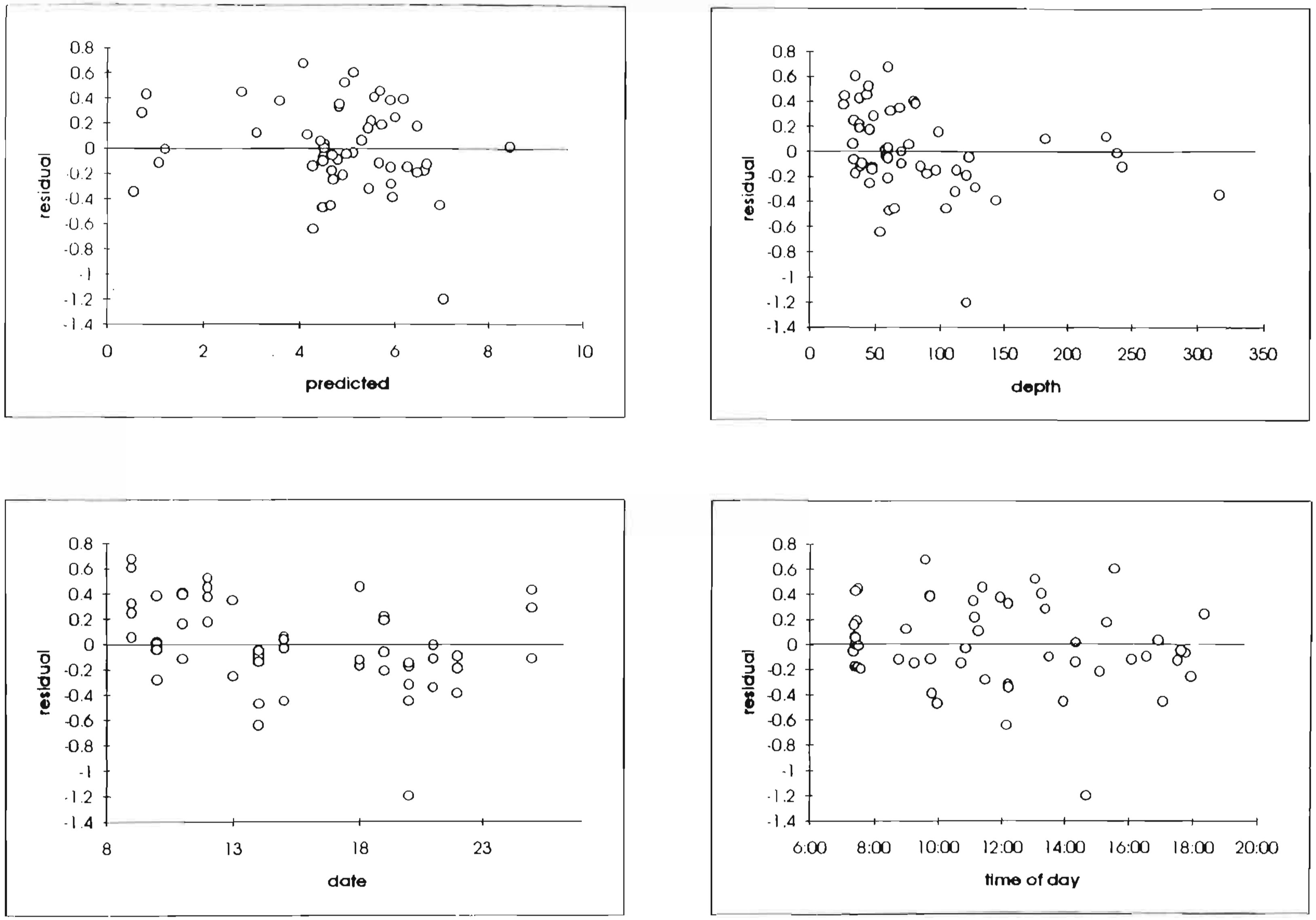
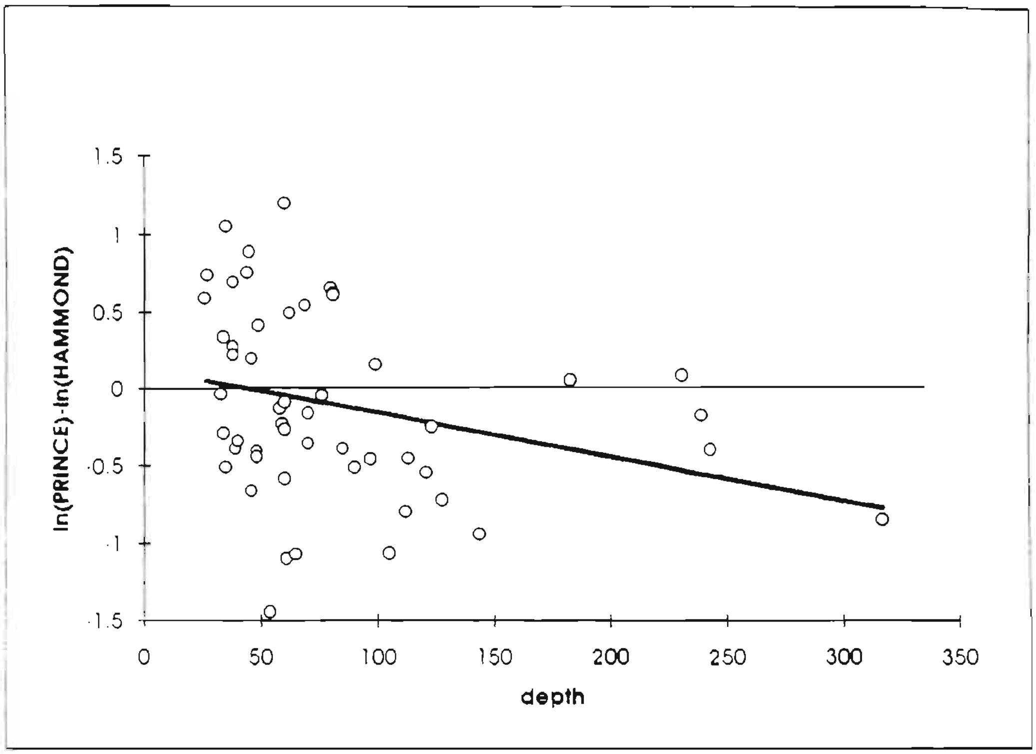


Figure 4. Plot of E.E.Prince residuals from the GLM testing for vessel effect in the 1985 paired cod catches
The Lady Hammond residuals mirror the E.E.Prince residuals around the zero line



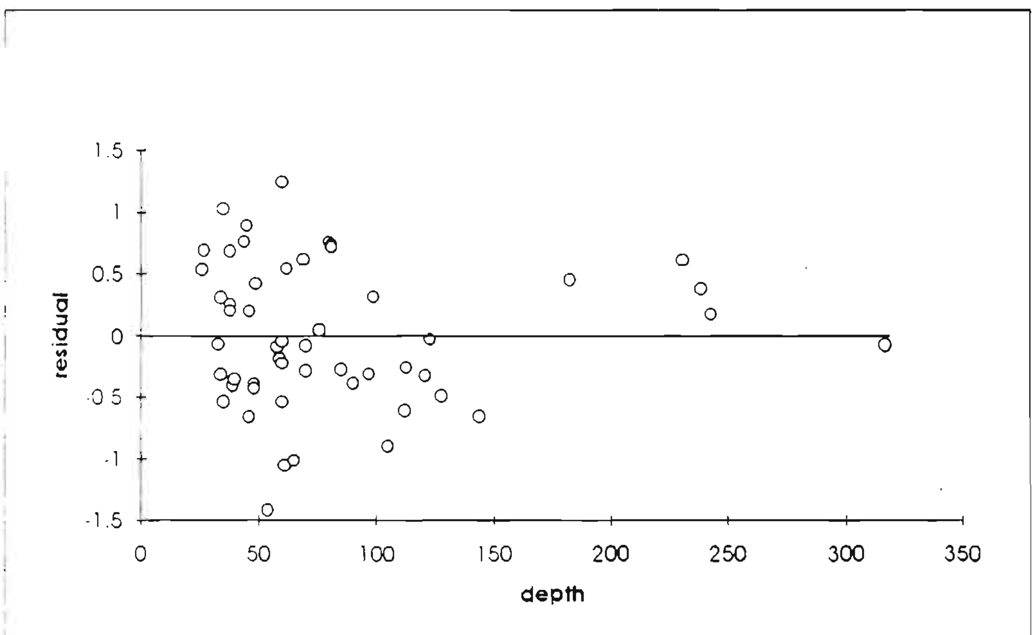


Figure 5. Regression line and residual plot of the GLM testing for depth effect in the 1985 paired cod catches

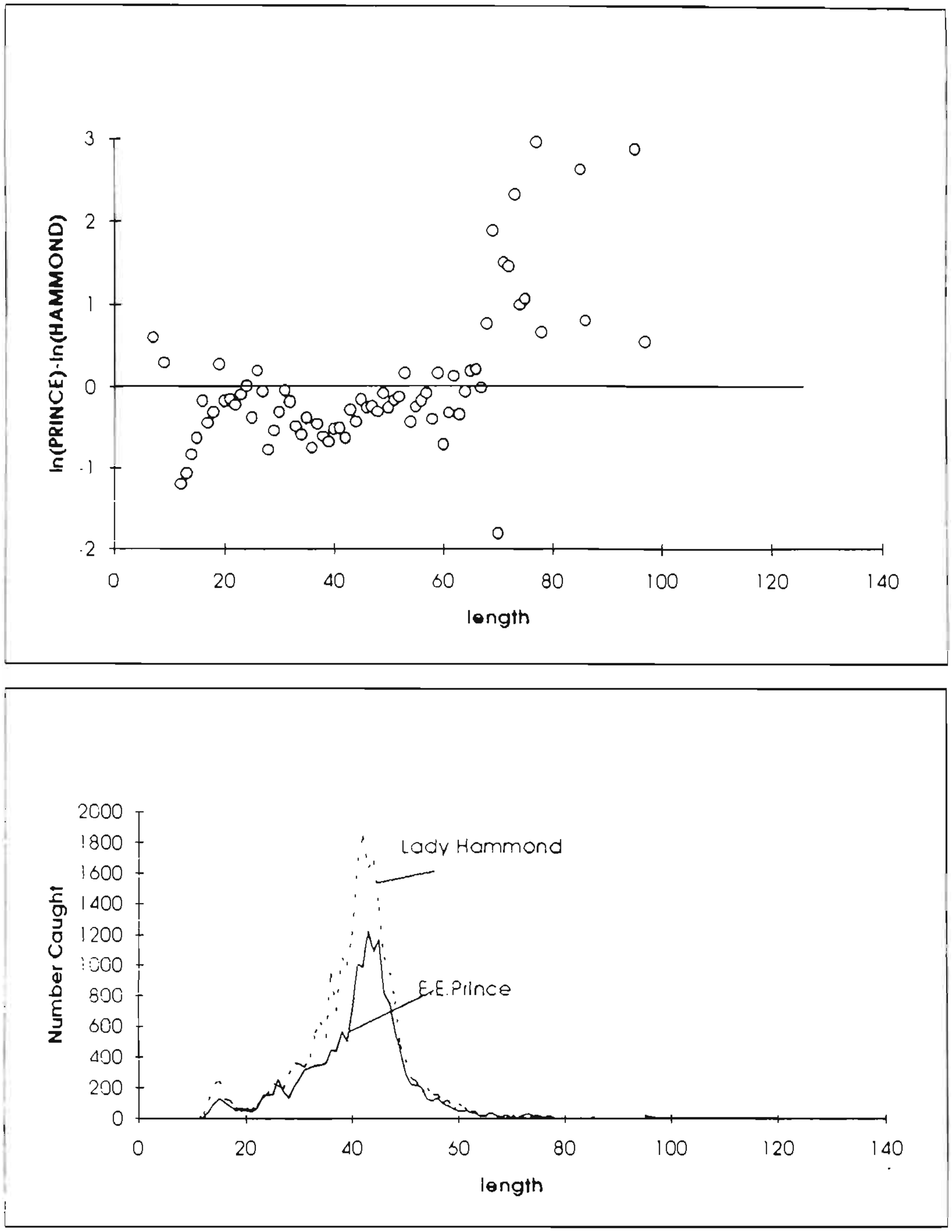
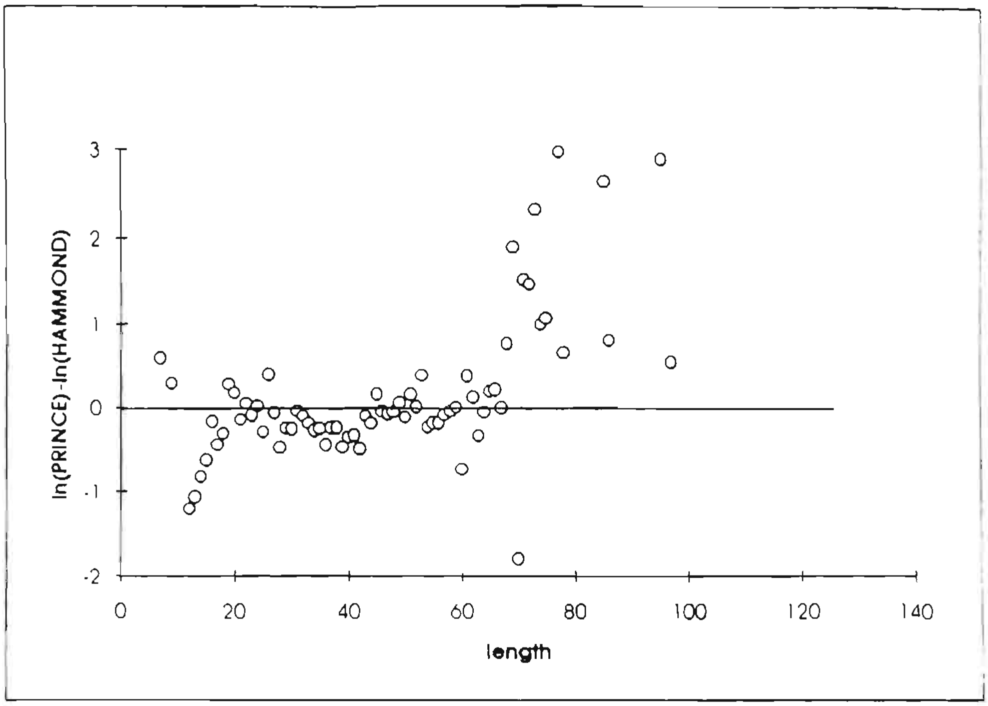


Figure 6. Comparison of cod catches at length in the 1985 experiment (including set 3)

a) difference in log-transformed catch at length

b) length frequencies of cod caught



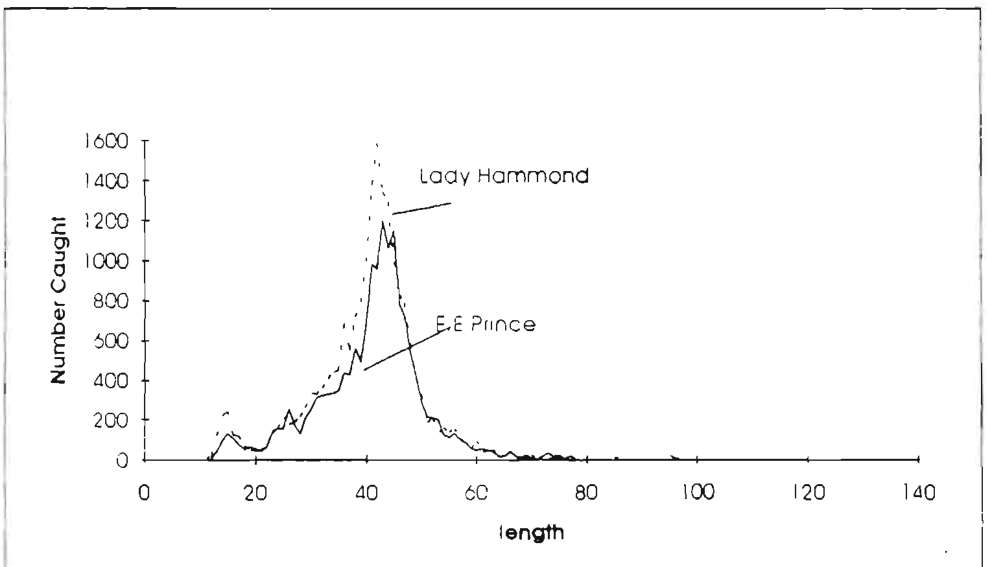


Figure 7. Comparison of cod catches at length in the 1985 experiment
(excluding set 3)
a) difference in log-transformed catch at length
b) length frequencies of cod caught

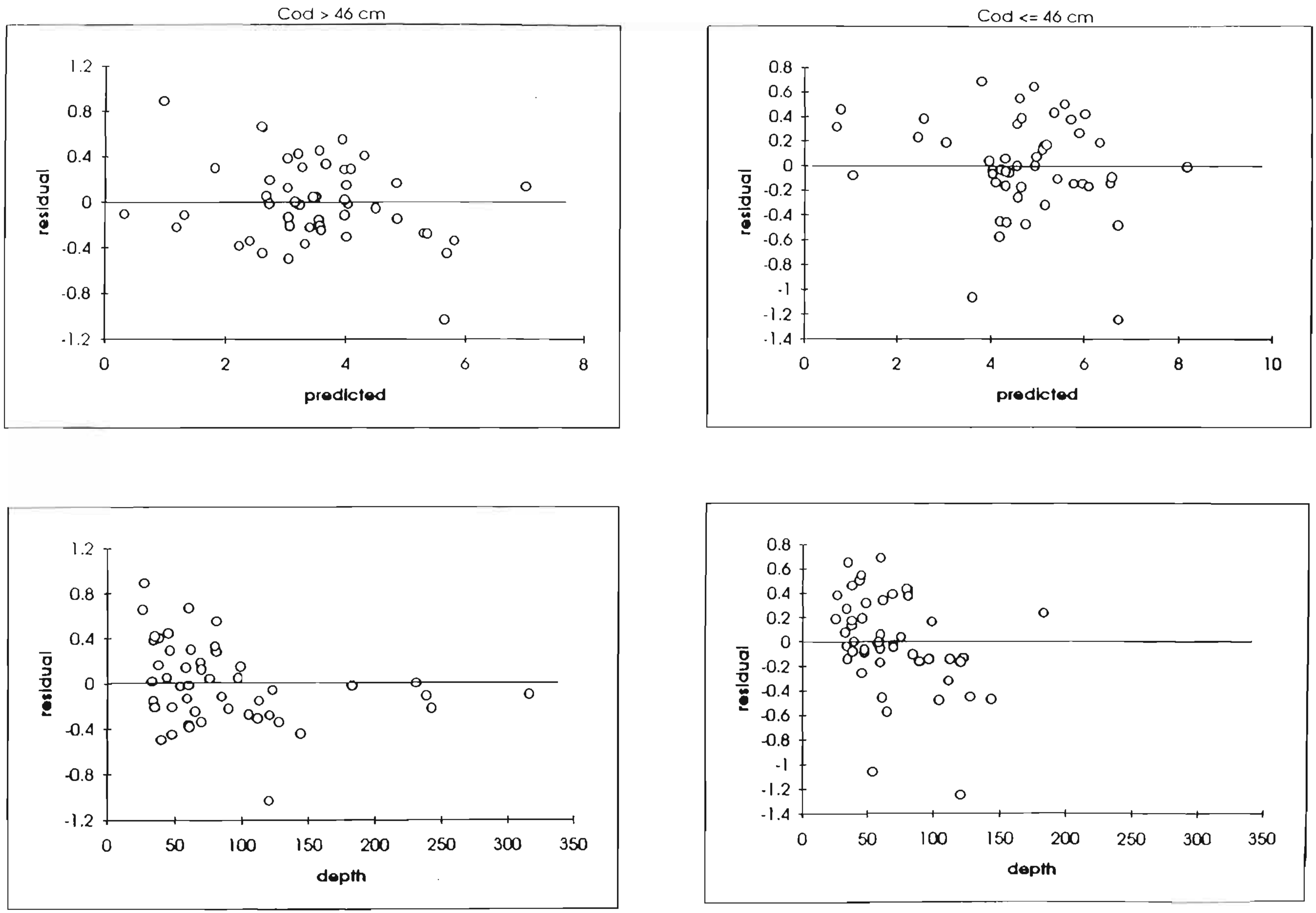
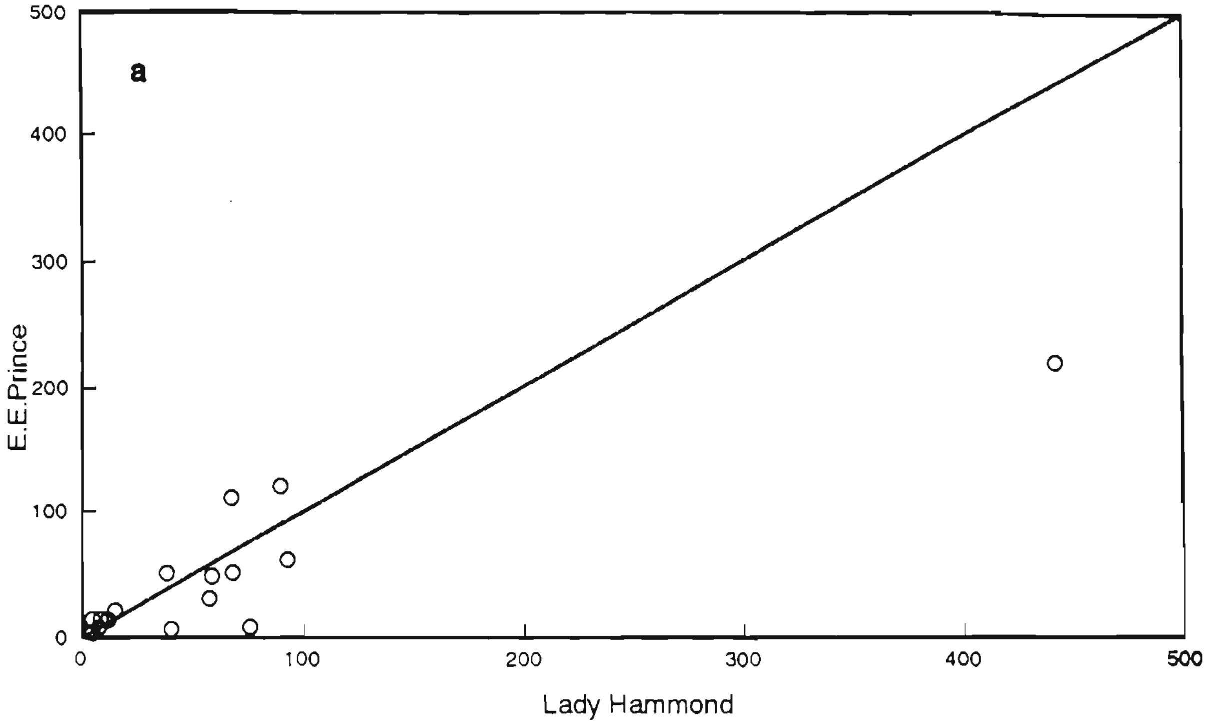


Figure 8. E.E.Prince residuals from the GLM testing for vessel effect within size classes.
Lady Hammond residuals mirror the E.E.Prince residuals around the zero line.



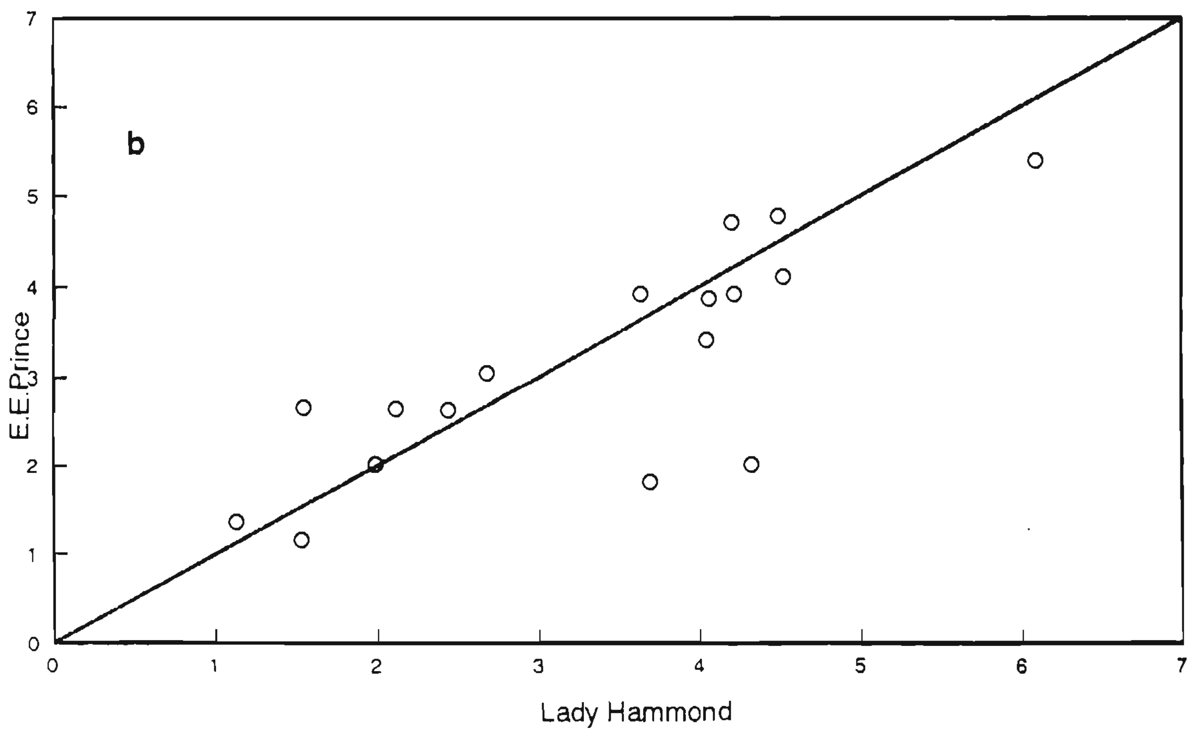


Figure 9. White hake catches in the 1985 comparative survey
a) numbers caught in the arithmetic scale
b) log-transformed numbers caught

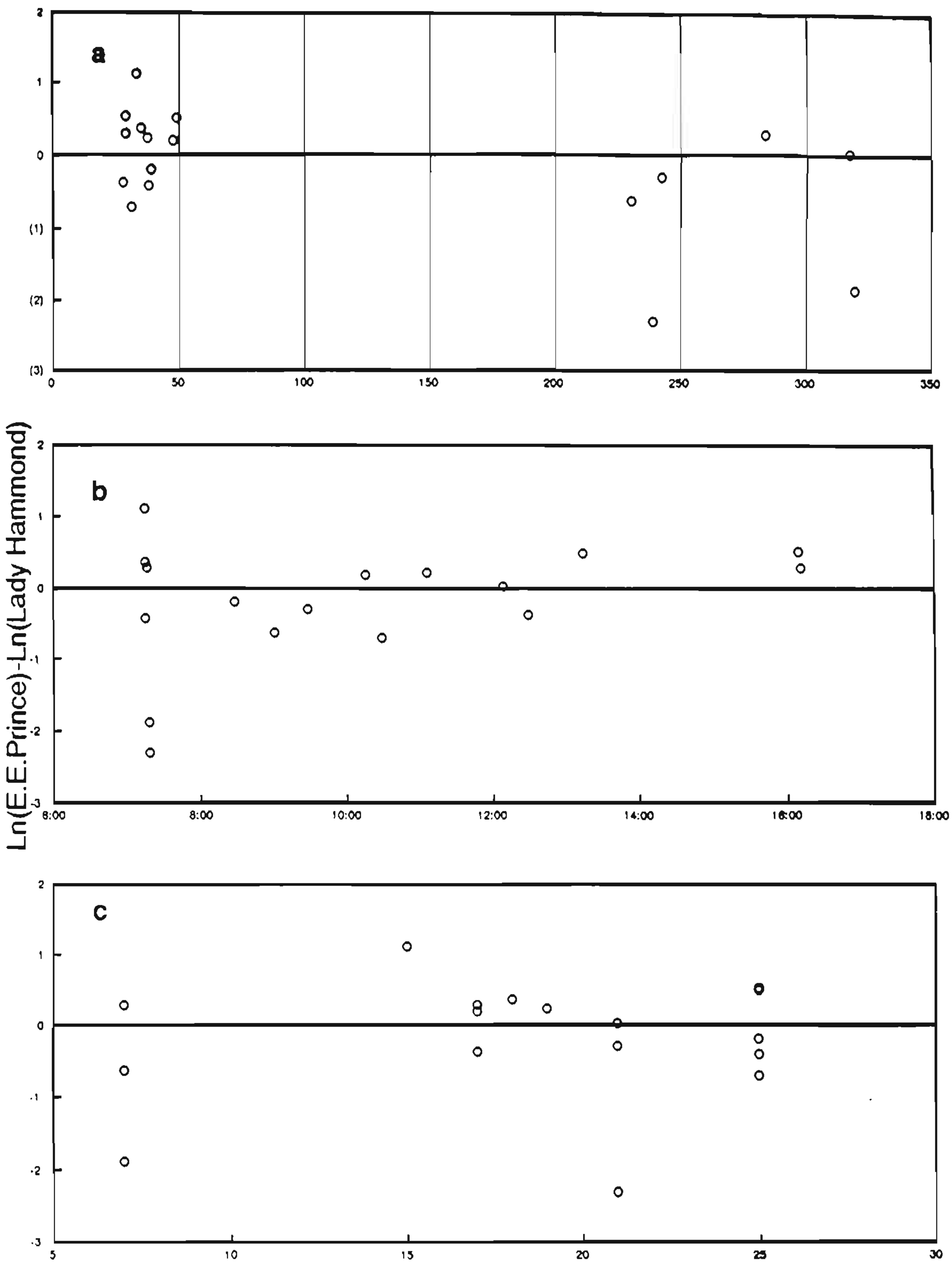


Figure 10. Difference in log-transformed white hake catches in the 1985 survey
a) versus depth of tow
b) versus time of day
c) versus day

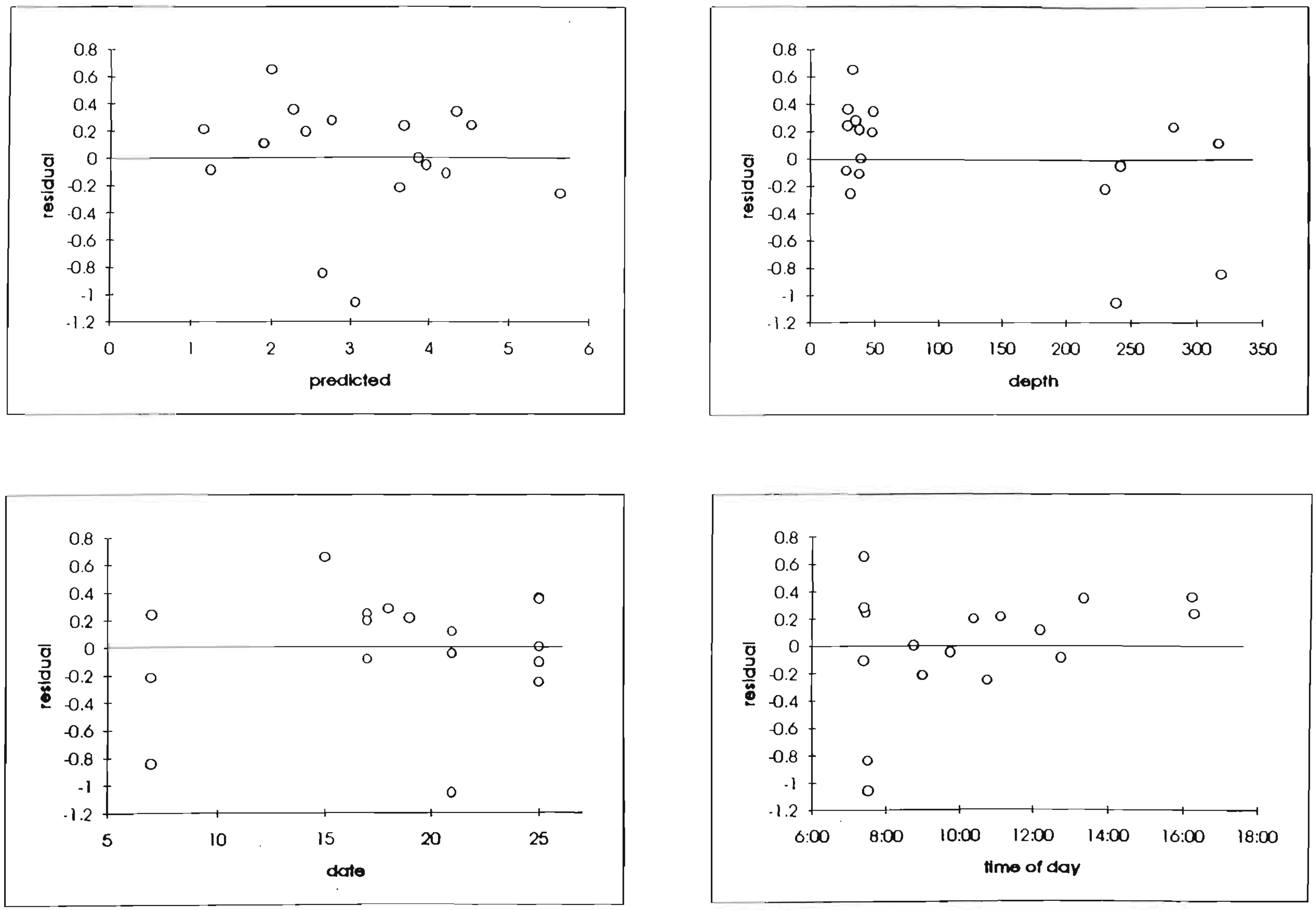


Figure 11. Plot of E.E.Prince residuals from the GLM testing for vessel effect in the 1985 paired hake catches
The Lady Hammond residuals mirror the E.E.Prince residuals around the zero line

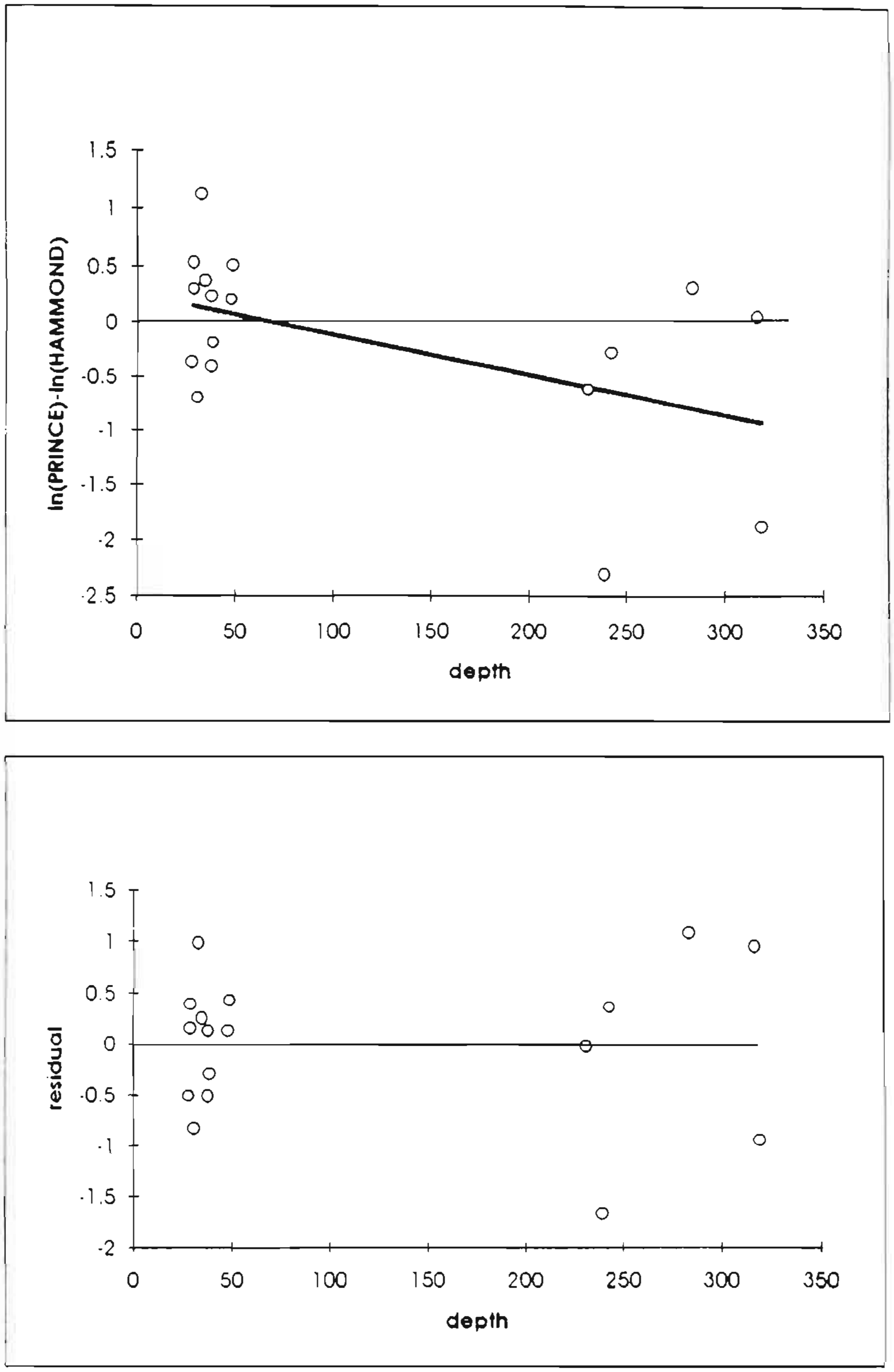
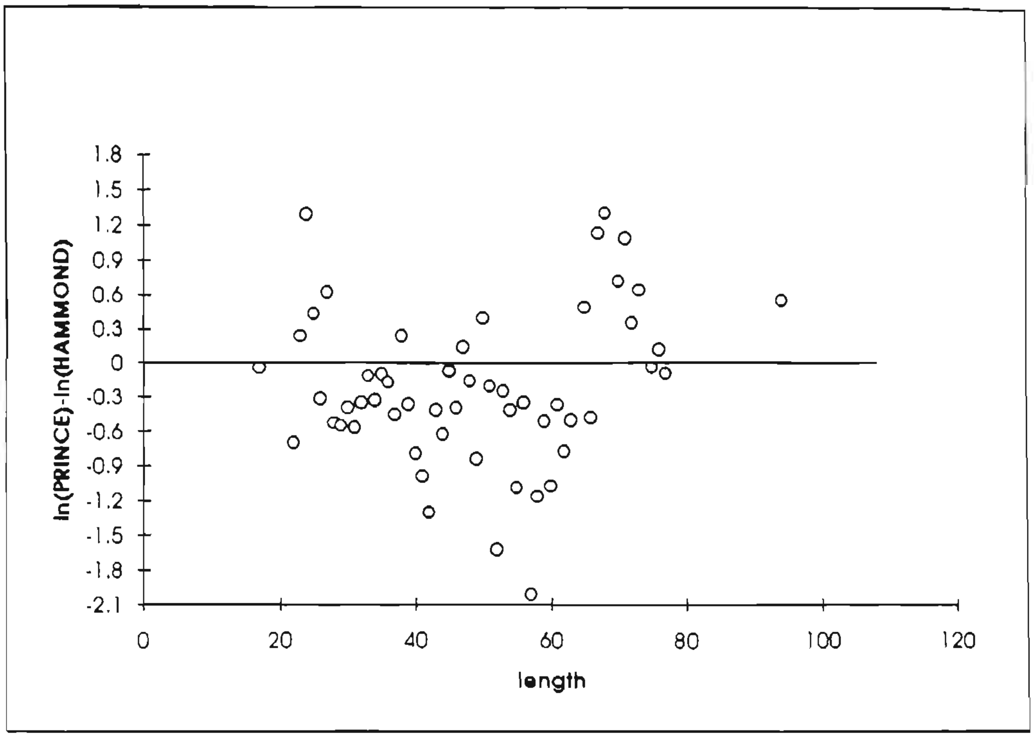


Figure 12. Regression line and residual plot of the GLM testing for depth effect in the 1985 paired white hake catches



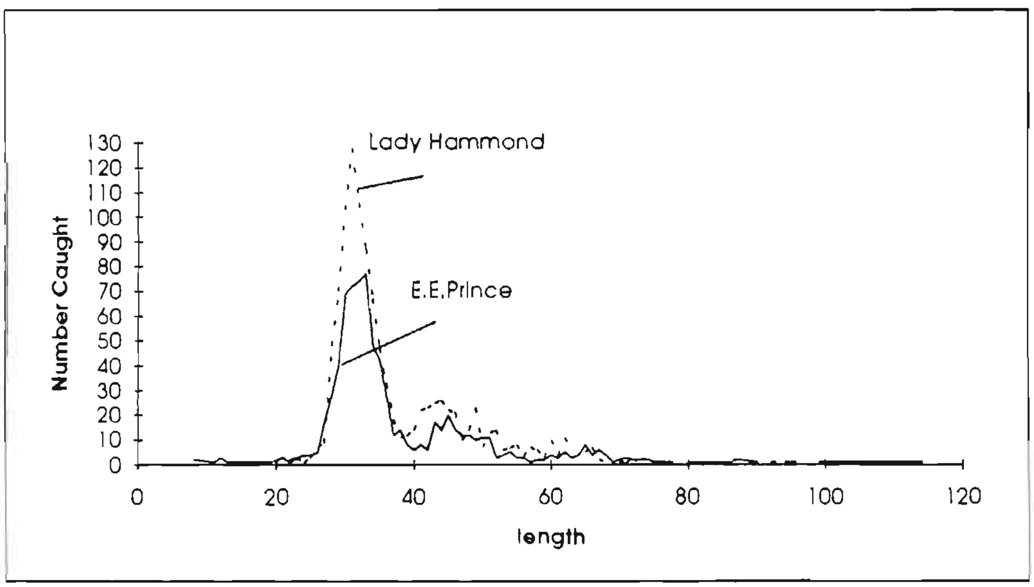


Figure 13. Comparison of white hake catches at length in the 1985 experiment
a) difference in log-transformed catch at length
b) length frequencies of cod caught

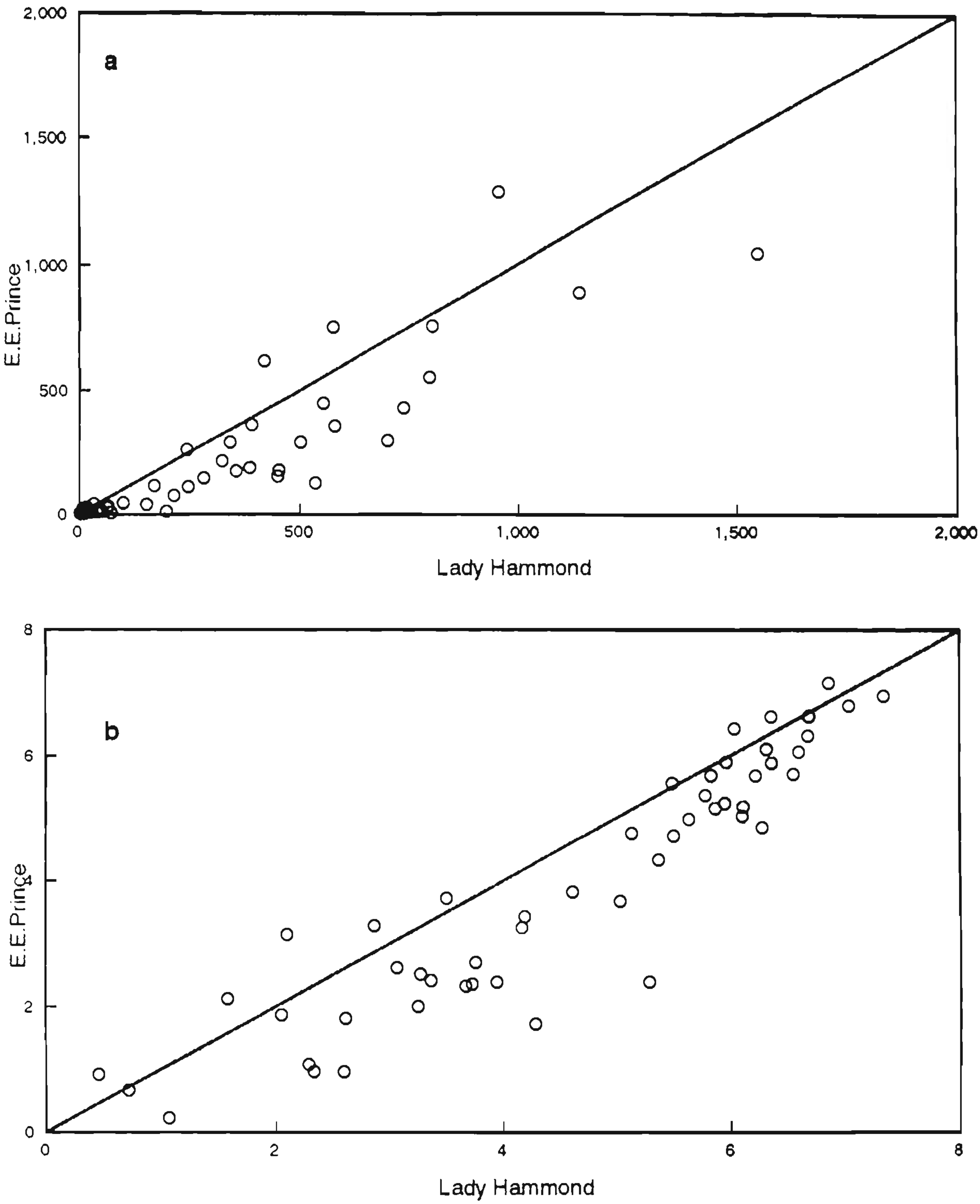


Table 14. American plaice catches in the 1985 comparative survey
a) numbers caught in the arithmetic scale
b) log-transformed numbers caught

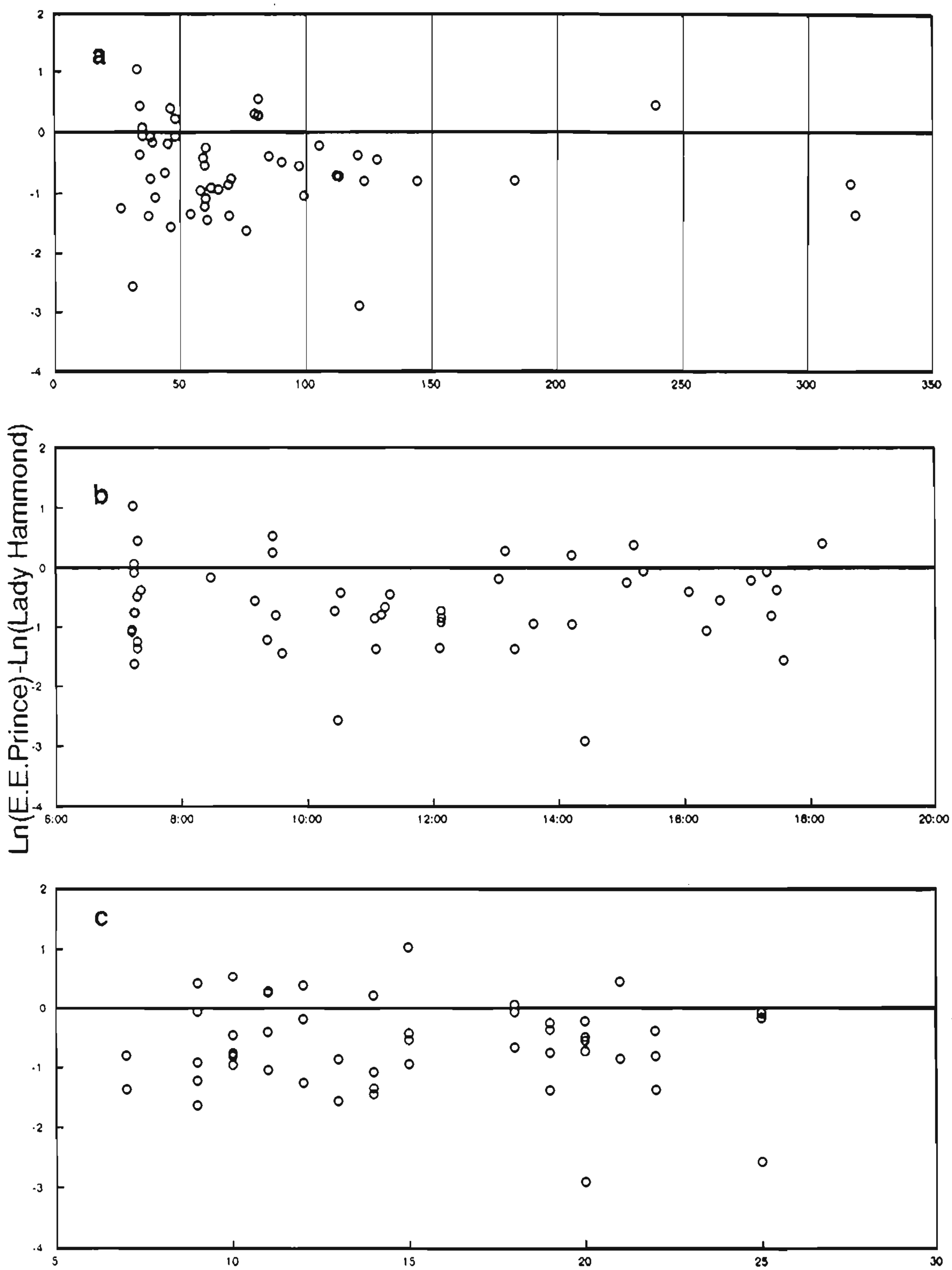


Figure 15. Difference in log-transformed plaice catches in the 1985 survey
a) versus depth of tow
b) versus time of day
c) versus day

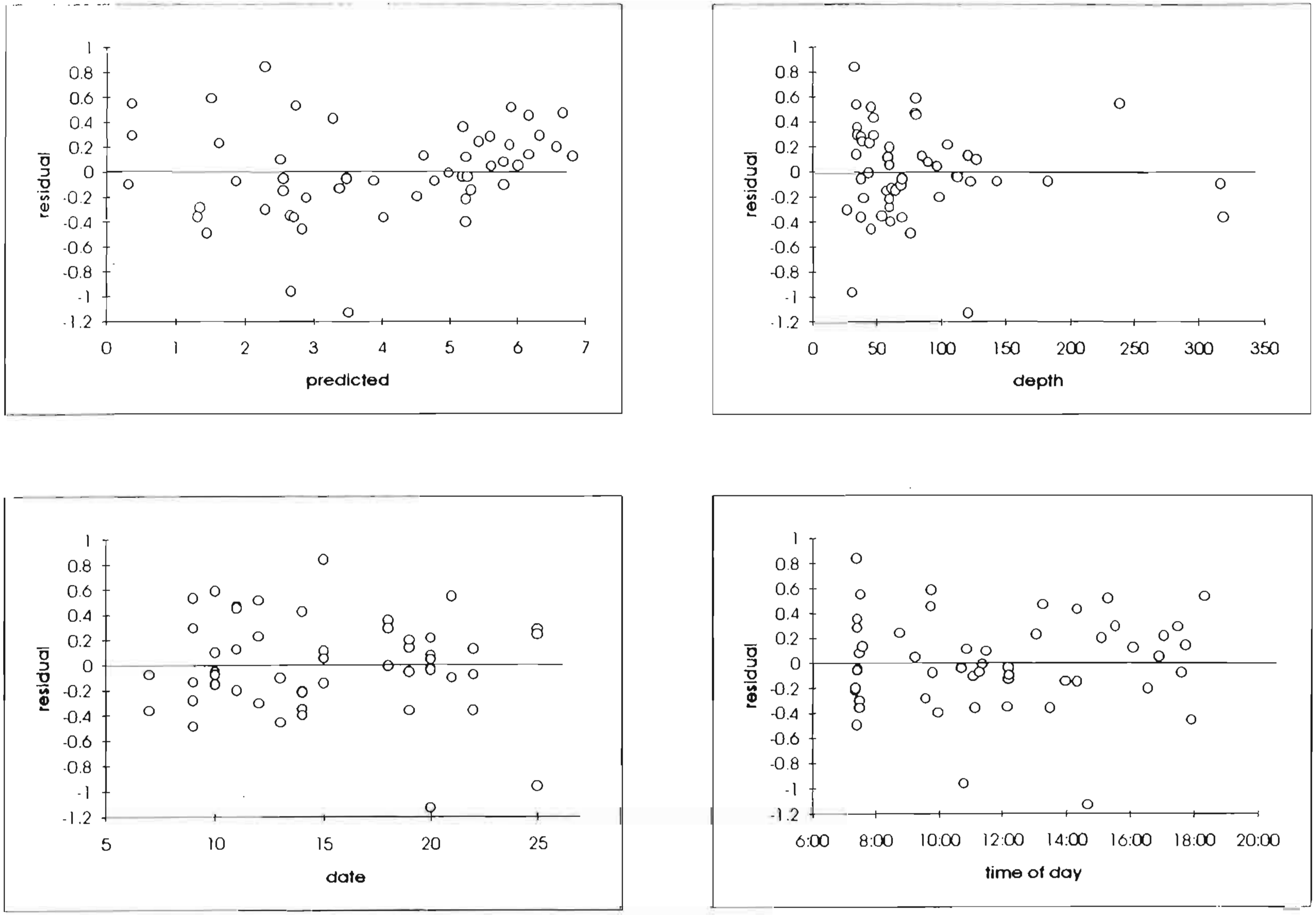
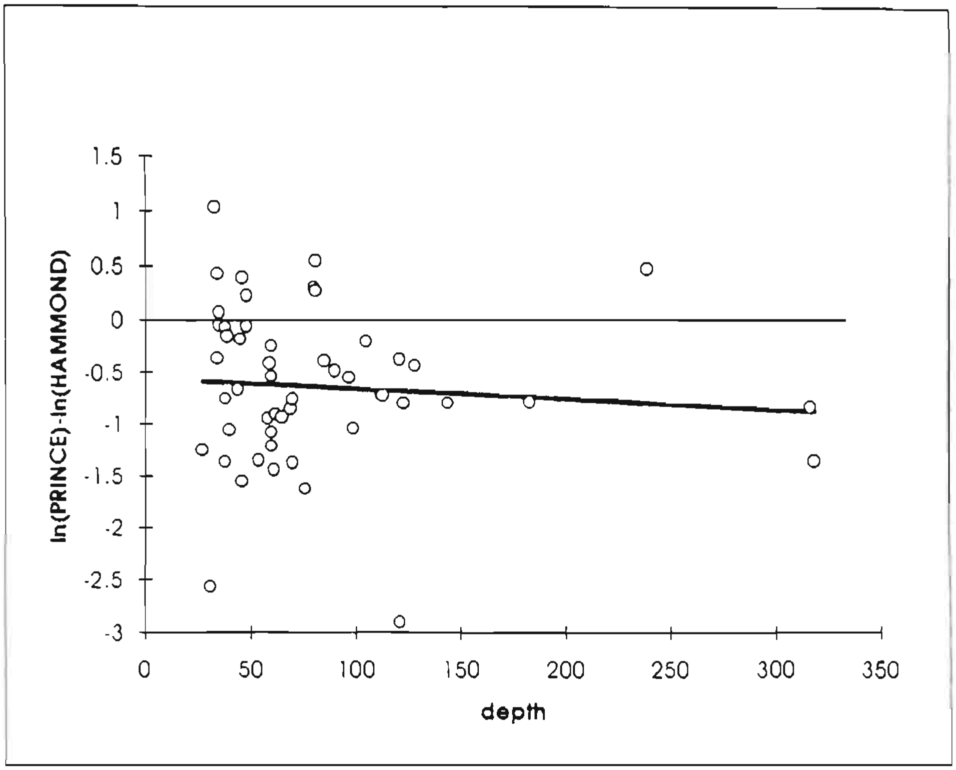


Figure 16. Plot of E.E.Prince residuals from the GLM testing for vessel effect in the 1985 paired plaice catches
The Lady Hammond residuals mirror the E.E.Prince residuals around the zero line



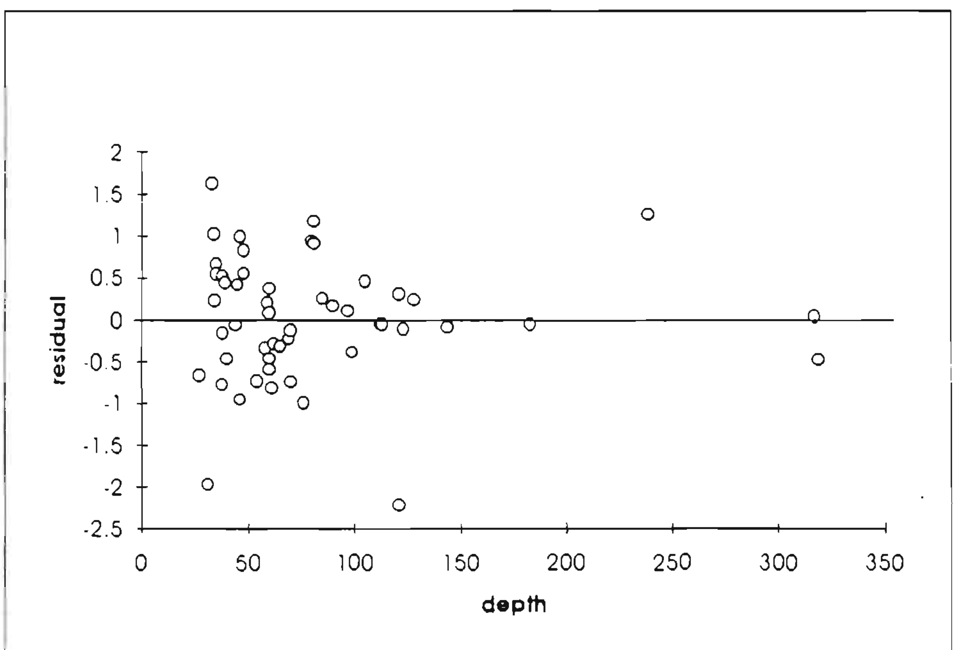


Figure 17. Regression line and residual plot of the GLM testing for depth effect in the 1985 paired American plaice catches

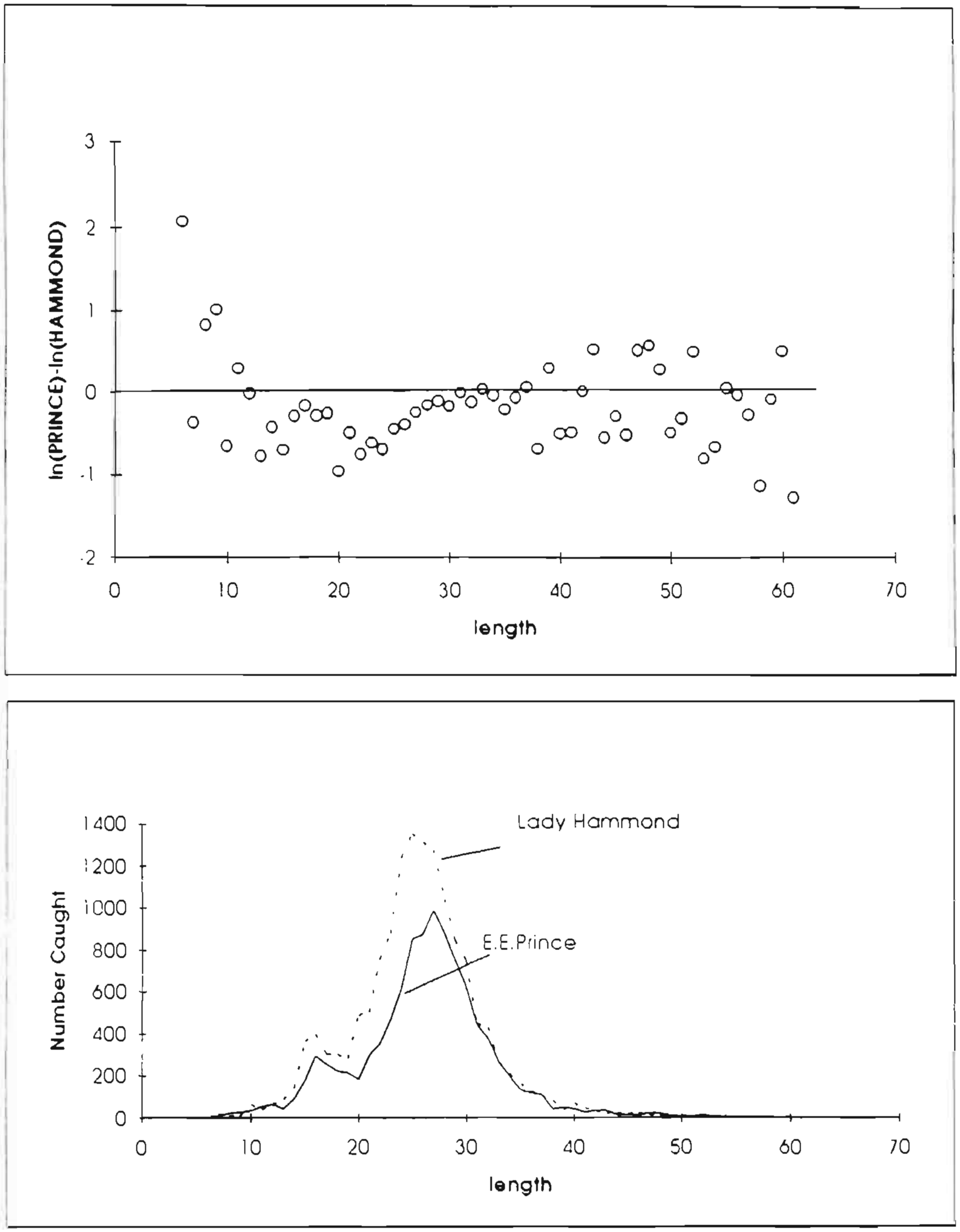


Figure 18. Comparison of American plaice catches at length in the 1985 experiment
a) difference in log-transformed catch at length
b) length frequencies of American plaice caught

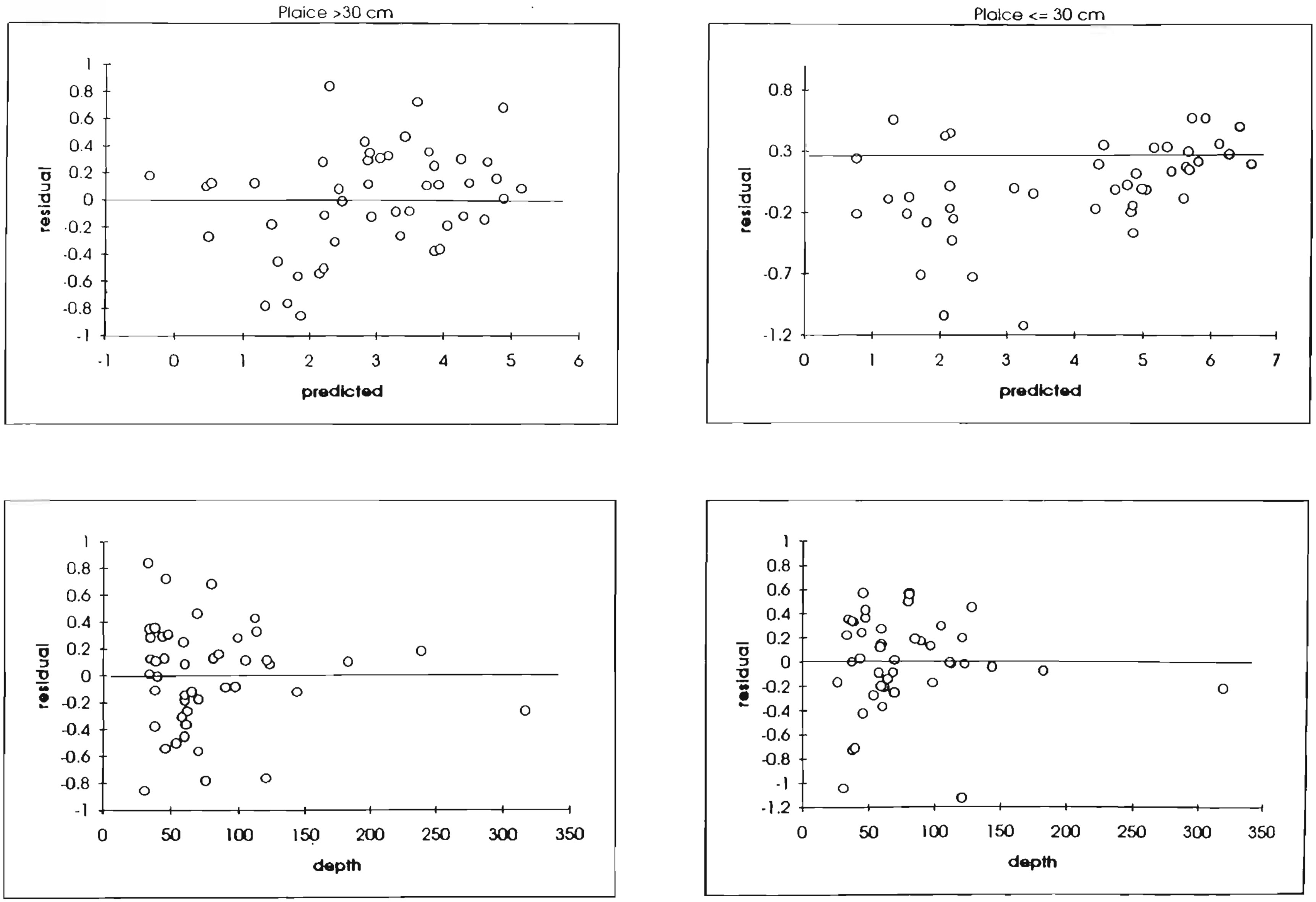


Figure 19. E.E.Prince residuals from the GLM testing for vessel effect within size classes. Lady Hammond residuals mirror the E.E.Prince residuals around the zero line.

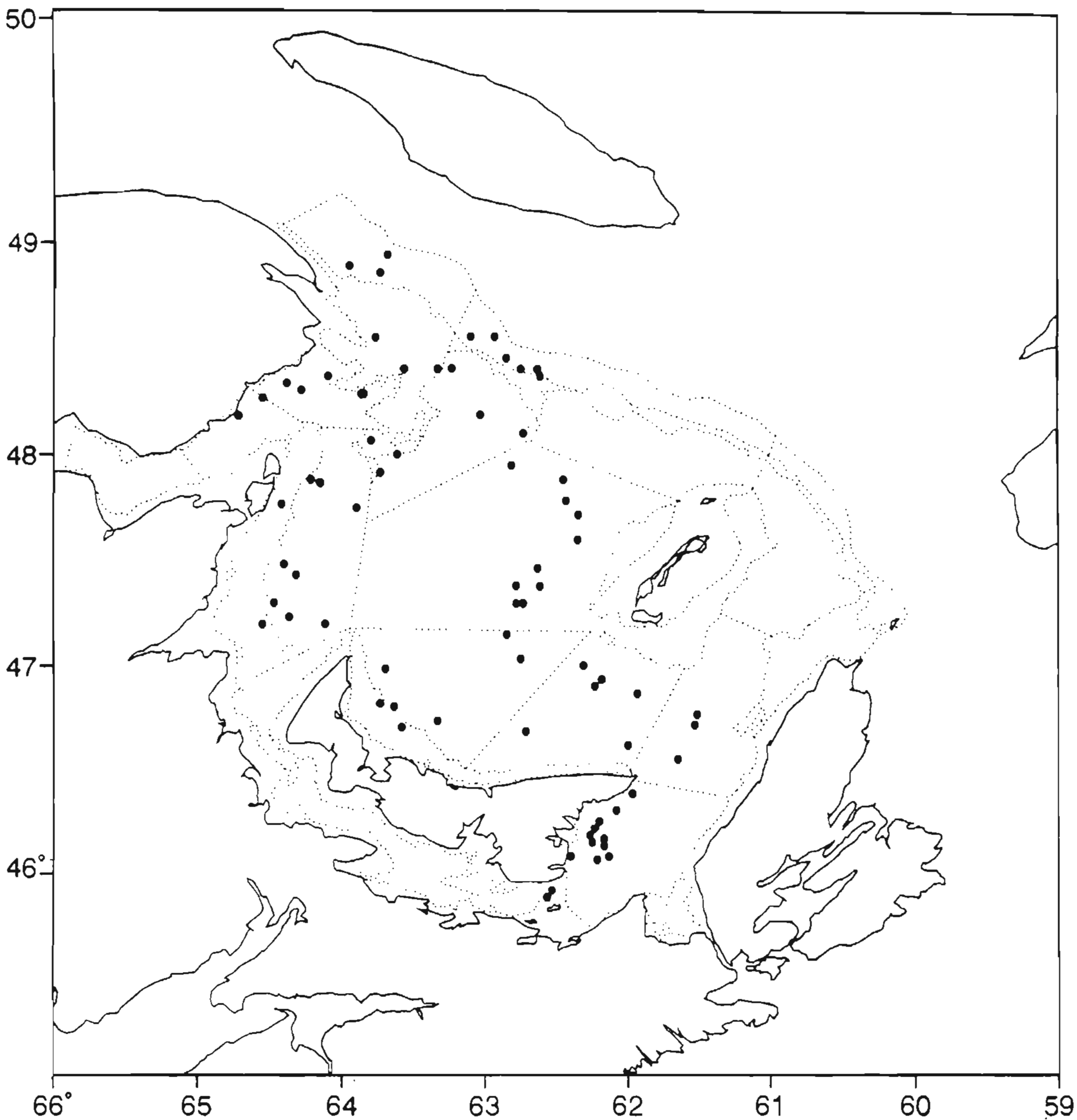


Figure 20. Location of fishing sets in the 1992 comparative survey

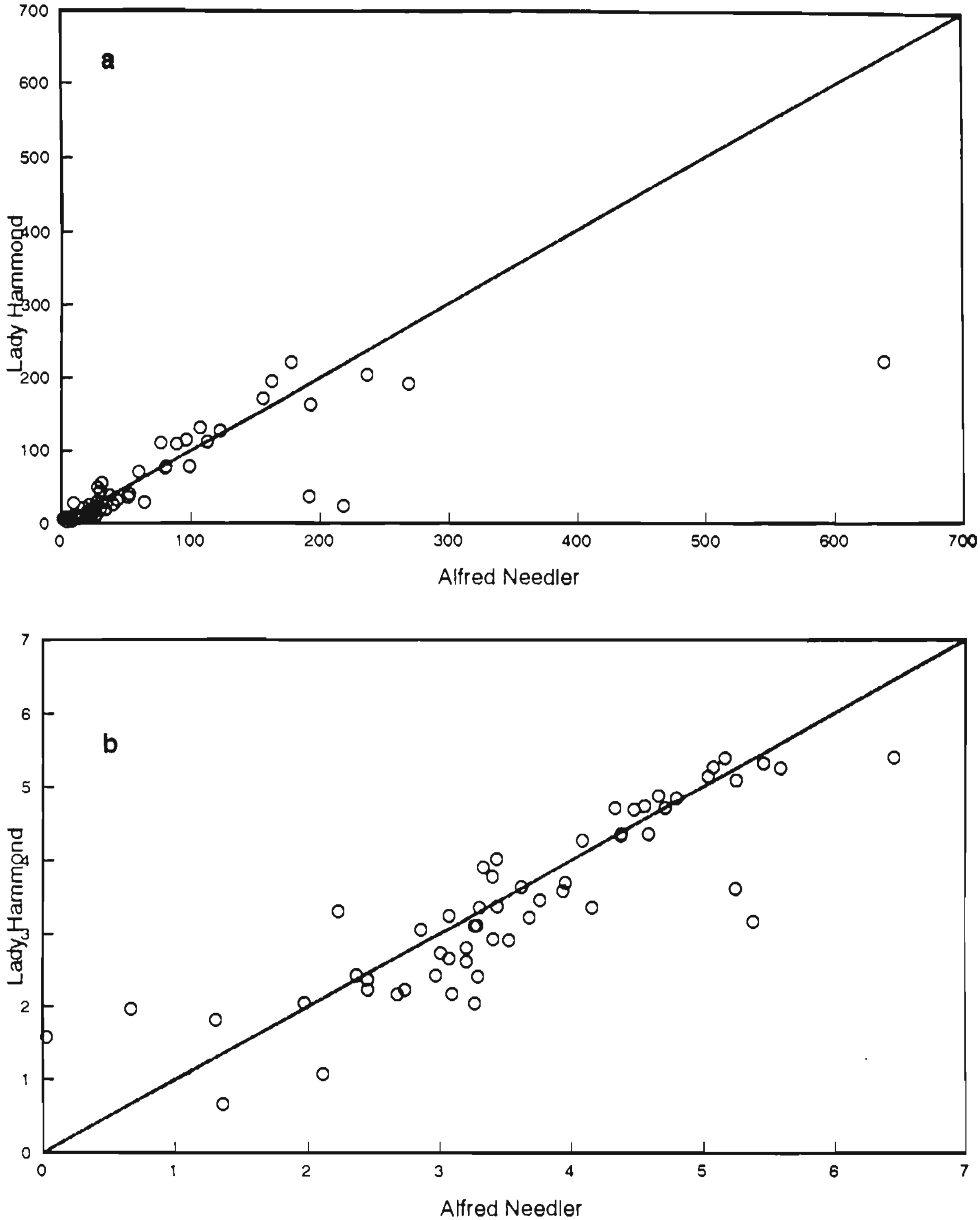


Figure 21. Cod catches in the 1992 comparative survey
a) numbers caught in the arithmetic scale
b) log-transformed numbers caught

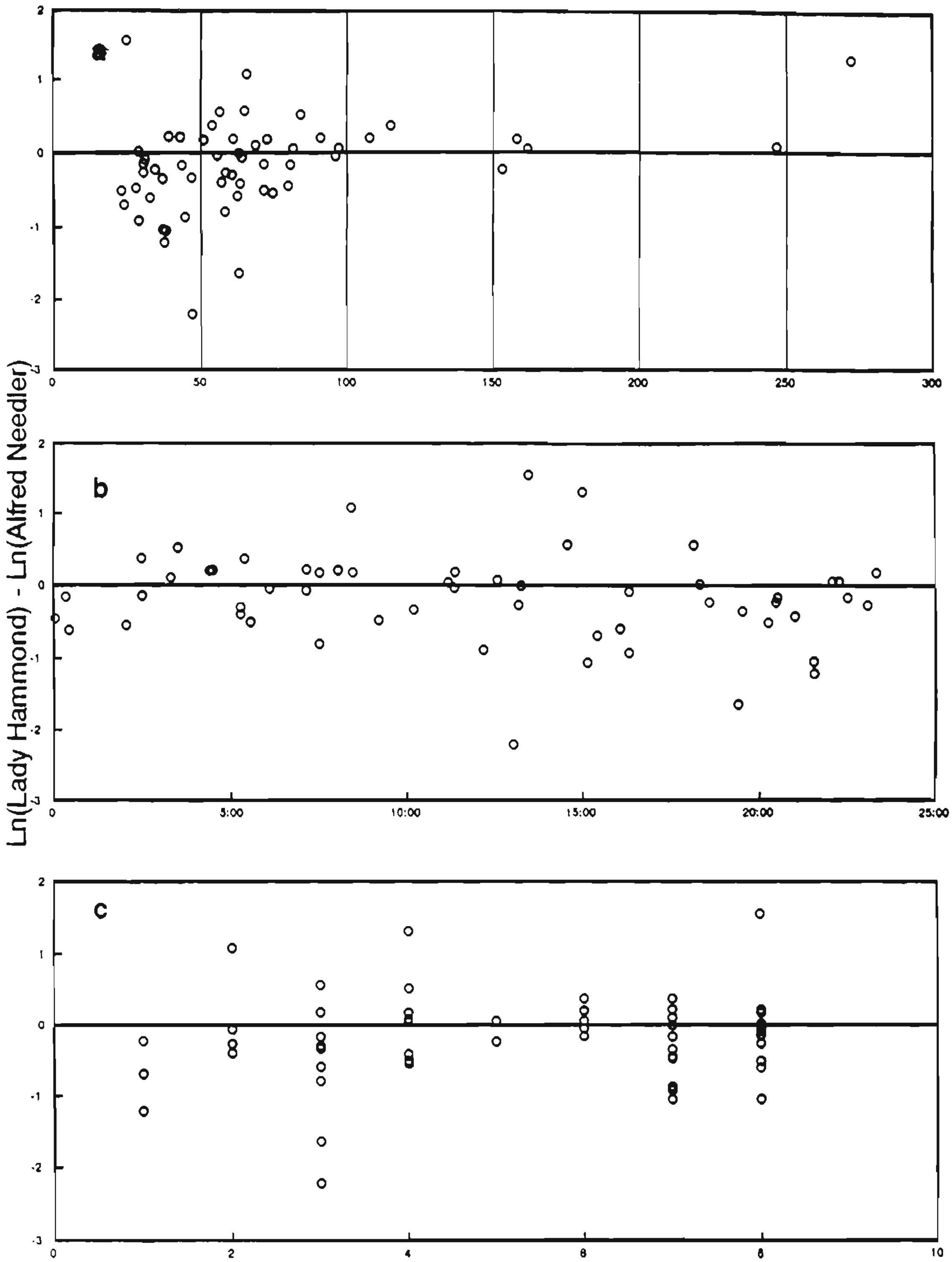


Figure 22. Difference in log-transformed cod catches in the 1992 survey
a) versus depth of tow
b) versus time of day
c) versus day

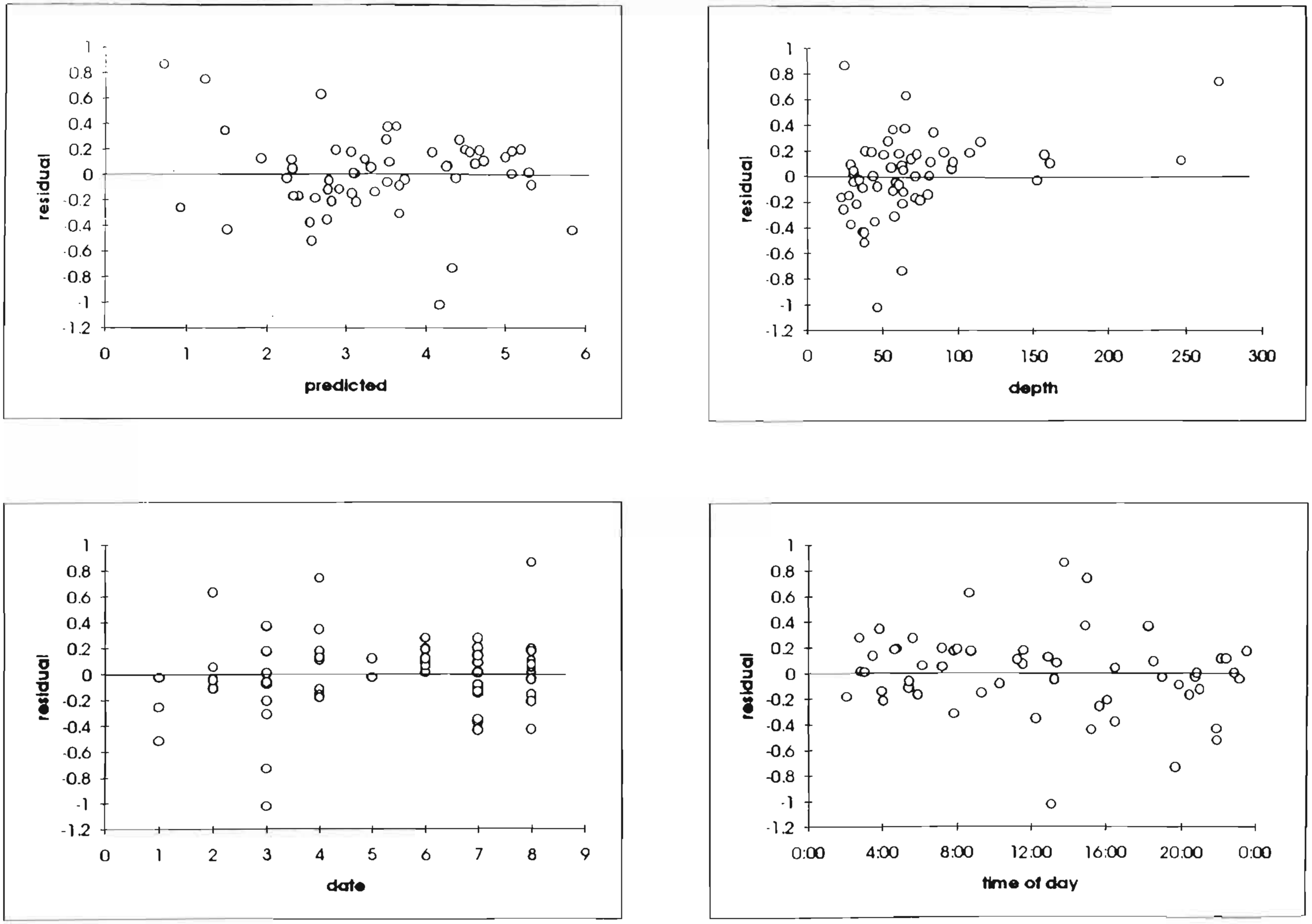


Figure 23. Plot of Lady Hammond residuals from the GLM testing for vessel effect in the 1992 paired cod catches The Alfred Needler residuals mirror the Lady Hammond residuals around the zero line

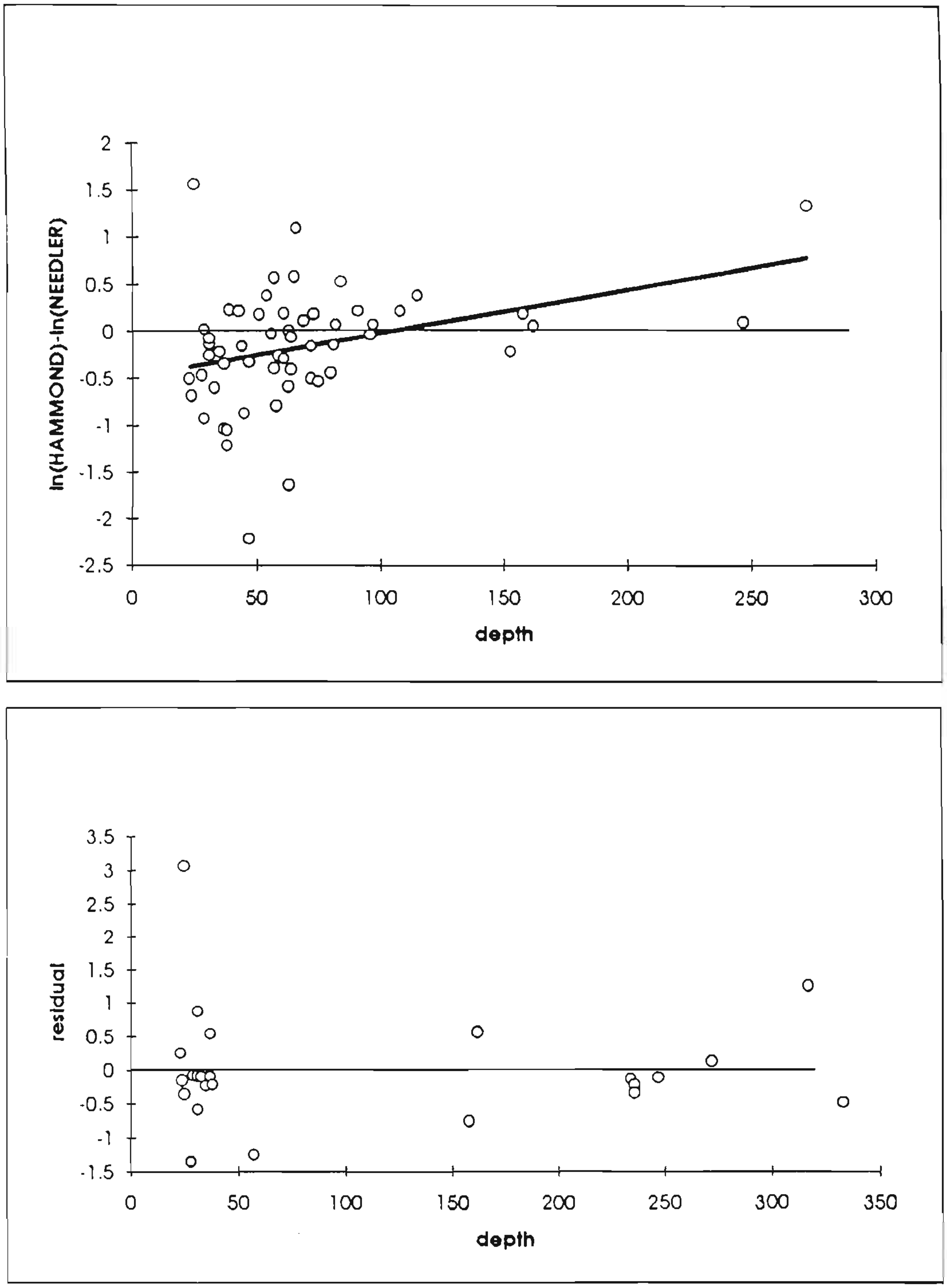


Figure 24. Regression line and residual plot of the GLM testing for depth effect in the 1992 paired cod catches

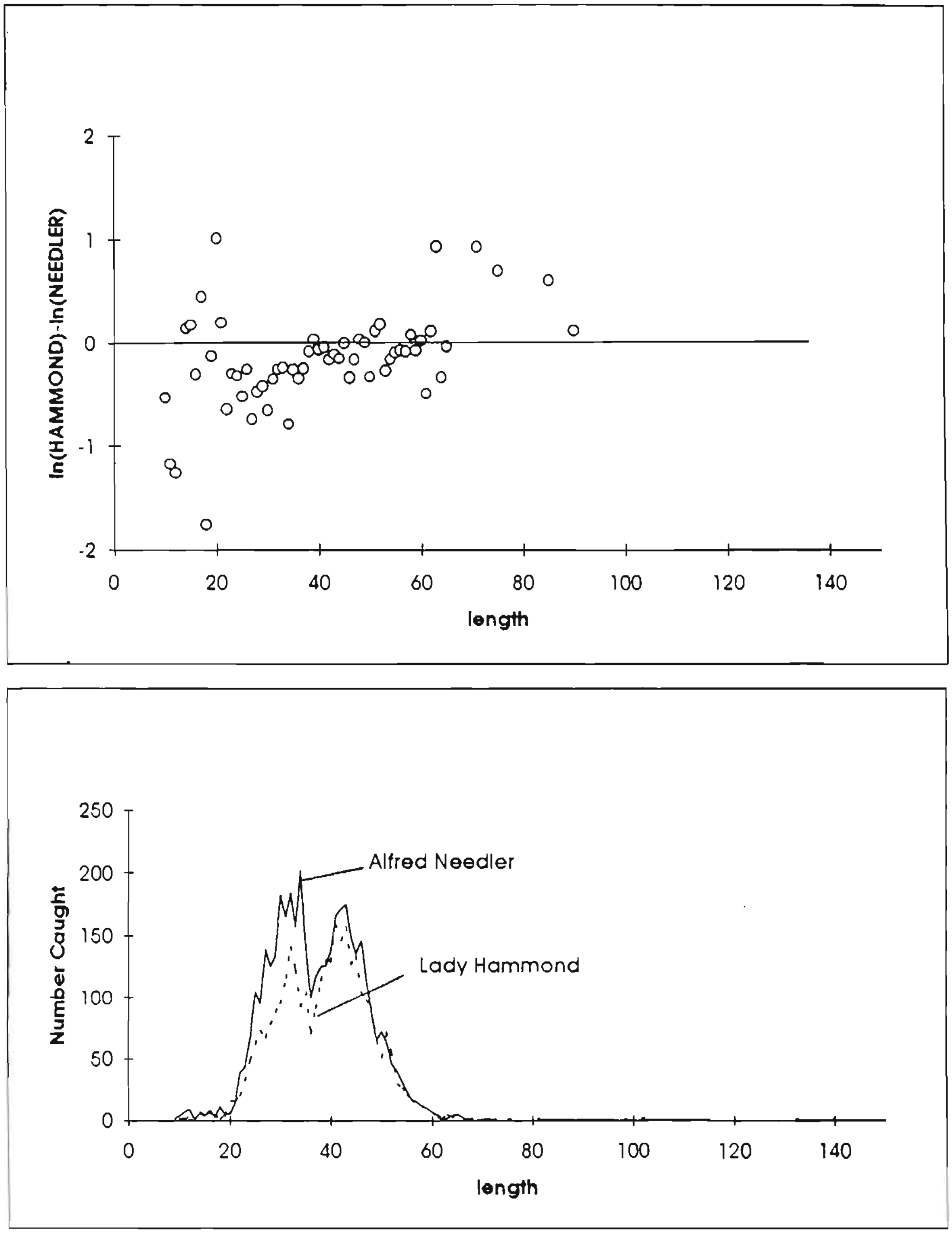


Figure 25. Comparison of cod catches at length in the 1992 experiment
a) difference in log-transformed catch at length
b) length frequencies of cod caught

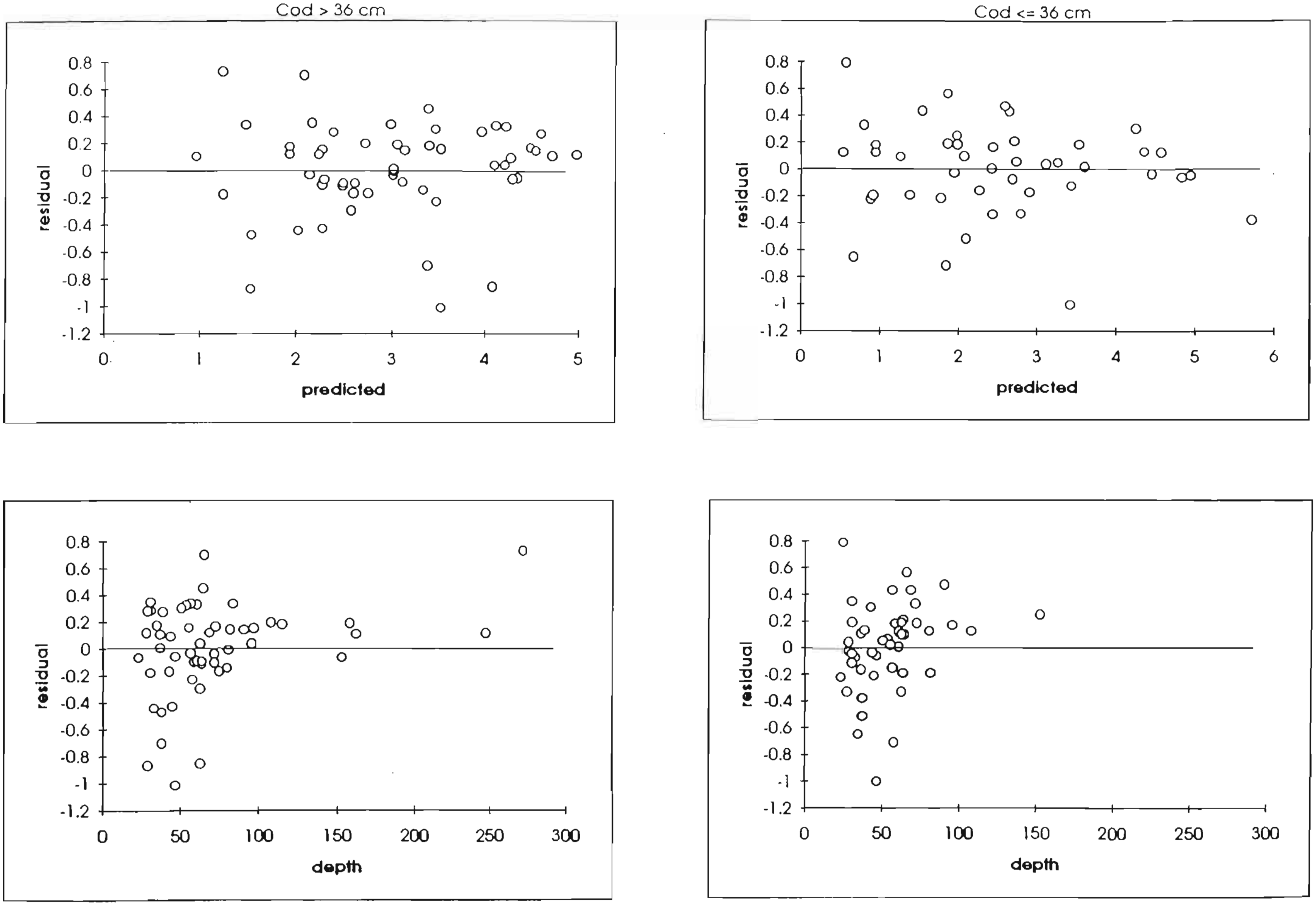
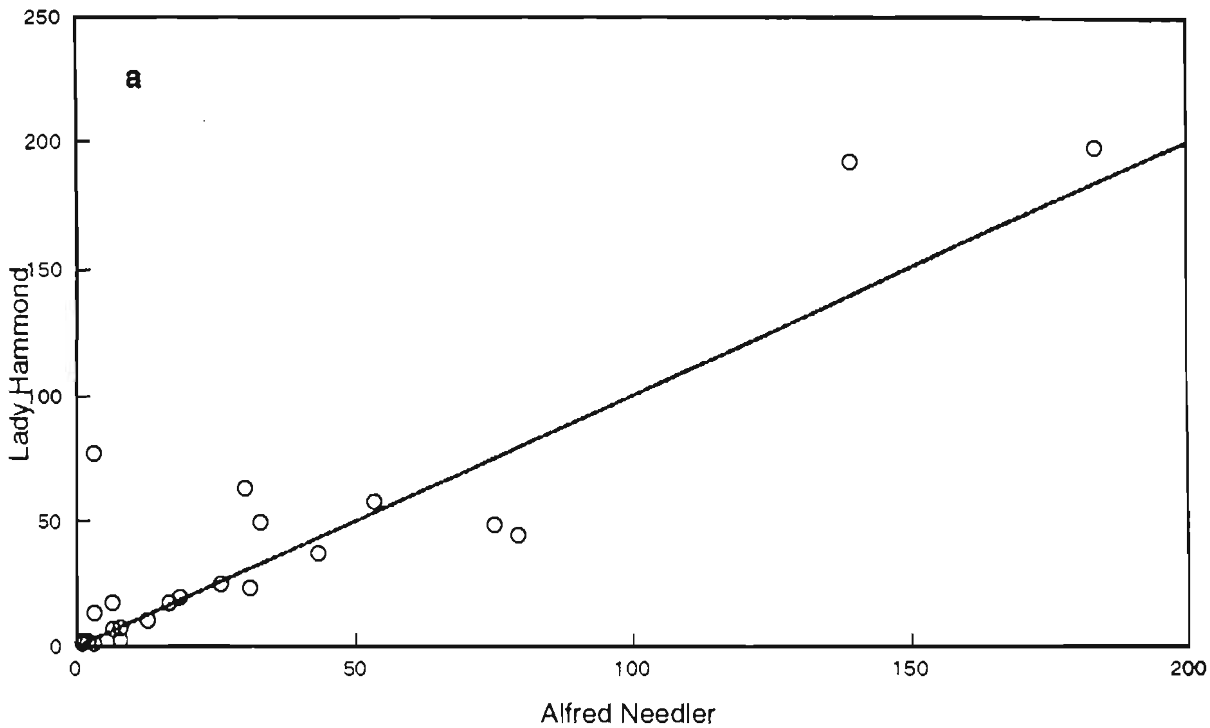


Figure 26. Lady Hammond residuals from the GLM testing for vessel effect within size classes. Alfred Needler residuals mirror the Lady Hammond residuals around the zero line.



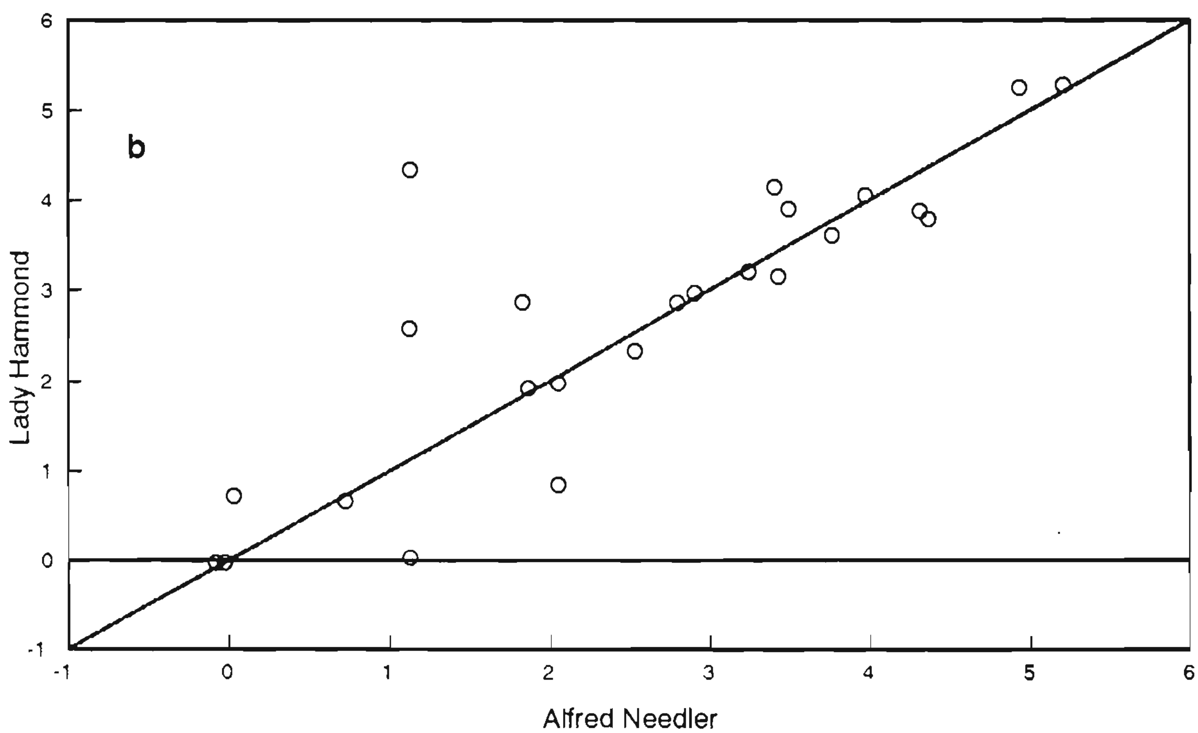


Table 27. White hake catches in the 1992 comparative survey
a) numbers caught in the arithmetic scale
b) log-transformed numbers caught

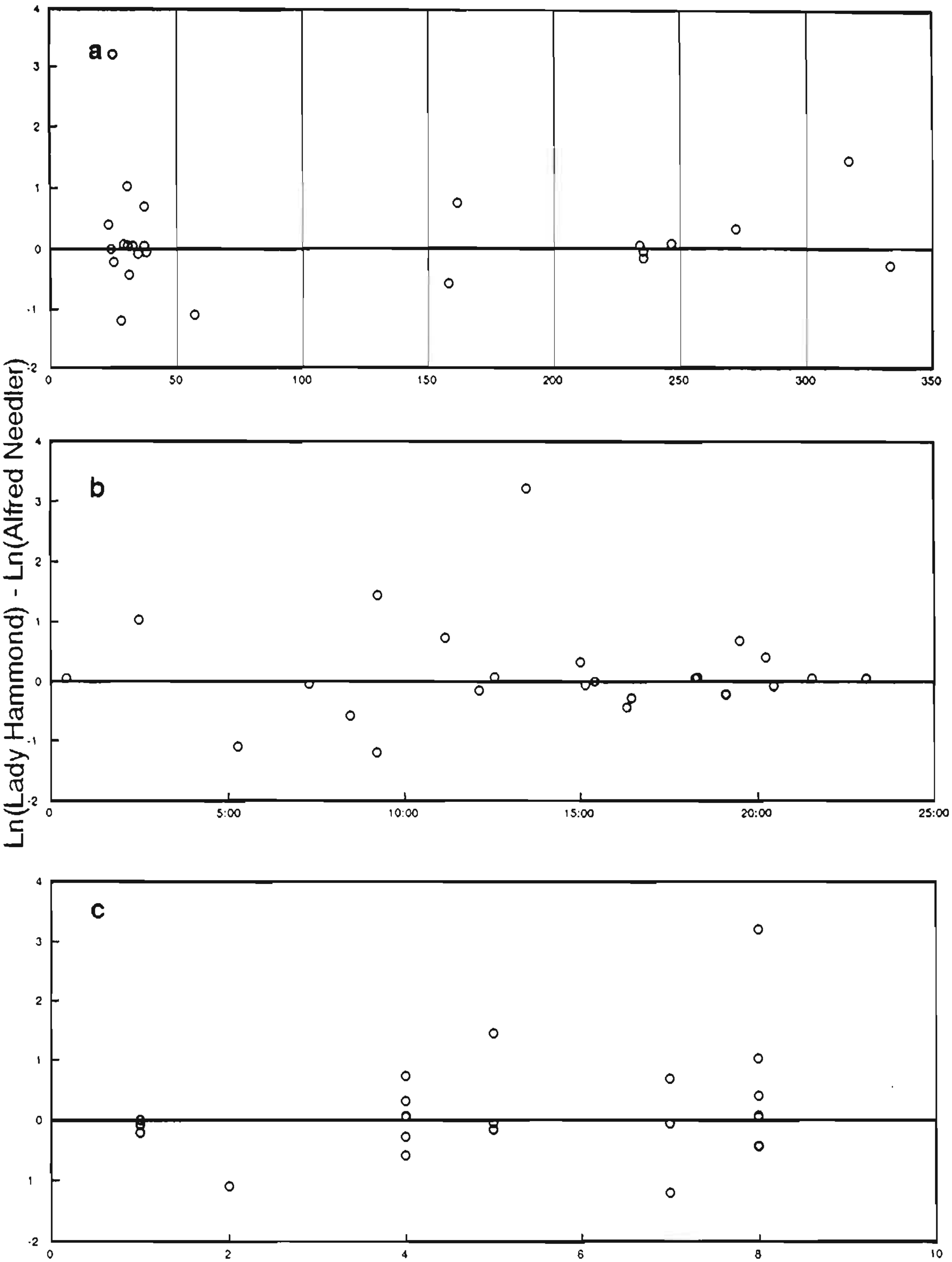


Figure 28. Difference in log-transformed white hake catches in the 1992 survey
a) versus depth of tow
b) versus time of day
c) versus day

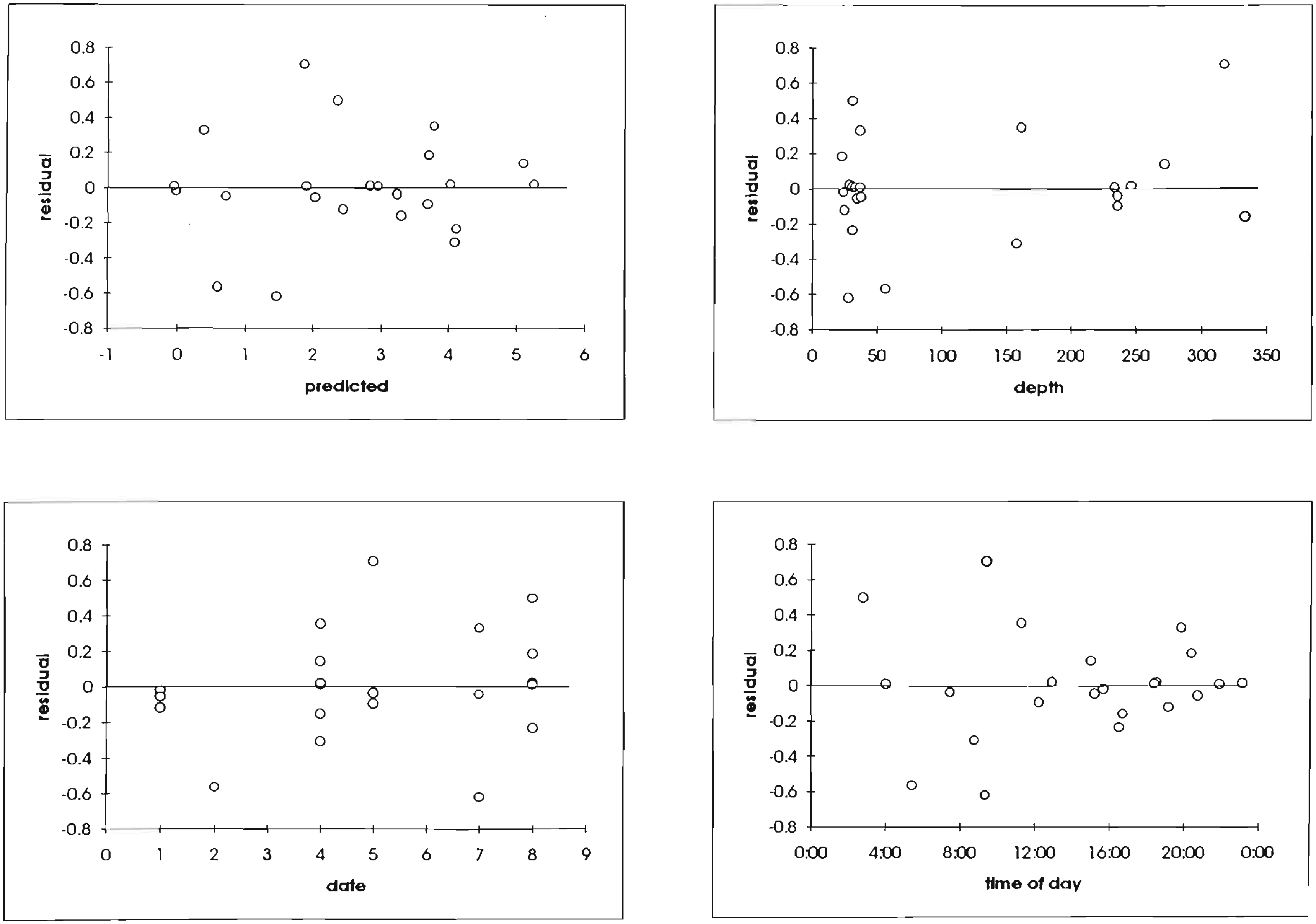


Figure 29. Plot of Lady Hammond residuals from the GLM testing for vessel effect in the 1992 paired hake catches
The Alfred Needler residuals mirror the Lady Hammond residuals around the zero line

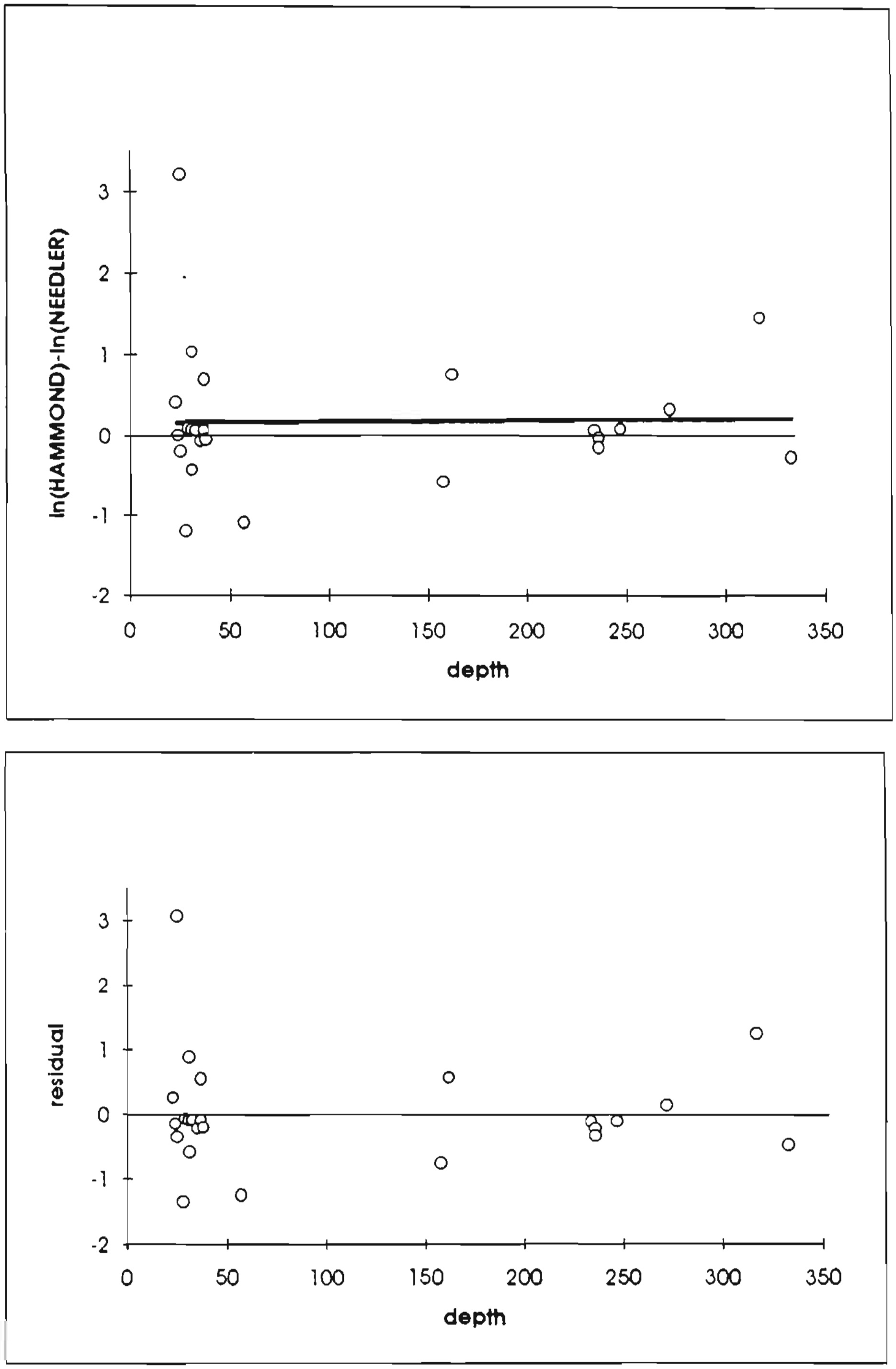
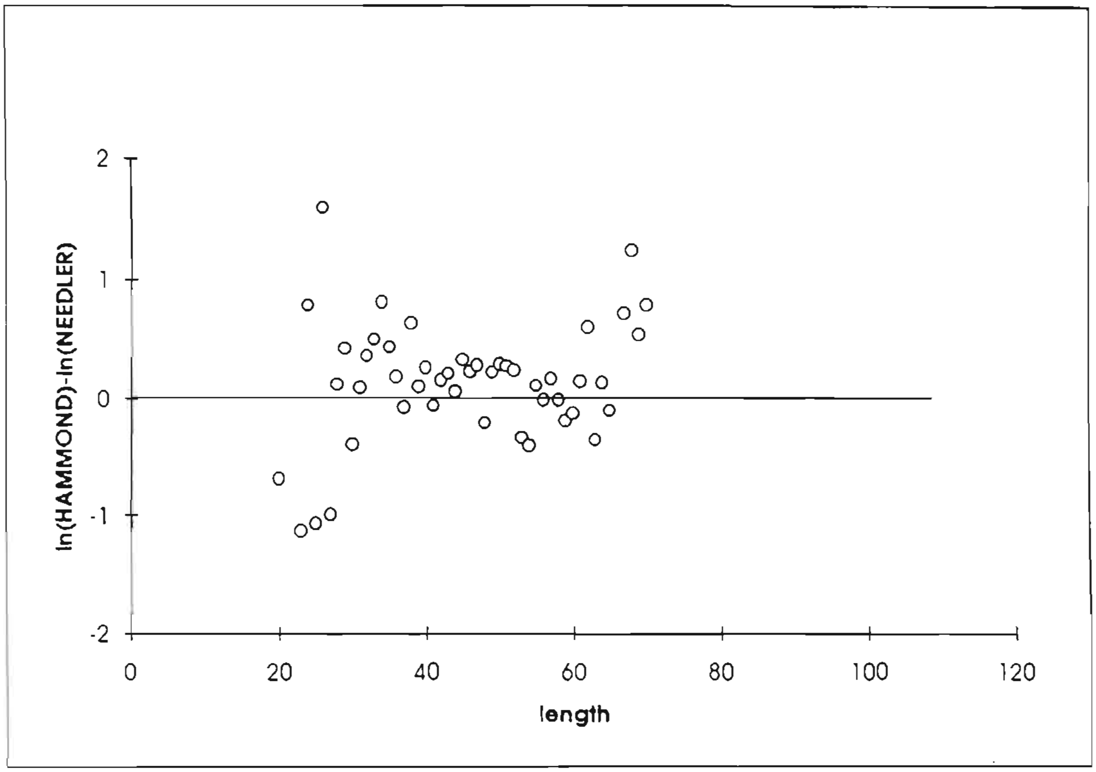


Figure 30. Regression line and residual plot of the GLM testing for depth effect in the 1992 paired white hake catches



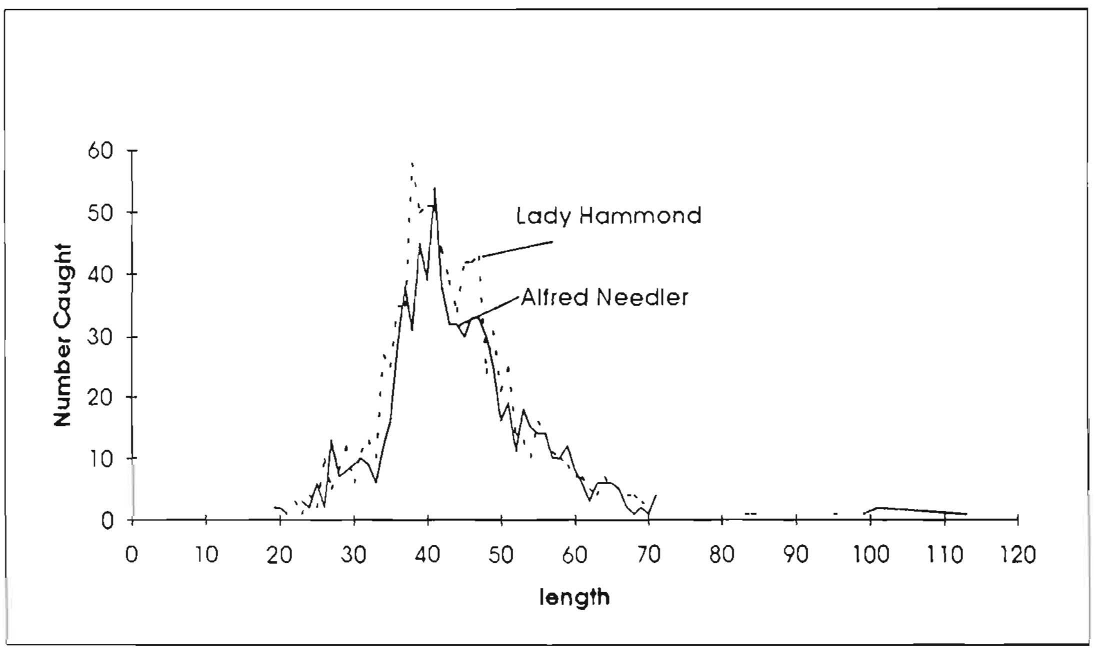
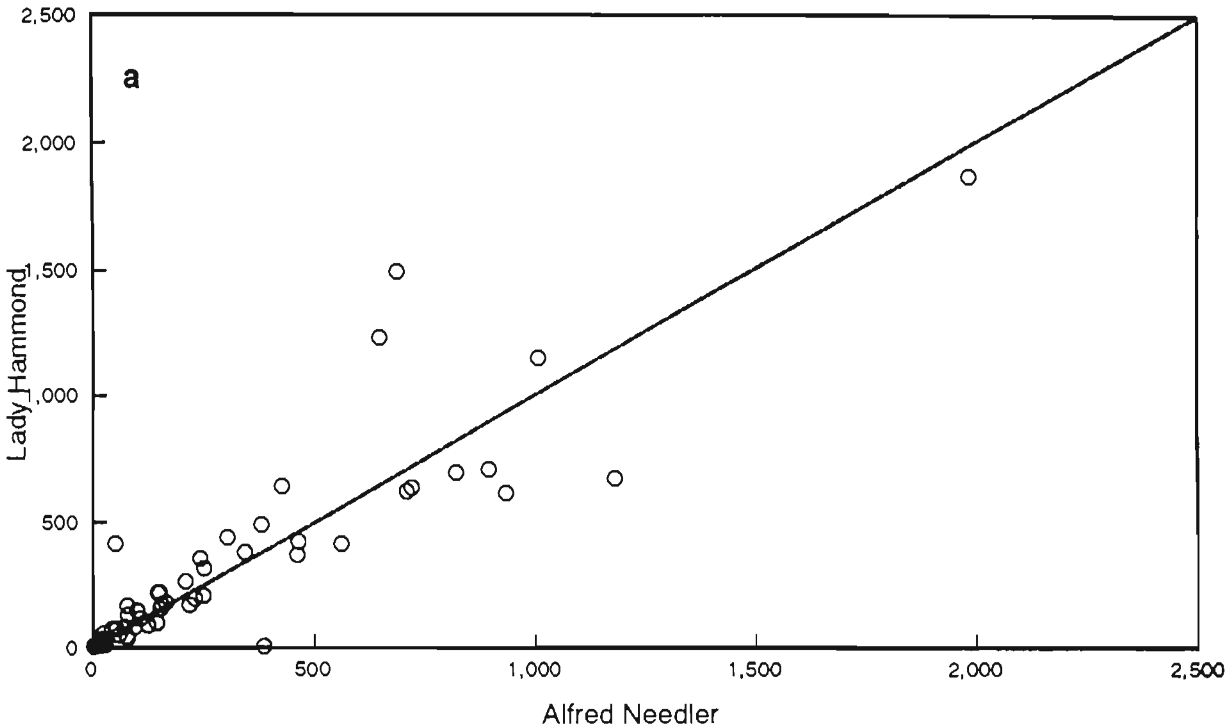


Figure 31. Comparison of white hake catches at length in the 1992 experiment
a) difference in log-transformed catch at length
b) length frequencies of white hake caught



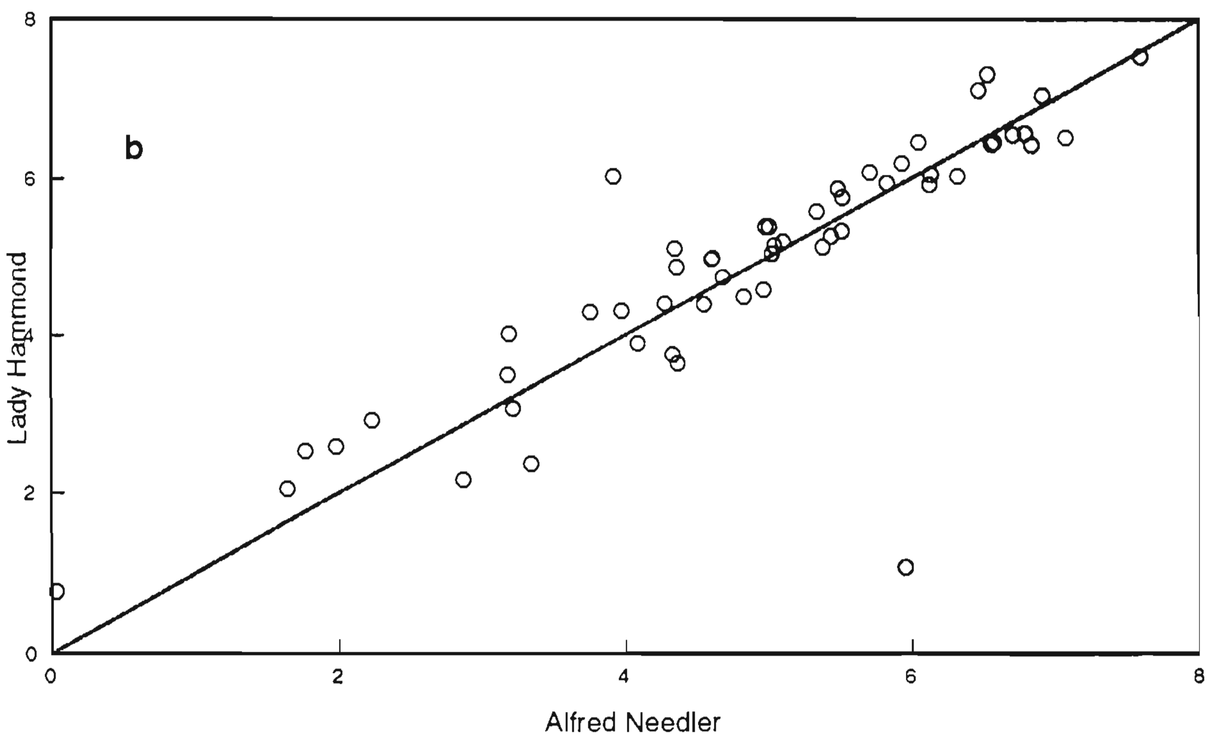


Table 32. American plaice catches in the 1992 comparative survey
a) numbers caught in the arithmetic scale
b) log-transformed numbers caught

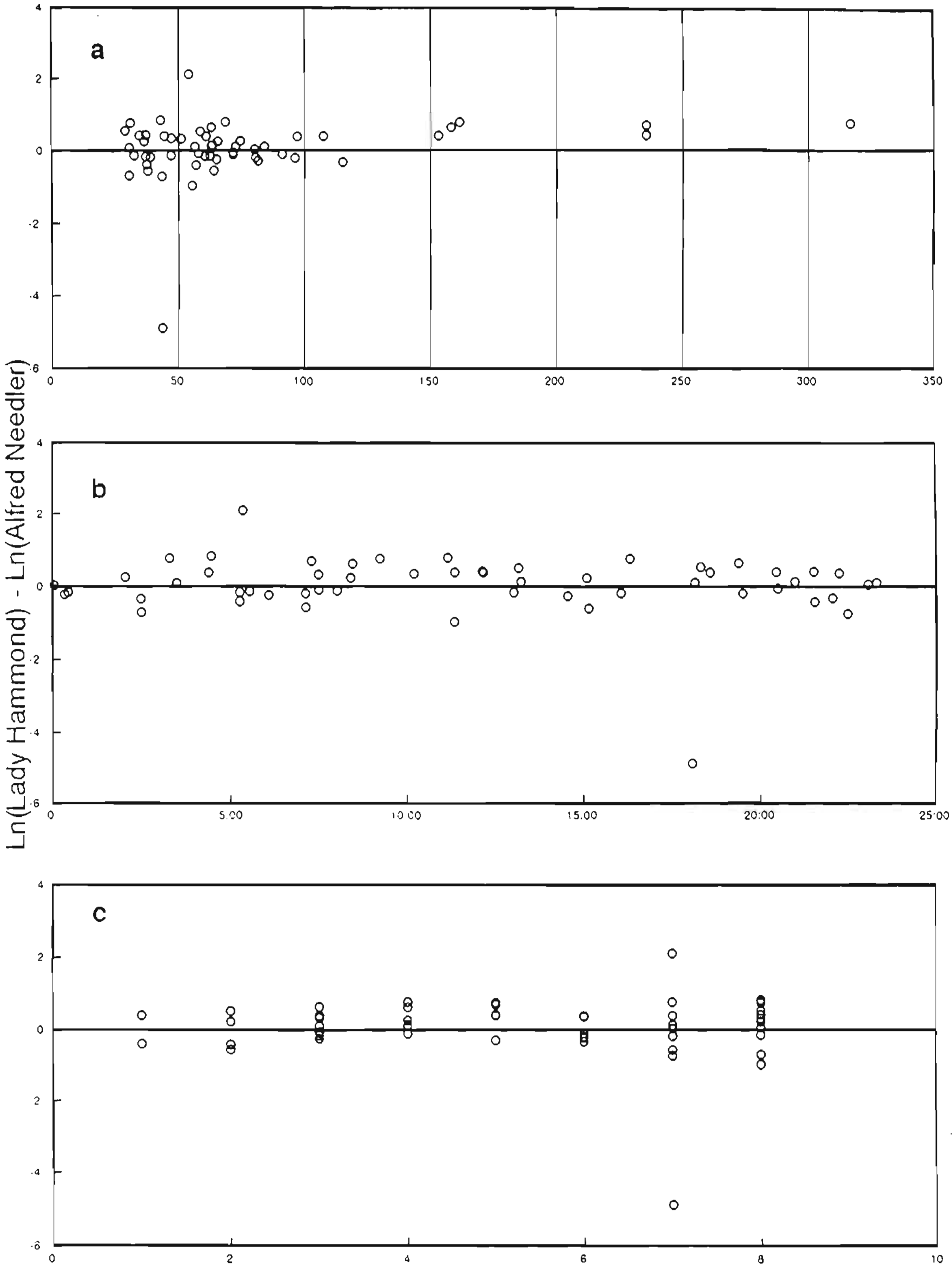


Figure 33. Difference in log-transformed plaice catches in the 1992 survey
a) versus depth of tow
b) versus time of day
c) versus day

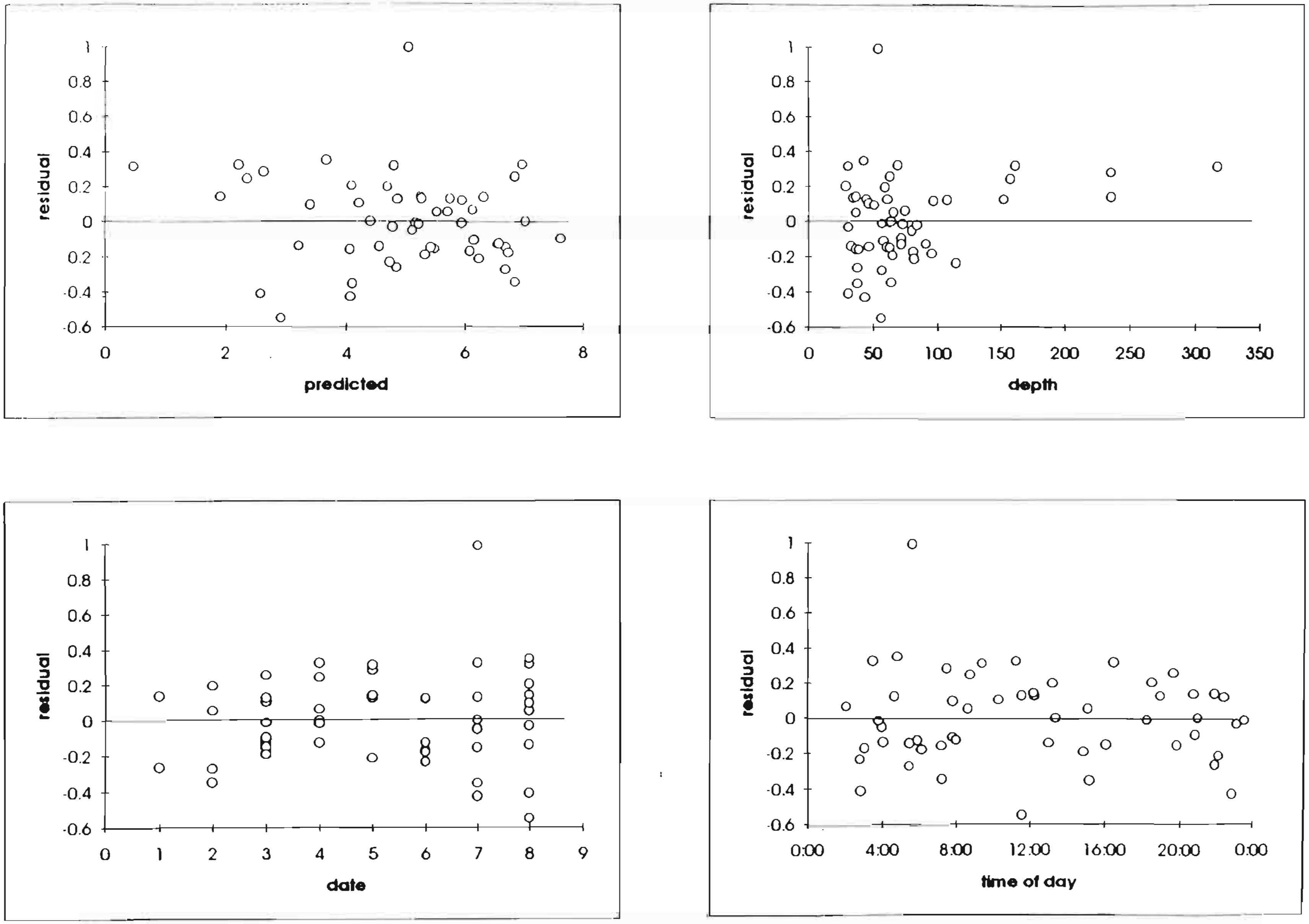


Figure 34. Plot of Lady Hammond residuals from the GLM testing for vessel effect in the 1992 paired plaice catches The Alfred Needler residuals mirror the Lady Hammond residuals around the zero line

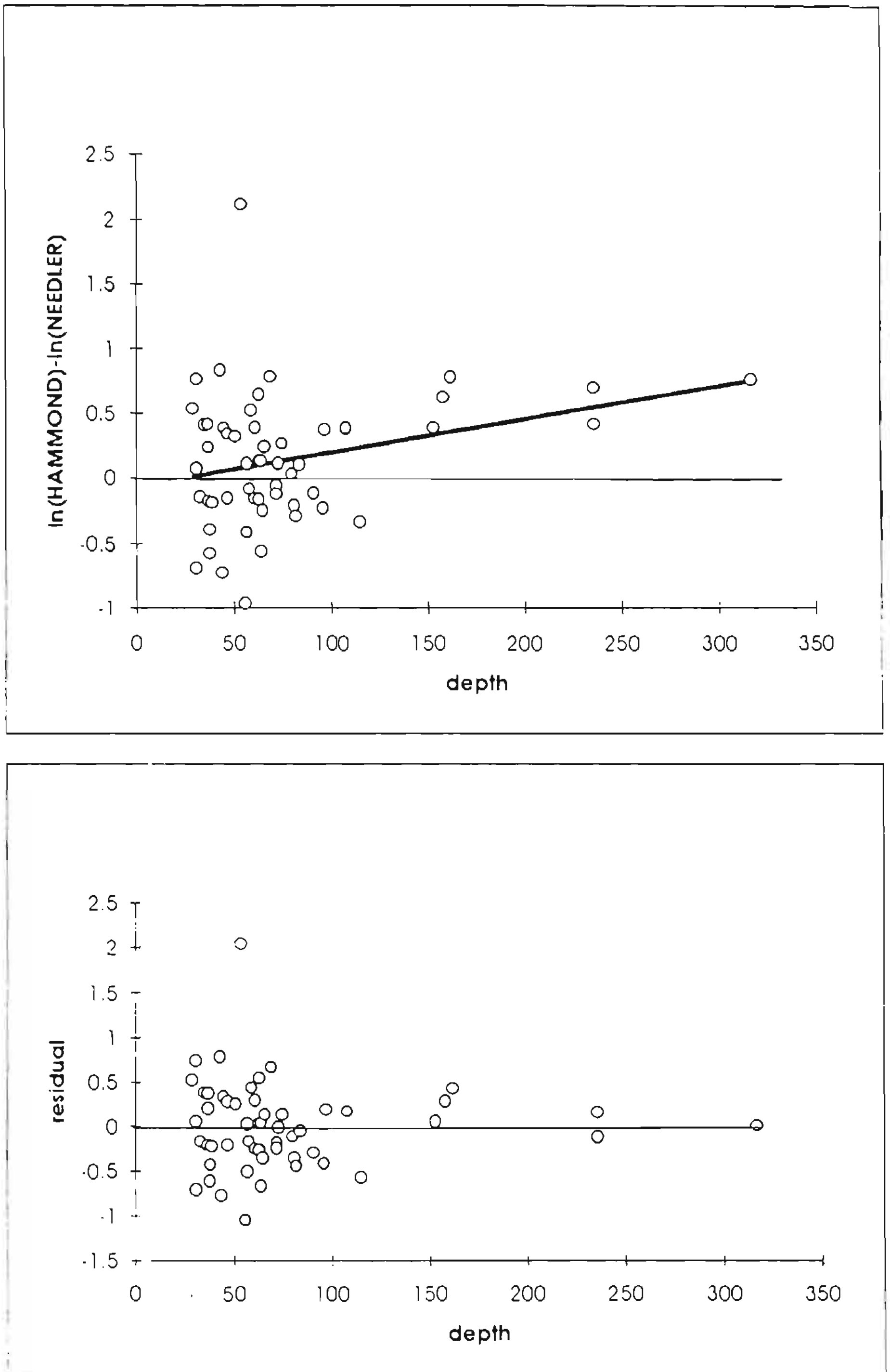
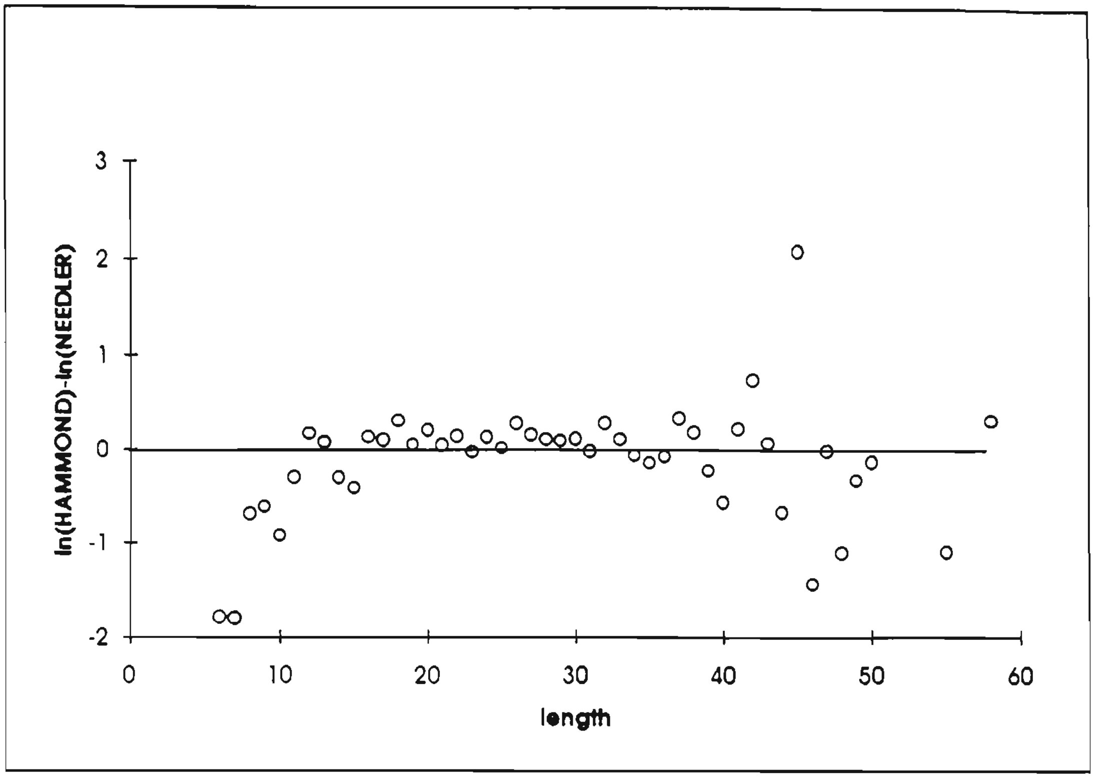


Figure 35 Regression line and residual plot of the GLM testing for depth effect in the 1992 paired American plaice catches



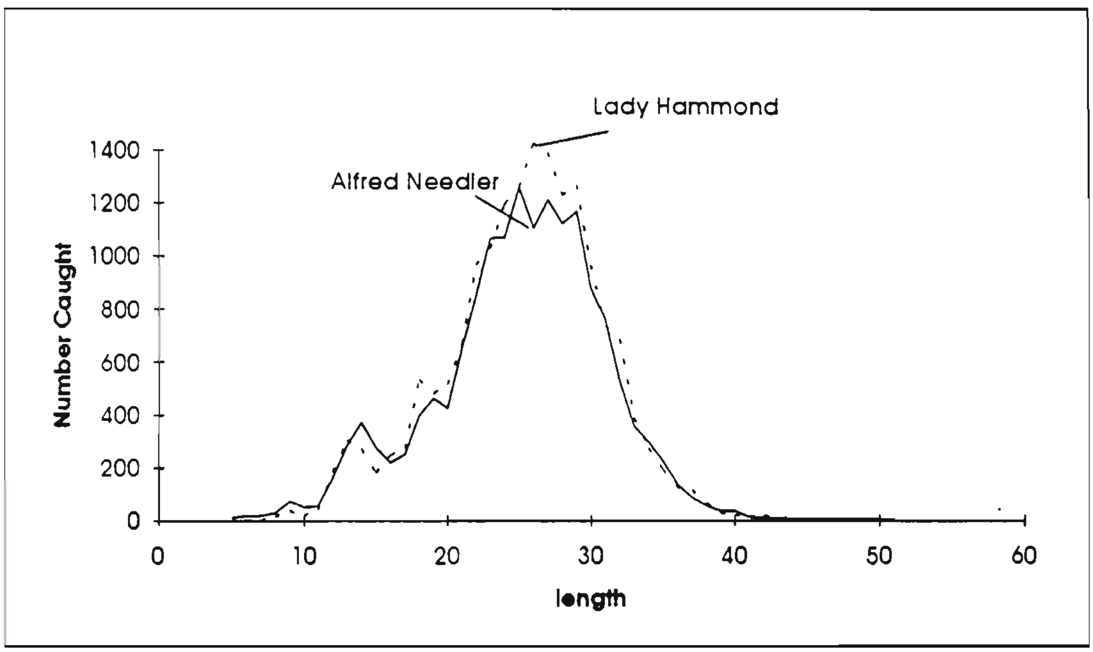


Figure 36. Comparison of plaice catches at length in the 1992 experiment
a) difference in log-transformed catch at length
b) length frequencies of American plaice caught