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Adjustment for diurnal variation in the catchability of witch flounder (*Glyptocaphalus cynoglossus* L.) to bottom-trawl surveys in the Gulf of St. Lawrence

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Abstract

Fishing efficiency for witch flounder during bottom-trawl surveys of the Gulf of St. Lawrence is higher at night than in day (0700≤time<1900) during August and September surveys but not during January surveys. During the August and September surveys the probability of catching witch was significantly greater at night than in day for all vessel and gear combinations, with the night probability averaging 1.4-1.5 times the day probability in most cases. The difference in average catch rates between night and day was also highly significant in all cases. Night catches by the *Lady Hammond* using a Western IIA trawl averaged 2.1 times day catches. Night catches by the *Alfred Needler* averaged about 3.2 times day catches using a Western IIA trawl and 1.6 times day catches using a URI trawl. Patterns in relative abundance were generally similar between unadjusted catch rate series and those adjusted to night catchability. However, the details of these patterns differed between the two series, particularly in the September series between the 1970s when fishing was mostly between 0700 and 1900 and the late 1980s and the 1990s when fishing was conducted 24-h per day.

Résumé

L'efficacité de capture de la plie grise au moment des relevés au chalut de fond réalisés dans le golfe du Saint-Laurent a été supérieure la nuit comparativement au jour (07h00 - 19h00) pendant les relevés d'août et de septembre, mais non pendant les relevés de janvier. En août et septembre, la probabilité de capturer des plies grises était significativement plus élevée la nuit que le jour pour toutes les combinaisons de bateaux et d'engins, la probabilité de capture de nuit étant en moyenne de 1,4 à 1,5 fois supérieure à celle de jour, la plupart du temps. L'écart entre les taux de capture moyens obtenus le jour ou la nuit était aussi fortement significatif dans tous les cas. Les captures de nuit réalisées par le *Lady Hammond* utilisant un chalut Western IIA s'élevaient en moyenne à 2,1 fois celles réalisées le jour. Les captures réalisées la nuit par le *Alfred Needler* s'élevaient en moyenne à 3,2 fois celles réalisées le jour, avec un chalut Western IIA et à 1,6 fois, avec un chalut URI. Les allures d'abondance relative des séries de taux de capture non corrigées et des séries corrigées pour le taux de capture de nuit étaient généralement semblables. Le détail des allures différait cependant entre les deux séries, notamment pour les séries de septembre entre les années 1970, où la pêche était surtout effectuée entre 07h00 et 19h00 et la fin des années 1980 et les années 1990 où elle était pratiquée 24 heures par jour.

Introduction

Three annual bottom-trawl surveys provide information on the abundance of witch flounder in the Gulf of St. Lawrence (NAFO divisions 4RST): a survey of the southern Gulf conducted each September since 1971, a survey of the northern Gulf conducted each August since 1984, and a January survey conducted in the northern Gulf from 1978 to 1994 (except 1982). For each particular survey, a goal has been to use the same standard fishing procedures each year, so that results will be comparable among years. When a change in vessel or gear has occurred, comparative fishing experiments have been conducted to determine relative fishing efficiencies of the different vessels or gears (e.g., Swain et al. 1998*a*).

A substantial change has occurred in the diurnal pattern of fishing in the southern Gulf survey. Fishing was conducted only in daytime (approx. 0700-1900 h) prior to 1985 and throughout the 24-h day since then. Even since 1985, the proportion of sets conducted during nighttime has varied widely among years for the strata where witch flounder are likely to be caught (Table 1). Thus, it may be important to correct annual abundance indices for diurnal variation in the catchability of witch flounder.

The purpose of this report is to test for diurnal variation in the catchability of witch flounder and to estimate correction factors to adjust witch catches for this diurnal variability. First, a comparative day/night fishing experiment conducted during the 1988 September survey is analyzed. Second, we examine diurnal variation in catch rates of witch flounder in each survey time series to test for differences between vessels, gears and seasons in the day/night effect on witch catchability. Finally, we compare survey abundance indices that have been adjusted for diurnal variation in catchability with the unadjusted indices.

Methods

1988 Comparative Fishing Experiment

During the 1988 September survey 67 paired tows were made to test for differences between day and night in groundfish catchability. Fishing was by the research vessel *Lady Hammond* using a Western IIA otter trawl with a19-mm liner (see Hurlbut and Clay (1989) for details of the gear and survey procedures). For each pair of tows at the same location, one was conducted during day and the other at night, usually within the same 24-h period. Tows beginning between 0700 (inclusive) and 1900 (exclusive) were defined as day tows, based on the distribution of tow starting times during the 1971-1984 surveys. The target fishing procedure was a 30-min tow at 3.5 knots. All catches were adjusted to a standard tow distance of 1.75 nautical miles. Separate analyses were conducted for the total number of witch caught per tow and for witch greater than or equal to 24 cm in length. The latter analyses were conducted because abundance indices combining the August and September surveys are restricted to this size class (Swain et al. 1998*a*).

We used three different approaches for analysis of the 1988 data. First, we used the approach commonly employed for comparative fishing experiments (e.g., Gavaris and Brodie 1984). In this approach, only the paired tows where both caught the target species are used, and catches are log transformed in an attempt to reduce skewness and stabilize the variance. A coefficient for the relative fishing power between night and day was estimated using a linear model with terms for set and time of day, i.e.

(1) $U_{ij} = \log_e Y_{ij}$
(2) $E[U_{ij}] = \mu_{ij} = \beta 0 + \beta 1_i + \beta 2_j$

where Y_{ij} is the catch in tow *i* at time of day *j* (*j*=1 denotes a day tow; $\beta 1_1$ and $\beta 2_1$ were set to 0) and the random components of the U_{ij} have independent Normal distributions with expected values μ_{ij} and constant variance σ^2. On the $\log_e$ scale, expected night efficiency relative to day efficiency ($U_{i2} - U_{i1}$) is given by $\beta 2_2$ (since $\beta 2_1$ is set to 0). This coefficient was back-transformed from the log scale with bias correction based on equation 3.3 in Bradu and Mundlak (1970).

This first approach assumes that the probability of catching witch does not differ between day and night. If this probability does differ, then pairs of tows where witch were caught at one time but not at the other also need to be included in the analysis. We conducted a second analysis including pairs where witch were caught at one time of day but not at the other. Inclusion of zero catches is a problem for log transormation. We added 1 to all catches to permit log transformation. Addition of this constant will tend to reduce the estimated correction factor.

We conducted a third analysis using a generalized linear model (McCullagh and Nelder 1989) that did not require assumptions of constant variance and appoximate normality of errors. We assumed a Poisson error distribution, because this distribution is often appropriate for counts data, including counts of organisms in sampling units (Pielou 1977). For the Poisson distribution, the natural link between the response variable and its predictors is the log. A log link has the advantage of ensuring positive predicted values and although this link does not permit predicted values of zero, predicted values may be infinitesimal and thus effectively zero. Our model was of the form:

(3) $E[Y_{ij}] = \mu_{ij} = \exp(\beta 0 + \beta 1_i + \beta 2_j)$

where Y_{ij} is the catch in tow i at time of day j ($\beta 1_1$ and $\beta 2_1$ were set to 0) and the random components of the Y_{ij} have independent Poisson distributions with expected values μ_{ij} and variance $\phi\mu_{ij}$. ϕ is a parameter for extra-Poisson variation. Extra-Poisson variation ($\phi>1$) was expected because organisms typically show a contagious rather than a random spatial pattern (e.g., Pielou 1977). The scale parameter ϕ was estimated using Pearson's χ^2-statistic (see McCullagh and Nelder 1989 for details). Significance of the day/night effect was assessed using analysis of deviance and the F test described by Venables and Ripley (1994, p. 187). $\beta 2_1$ was set to 0 ($\exp(\beta 2_1)=1$) in the parameter estimation, so $\exp(\beta 2_2)$ gives an estimate of night fishing power relative to day fishing power.

These approaches will give different estimates of the difference in fishing power between day and night. A good conversion factor would be one that gave the same mean catch rate in a survey fished during the day and in the same survey (i.e., the same sites visited at approximately the same times) fished at night. The comparative fishing experiment provides such a pair of identical surveys, one fished in day and the other at night. We compared the conversion factors estimated using the above models to that required to convert the mean day catch in the 1988 experiment to the mean night catch in this experiment (*B* in Table 2).

Analyses of the survey time series

Data were initially explored using generalized additive models, calculated using S-Plus (StatSci, 1995). We modelled the relationship between witch flounder catch rates and time of day using the local regression smoother LOESS. This function fits a curve to the data points locally, so that the curve at any point depends only on the observations in the neighborhood of that point. The model was fit over two duplicates of the data; in one duplicate, times from 12.0 to 24.0 h were recoded as -12.0 to 0.0, and those from 0.0 to 11.99 were recoded as 24.0 to 35.99. We used a neighborhood of 20% of the (duplicated) data, and fitted locally-weighted quadratic polynomials assuming an underlying Poisson distribution with overdispersion.

To test effects of time of day, the survey time series were analysed using generalized linear models with terms for year, stratum and time of day. Time of day was included as a factor with two levels (day: $0700 \leq \text{time} < 1900$):

(4) $E[Y_{ijk}] = \mu_{ijk} = \exp(\beta 0 + \beta 1_i + \beta 2_j + \beta 3_k)$

where Y_{ijk} is the catch in stratum i at time of day j in year k ($\beta 1_1$, $\beta 2_1$ and $\beta 3_1$ were set to 0) and the random components of the Y_{ijk} have independent Poisson distributions with expected values μ_{ijk} and variance $\phi\mu_{ijk}$. A year×stratum interaction term was also included in models for the September series, but not for the August series because of many empty year×stratum cells in the latter series. The September series was analysed in two parts: 1985-1991, when the *Lady Hammond* and a Western IIA trawl were used, and 1992-

1997, when the *Alfred Needler* and a Western IIA trawl were used. Two periods were also analysed separately for the August series: 1984-1989, when the *Lady Hammond* and a Western IIA trawl were used, and 1990-1997, when the *Alfred Needler* and a URI trawl were used. Logistic models (binomial error and a logit link, $\phi=1$) with the data recoded as 0 (no catch) and 1 (catch) were used to test for differences between day and night in the probability of catching witch. The Poisson models (Poisson error and a log link, with ϕ estimated from the Pearson residuals) were used to estimate relative fishing power between day and night.

An exceptionally large catch of witch flounder in the 1986 August survey (set 144) was omitted from all analyses (see Swain et al. 1998*b* for further details). This set was a night set. Its omission did not have a substantial effect on the estimates of relative fishing efficiency between day and night.

Comparison of adjusted and unadjusted abundance indices

Stratified mean numbers per tow and their SE were calculated using the usual formulae for stratified random designs. All catches were adjusted to a standard tow of 1.75 nautical miles (even the 1990-1997 August surveys when the target tow distance varied between 0.83 and 1.20 nautical miles). In the September series, strata were not sampled in four cases: strata 424 and 428 in 1978, and stratum 421 in 1983 and 1988. Strata were sampled only once in six cases: strata 421 and 431 in 1976, stratum 428 in 1977, stratum 435 in 1982 and strata 427 and 428 in 1984. Witch flounder are very rarely caught in these strata, particularly strata 421, 428, 431 and 435. We replaced these missing values with the average values for these strata over the 27-yr time series for the 4 (out of 648) cases where strata were not sampled to calculate the stratified mean and and for the 10 cases where sample size in a stratum was 1 or less to calculate the SE of the mean. Missing values were more frequent in the August survey and occurred in strata where witch catches were frequently high. More complicated procedures are required to replace these missing values, and these are deferred to the final calculation of abundance indices in Swain et al. (1998*b*). For this analysis, stratum weights were adjusted to be a proportion of the area sampled in each particular August survey. This is equivalent to replacing missing values with the average value for the year in question.

Results and Discussion

1988 Comparative Fishing

Out of the 67 paired tows in the 1988 experiment, witch flounder were caught in both the day and night tows in 20 cases, in only the night tow in 11 cases, and in only the day tow in 2 cases. Thus, in this sample of 67 paired tows, the probability of catching witch was 0.463 in a night tow and 0.328 in a day tow. This suggests that the probability of catching witch at night is about 1.4 times the probability of catching witch during the day.

The size of witch catches also tended to be greater during the night than during the day (Fig. 1). This difference was significant in all tests (Table 2: $P<0.025$ in tests using the lognormal model, and $P<0.005$ using the Poisson model). No trend in the difference between night and day catches was evident with fish length (Fig. 2), so fishing efficiency at night relative to day was estimated for all lengths combined. Residuals from both the lognormal and Poisson models did not indicate any serious departures from the model assumptions, though the residual distribution was somewhat long-tailed in both cases and quite leptokurtic in the case of the lognormal model (Fig. 3). Estimates of the day/night effect were slightly greater using the Poisson model than using the lognormal model (Table 2). The lognormal model appeared to underestimate the effect. In all cases, the estimated night efficiency relative to day efficiency (b in Table 2) was equal to the factor required to convert the mean day catch to the mean night catch (B in Table 2) using the Poisson model, but less than this factor using the lognormal model. Including only those tows where witch were caught in both day and night appeared to underestimate the day/night effect by about 15%. Estimates were not affected by the number of double zero catches included in the analysis using the Poisson model but were strongly affected by this number using the lognormal model (using the Poisson model the estimate of night efficiency relative to day efficiency was 2.24 either using the 33 paired tows with witch caught in at least one tow or using all 67 tows, whereas this estimate was 1.91 in the former case and only 1.38 in the latter case using the lognormal model). From this analysis, the best estimate of night efficiency relative to day efficiency is 2.24, obtained from the analysis using the Poisson model and including all pairs of tows where witch were caught in either tow.

Results were similar restricting the analysis to witch 24 cm or longer in length (not shown here). In this case, the estimate of night efficiency relative to day efficiency is 2.21.

Analyses of the survey time series

Scatter Plots of Catch Rates

Smoothed scatter plots of witch catch rates suggested a substantial day/night effect, with higher catch rates at night, for both the August and September surveys but not for the January survey (Fig. 4). These plots suggested that the use of two levels for diurnal variation in catchability, with times between 0700 and 1900 classified as day, is a reasonable simplification for the August and September surveys. The smoothed curves of catch rate versus time suggest peak catch rates before dawn and after dusk for these surveys. However, the extent and timing of these peaks varied from case to case. In all four cases, catches throughout the night (1900-0700) tended to be greater than those throughout the day (0700-1900). In the September survey, diurnal variation in catchability appeared to be greater in the 1992-1997 period when fishing was by the *Alfred Needler* using a Western IIA trawl than in the earlier period when fishing was by the *Lady Hammond* using the same trawl. Day catches tended to be similar between the two vessels, but the increase in catch rates at night appeared to be much stronger for the *Alfred Needler* than for the *Lady Hammond*. In the August survey, diurnal variation in catchability appeared to be somewhat greater in the 1985-1989 period when fishing was by the *Lady Hammond* using a Western IIA trawl than in the later period when fishing was by the *Alfred Needler* using a URI trawl.

Diurnal variation in catchability in the January survey clearly differed from the pattern in the summer surveys. There was no tendency for catch rates to be generally higher at night (1900-0700) than in day (0700-1900). The scatter plot for the January survey did suggest a tendency for catch rates to be higher from about 1200-2400 than from 0000-1200. Fish behaviour often shows diurnal cycles that could explain the diurnal variation in catchability seen in the summer surveys. The pattern seen in the summer surveys is also consistent with an explanation involving diurnal variation in light levels. Neither explanation seems consistent with the pattern suggested by the scatter plots for the January survey, and we have not explored the January data any further here.

Probability of Catching Witch

Diurnal variation in the probability of catching witch was highly significant in all cases (Table 3). For the September survey, estimates of the ratio in this probability between night and day were similar between models with or without a year×stratum interaction term and between the 1985-1991 period when fishing was by the *Lady Hammond* and the 1992-1997 period when fishing was by the *Alfred Needler*. Averaging over all years and strata, the estimated probability of catching witch at night was about 1.4 (1985-1991) or 1.5 (1992-1997) times the daytime probability. These values are comparable to the value of 1.4 obtained in the 1988 comparative fishing experiment. The same value was also obtained in the August survey during the 1990-1997 period when fishing was with the URI trawl. However, a considerably lower ratio was estimated for the August survey in the 1984-1989 period. This lower ratio was associated with a much higher probability of catching witch in both day and night.

Relative Fishing Efficiency between Day and Night

Because of the strong difference between day and night in the probability of catching witch, tests for a difference in fishing efficiency between day and night used all tows, not just those catching witch. These data include many zero catches. Thus, we used Poisson models (dependent variable: catch rate Y) which are not adversely influenced by zero catches (see the section on the 1988 experiment) for these tests rather than lognormal models (dependent variable: $\log_e(Y+1)$) which are strongly biased by zero catches.

The difference in fishing efficiency between day and night was highly significant in all cases, with greater efficiency at night (Table 4). For the September survey in 1985-1991, night fishing efficiency was estimated to be 2.17 times day efficiency, very close to the value of 2.24 estimated from the 1988 comparative fishing experiment. For the August survey in the 1984-1989 period when fishing was also by the *Lady Hammond* using a Western IIA trawl, the estimated ratio of night efficiency to day efficiency was 1.84, fairly close to the September values.

The day/night effect appeared to be much stronger for the *Alfred Needler* using a Western IIA trawl (September 1992-1997), with night efficiency about 4 times day efficiency (Table 4). We tested the significance of this difference between vessels using an analysis covering the entire 1985-1997 time period, with terms for vessel, year nested within vessel, stratum, time and vessel×time interaction. The interaction term was highly significant (P=0.0042).

The estimate for the *Alfred Needler* was strongly influenced by data from one year, 1993, when very few witch were caught in day tows. In this year, the strata with the highest witch densities (437 and 415) were fished mostly at night. The estimated day/night effect in 1993 was an order of magnitude stronger than estimates for other years (Table 5). The pattern of residuals for the 1993 analysis does not indicate any serious problem with the model for that year (Fig. 5), though two points do stand out in the residual plot, a large negative residual for an observed catch of 0 and a large positive residual for the largest observed catch. Nonetheless, estimates of the day/night effect both for 1993 alone and for the entire 1992-1997 period are strongly influenced by the three largest catches in 1993. If these three tows are omitted, the estimate for 1993 decreases from 29.52 to 12.55 (Table 5), and for the entire period from 3.98 to 3.17 (Table 4). In our view, it is not reasonable to use an estimate that is so strongly dependent on only 3 of the 233 tows that caught witch in the 1992-1997 period, and we conclude that 3.2 would be a more prudent value to use for night fishing efficiency relative to day efficiency in the September survey in the 1992-1997 period. Alternatively, all the data for 1993 could be omitted from the analysis. This leads to an even lower estimate of 2.94 (Table 4). However, in one sense, 1994 is as extreme as 1993 but in the opposite direction: the estimate of b_N for 1993 is about three times the average for 1992, 1995-1997 whereas the estimate for 1994 is about one-third of this average. (In 1994, the stratum where witch densities tend to be highest (437) was not fished at night.) An analysis omitting both 1993 and 1994 also leads to an estimate of 3.2 for night efficiency relative to day efficiency (Table 4).

The estimate for night efficiency relative to day efficiency appeared to be considerably lower for the *Alfred Needler* using a URI trawl in the August survey compared to the estimate using a Western IIA trawl in the September survey (Table 4). This difference may be related to the lower efficiency of the URI trawl compared to the Western IIA for witch flounder greater than 23 cm in length (Swain et al. 1998*a*).

Results were similar restricting the analysis to catches of witch flounder 24 cm or greater in length (Table 6).

Comparison of adjusted and unadjusted abundance indices

Based on the analyses presented above, we adjusted day catches of witch to be equivalent to night catches by multiplying day catches by the following factors:

Survey	All lengths	Length≥24 cm
September 1985-1991	2.1	2.1
September 1992-1997	3.2	3.3
August 1984-1989	2.1	2.1
August 1990-1997	1.6	1.6

The values for September 1985-1991 and August 1984-1989 are the average of the three estimates for the *Lady Hammond* using a Western IIA trawl.

For September 1971-1984, when fishing was entirely during daytime by the *E.E.Prince* using a Yankee 36 trawl, we multiplied catches by 2.1 to make them equivalent to night catches by the *Lady Hammond* using a Western IIA trawl. This follows from a comparative fishing experiment between the *E.E.Prince* and the *Lady Hammond* in 1985. This experiment failed to reveal a significant difference between the two vessels and gears in daytime catches (Nielsen 1994).

Trends in relative abundance were roughly similar between adjusted and unadjusted time series (Fig. 6). However, for the September series, catch rates in the 1970s tended to be higher relative to those in the late 1980s and the 1990s in the adjusted series compared to the unadjusted series. In the unadjusted series, catch rates in the 1970s tended to low to medium compared to those in the late 1980s and the 1990s. In the adjusted series, catch rates in the 1970s tended to be medium to high relative to those in the late 1980s and the 1990s. In both series, catch rates were lowest between 1980 and 1985. Some differences in relative abundance are also apparent between the two series since 1985. The most striking differences are for 1993 and 1994. In 1993, the stratum with the highest longterm average witch catch rate (437) was fished mostly at night and the stratum with the second highest longterm average catch rate (415) was fished entirely at night. Consequently, witch were caught almost entirely in night tows in 1993, and there is little difference between the unadjusted mean and the mean adjusted to night efficiency. On the other hand, stratum 437 was fished entirely in daytime in 1994. Thus, a high proportion of witch were caught in day tows in 1994, and there is a relatively large difference between the unadjusted mean and the mean adjusted to night efficiency.

Trends in relative abundance are very similar between adjusted and unadjusted series for the August survey. The main differences between the two series are sharper declines in relative abundance in 1989 and 1993 in the adjusted series.

Adjustments for diurnal variation in catchability are problematic because of the difference between day and night in the probability of catching any witch at all. In a sense, nonzero catches are 'over-adjusted' to compensate for the difference between day and night in the probability of catching witch. An alternative approach would be one which treated zero and nonzero catches separately (e.g., Pennington 1983). We plan to explore this alternative approach.

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Table 1. Percent of tows made at night during the September bottom-trawl survey of the southern Gulf of St. Lawrence, 1985-1997, for the strata where witch flounder are most likely to be caught.

year	415	416	417	425	426	434	437	438
85	50	40	29	50	0	38	20	67
86	50	44	50	67	67	63	29	0
87	50	44	57	33	33	67	40	33
88	50	46	50	50	50	43	33	50
89	67	29	67	50	75	25	40	33
90	60	63	75	33	33	63	25	67
91	43	67	40	60	0	43	80	75
92	60	67	40	0	0	25	50	33
93	100	11	80	20	25	70	75	25
94	80	38	100	0	67	75	0	100
95	20	75	20	80	33	70	50	100
96	57	44	40	67	40	17	67	100
97	43	50	40	60	50	46	33	40

Table 2. Tests for a difference in fishing efficiency between day and night in the 1988 comparative fishing experiment. β_N is the estimate of the model parameter for night (β_{Day}=0), SE is its standard error, and *P* is the probability that β_N=0. *b* is the corresponding estimate of night fishing efficiency relative to day efficiency (*b*=exp(β_N) for the Poisson model or exp(β_N) multiplied by a term for bias correction for the lognormal model). *B* is the mean night catch divided by the mean day catch.

Data	Model	Dependent Variable	β_N	SE	*P*	*b*
Witch in both	Lognormal	ln(Y)	0.5741	0.2314	0.023	1.7262
N=20	Lognormal	ln(Y+1)	0.4893	0.1938	0.021	1.5992
B=1.9355	Poisson	Y	0.6604	0.2122	0.0045	1.9355
Witch in either	Lognormal	ln(Y+1)	0.6603	0.1697	0.0005	1.9068
N=33	Poisson	Y	0.8059	0.1870	<0.0001	2.2387
B=2.2387						
All tows	Lognormal	ln(Y+1)	0.3252	0.0924	0.0008	1.3783
N=67	Poisson	Y	0.8059	0.1305	<0.0001	2.2387
B=2.2387						

Table 3. Tests for a difference between day and night in the probability of catching witch. Results are from logistic models (binomial error, logit link, $\phi=1$) with terms for year, stratum (and in some cases, their interaction) and time of day. β_N is the estimate of the model parameter for night ($\beta_{Day}=0$), SE is its standard error, and P is the probability that $\beta_N=0$. p_D is the predicted probability of catching witch in the day, averaged over all combinations of year and stratum. p_N is the corresponding probability for night.

Data	Interaction Term	β_N	SE	P	p_D	p_N	p_N/p_D
Sep 85-91	Yes	1.1814	0.2128	<0.0001	0.29	0.40	1.38
Sep 85-91	No	1.0770	0.1878	<0.0001	0.28	0.41	1.45
Sep 92-97	Yes	1.4503	0.2761	<0.0001	0.23	0.34	1.49
Sep 92-97	No	1.1751	0.2237	<0.0001	0.23	0.34	1.50
Aug 84-89	No	0.4769	0.2154	0.026	0.82	0.87	1.06
Aug 90-97	No	0.9452	0.1262	<0.0001	0.44	0.62	1.40

Table 4. Tests for a difference in fishing efficiency for witch flounder between day and night in the September and August bottom-trawl surveys. Results are from Poisson models (Poisson error, log link, ϕ estimated from Pearson's χ^2) with terms for year, stratum (and their interaction for the September surveys) and time of day. β_N is the estimate of the model parameter for night ($\beta_{Day}=0$), SE is its standard error, and P is the probability that $\beta_N=0$. F is the F-value for this test, and df its degrees of freedom. b is the corresponding estimate of night fishing efficiency relative to day efficiency ($b=\exp(\beta_N)$.

Data	β_N	SE	F	df	P	b
Sep 85-91 (*Hammond*, Western IIA)	0.7745	0.0893	78.45	1,923	<0.0001	2.17
Sep 92-97 (*Needler*, Western IIA)	1.3820	0.1173	113.99	1,927	<0.0001	3.98
Sep 92-97 -3 catches>50 in 1993	1.1547	0.1113	126.57	1,924	<0.0001	3.17
Sep 92,94-97	1.0778	0.1199				2.94
Sep 92,95-97	1.1688	0.1143				3.22
Aug 84-89 (*Hammond*, Western IIA)	0.6072	0.0818	58.02	1,923	<0.0001	1.84
Aug 90-97 (*Needler*, URI)	0.4951	0.0919	29.70	1,1409	<0.0001	1.64

Table 5. Estimates of night fishing efficiency relative to day efficiency for witch flounder in the September survey for individual years. Results are from Poisson models with terms for stratum and time of day. Symbols are as in Table 3.

Year	β_N	SE	*b*
1992	0.8365	0.2627	2.31
1993	3.3850	0.3038	29.52
1994	0.3658	0.4622	1.44
1995	1.0074	0.1940	2.74
1996	1.2279	0.2247	3.41
1997	1.2550	0.2339	3.51
1993 minus 3 catches>50	2.5301	0.3183	12.55

Table 6. Tests for a difference in fishing efficiency between day and night in the September and August bottom-trawl surveys for witch flounder 24 cm or longer in length. Results are from Poisson models (Poisson error, log link, ϕ estimated from Pearson's χ^2) with terms for year, stratum (and their interaction for the September surveys) and time of day. Symbols as in Table 3.

Data	β_N	SE	*b*
Sep 85-91 (*Hammond*, Western IIA)	0.7809	0.0904	2.18
Sep 92-97 (*Needler*, Western IIA)	1.4228	0.1195	4.15
Sep 92-97 -3 catches>50 in 1993	1.2055	0.1140	3.34
Aug 87-89 (*Hammond*, Western IIA)	0.6606	0.1026	1.94
Aug 90-97 (*Needler*, URI)	0.4597	0.1108	1.58

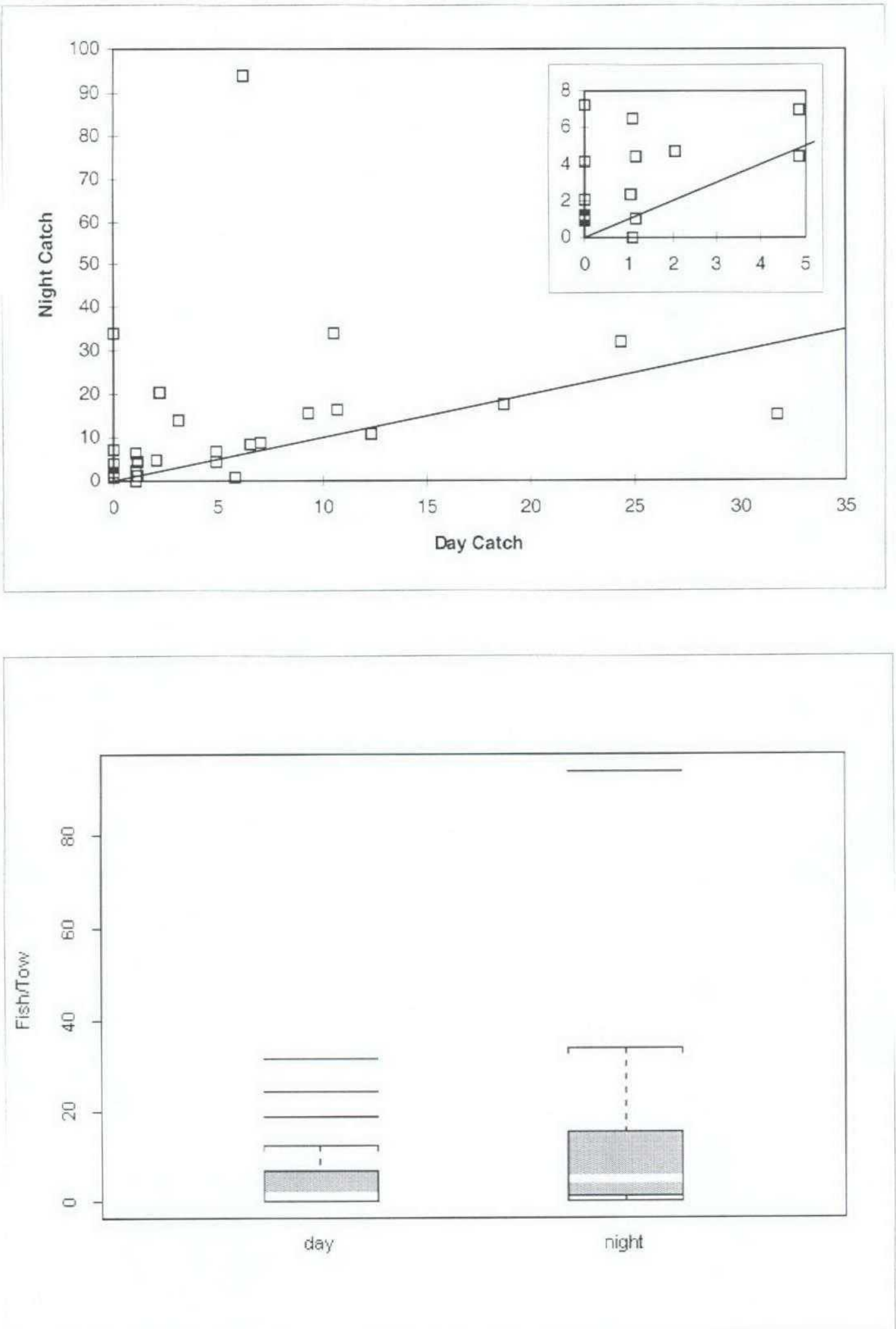

Figure 1. Catches of witch flounder in day and night from paired tows in September 1988.

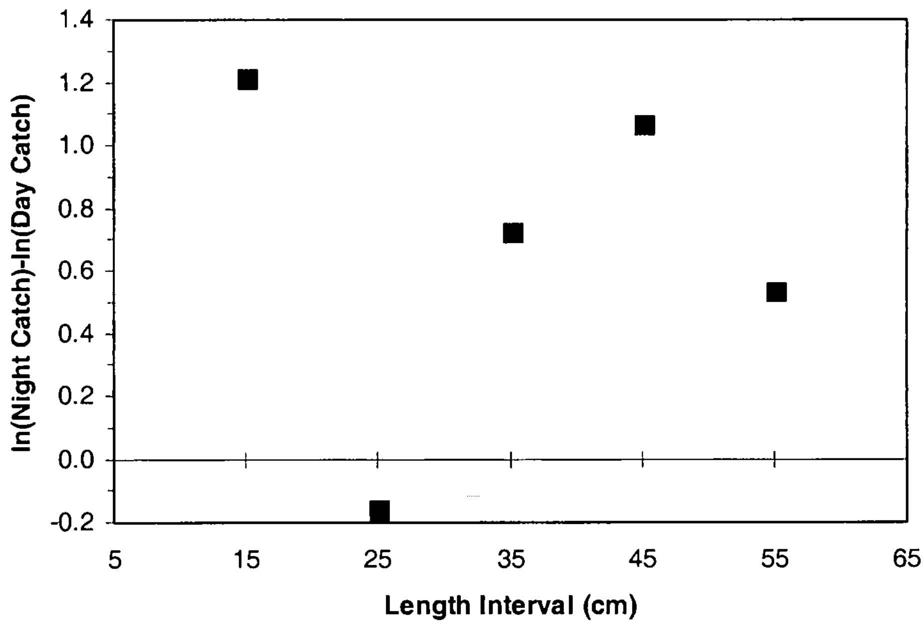

Figure 2. Difference between night and day catches of witch flounder by length interval. Catches are summed over the 33 paired tows where witch were caught in at least one of the two tows. Data are plotted at the center of each 10-cm length interval.

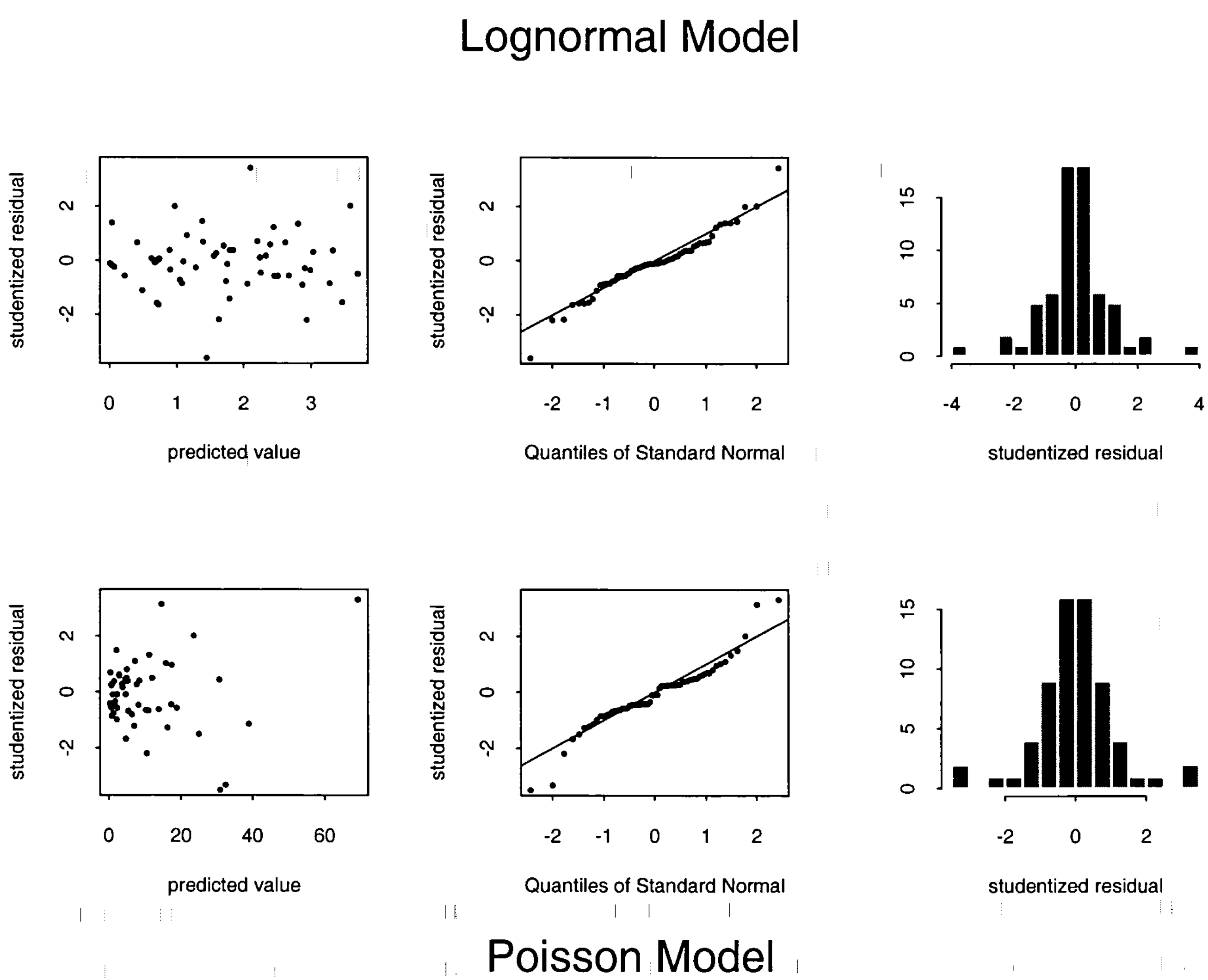

Figure 3. Residuals from models using the 33 paired tows with witch caught in at least one tow per pair

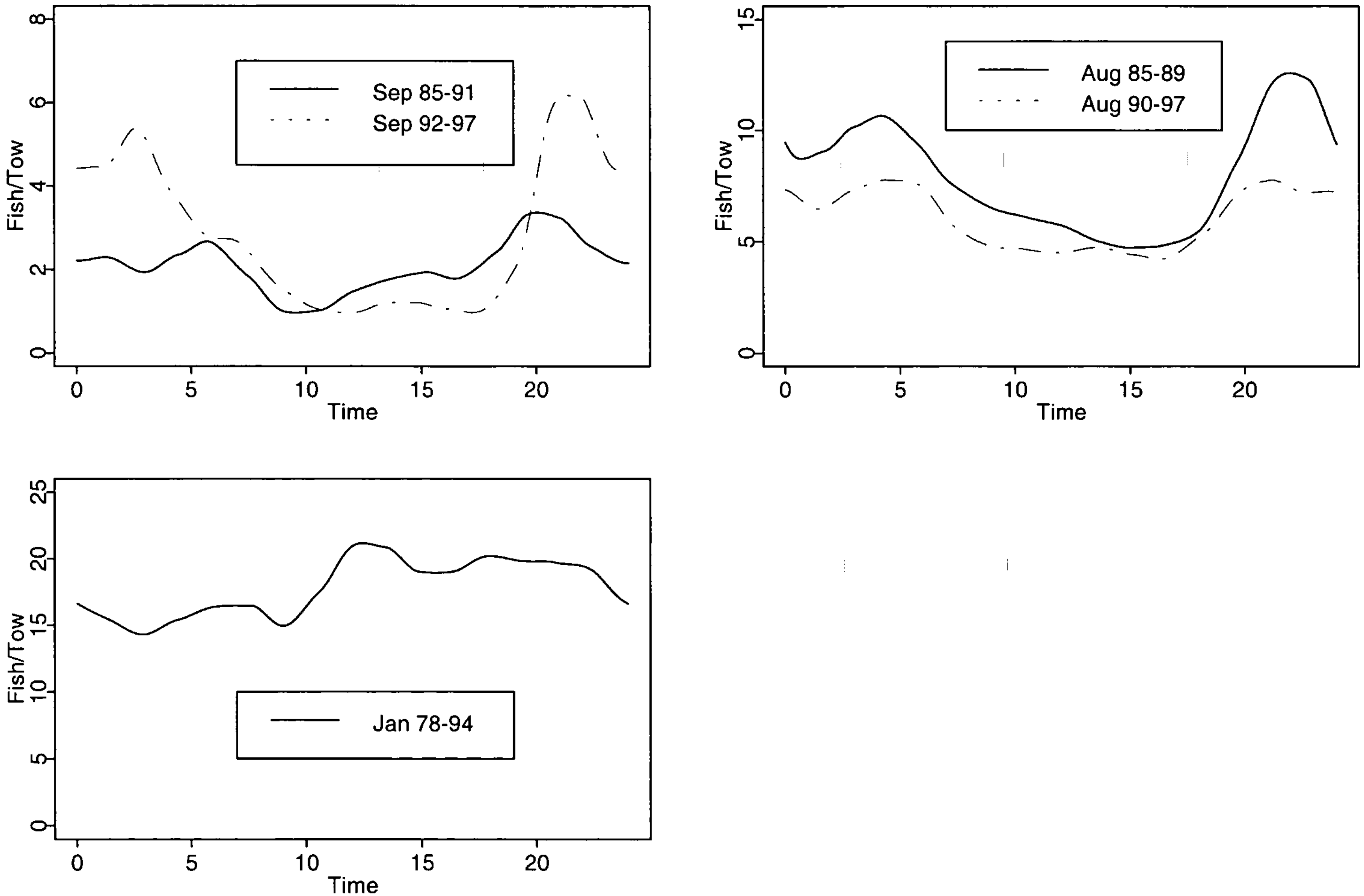

Figure 4. Witch flounder catch rates by time of day.

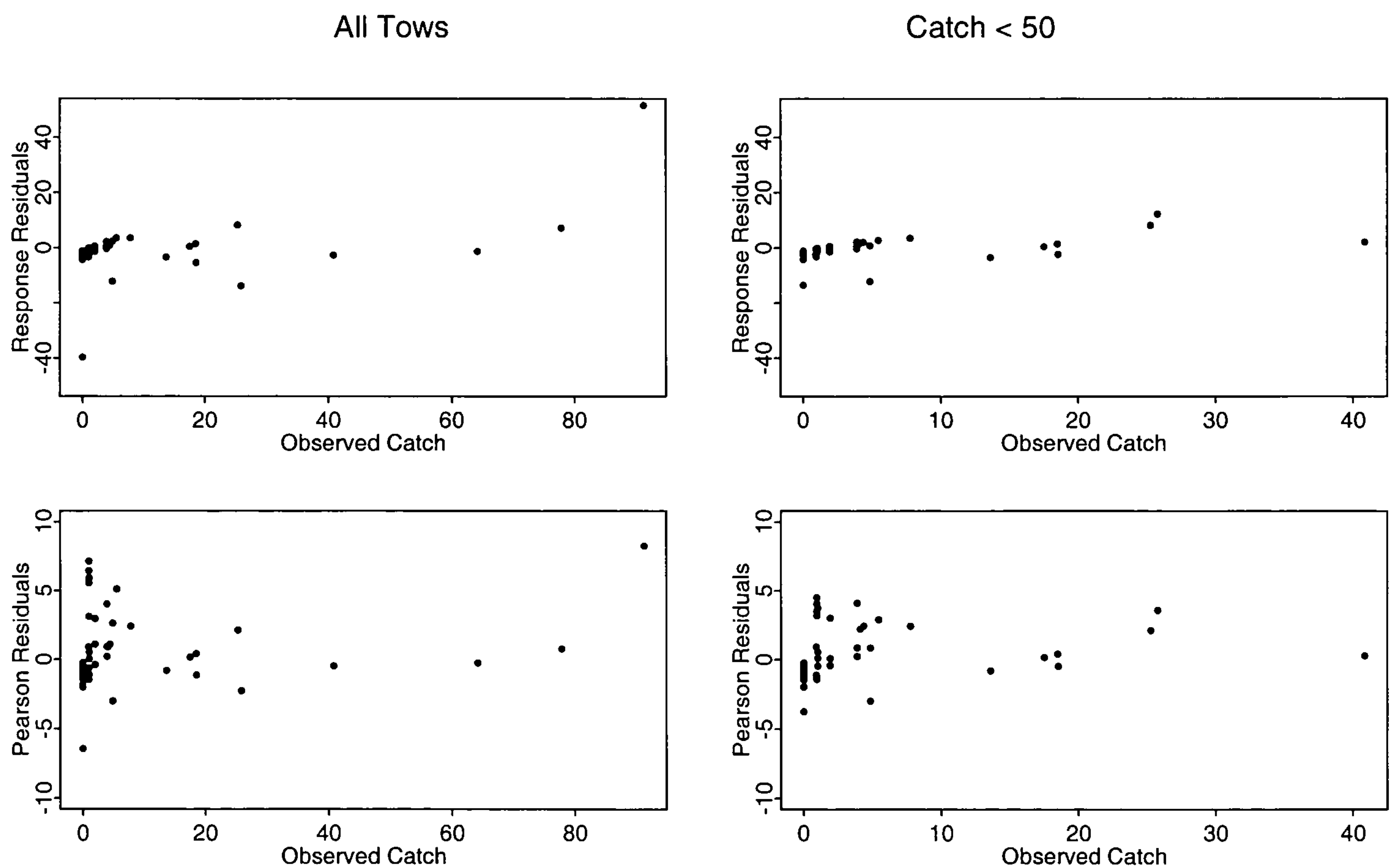

Figure 5. Residuals from Poisson models for 1993.

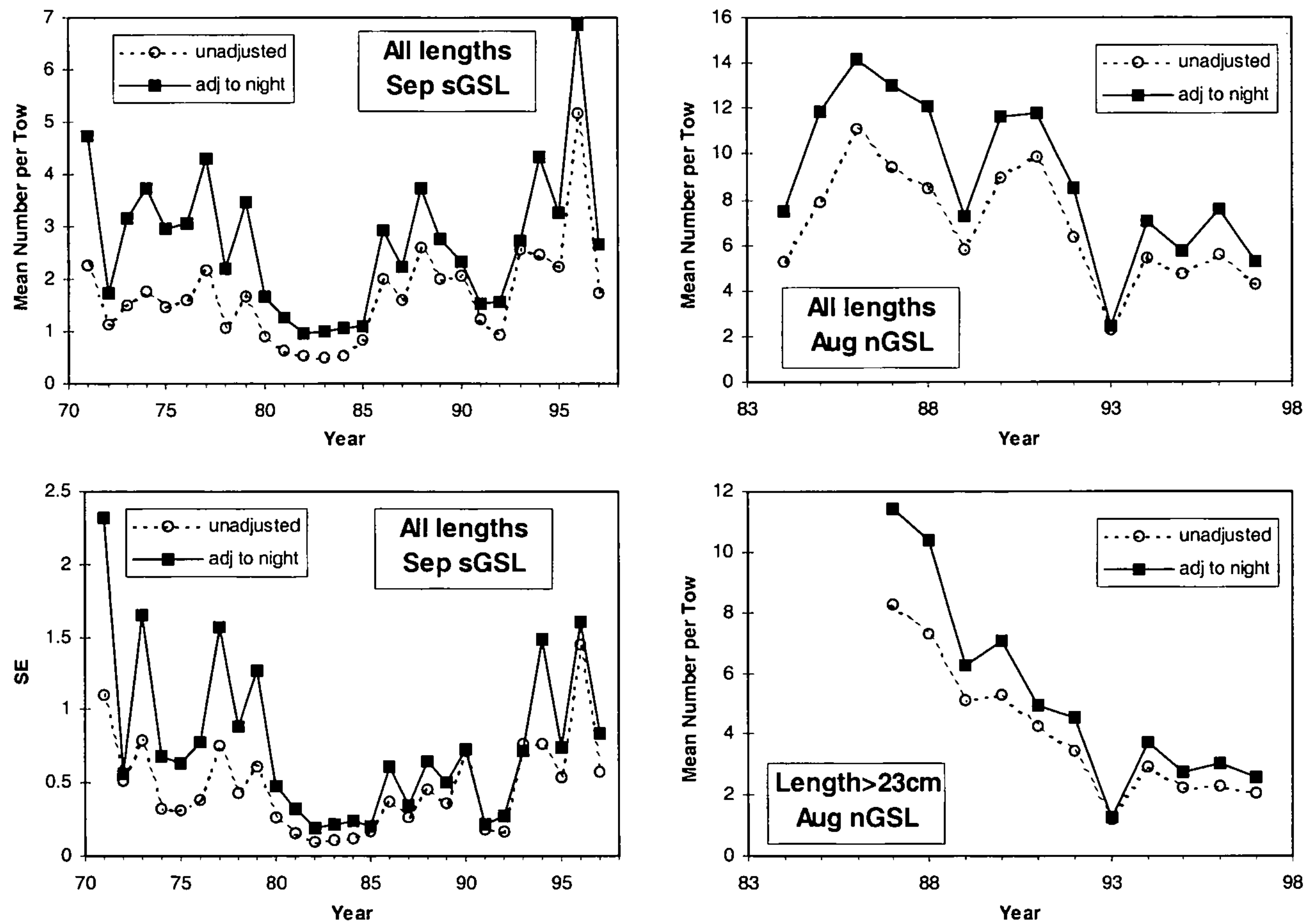

Figure 6. Comparison of unadjusted witch flounder abundance indices and indices adjusted to night catchability. Note that no adjustments have been made for changes in vessel and gear. In the southern Gulf (sGSL), the survey vessel changed in 1992. In the northern Gulf (nGSL), a change in vessel and gear occurred in 1990.