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An Evaluation of Commercial Fishery Catch Rates as an Index of Abundance for Pollock in Divs. 4X5

Évaluation des taux de capture de la pêche commerciale comme indice d'abondance de la goberge dans les divisions 4X5

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ABSTRACT

As part of a Framework Assessment of pollock (*Pollachius virens*), the utility of commercial fishery indicators of abundance was evaluated. It was recommended that the mobile gear catch rates continue to be used as an index of abundance. The age-specific indices indicated some consistency in the interpretation of year-class strength that appears to support the current use of commercial fishery catch rates in an age-disaggregated mode. However, attempts to refine the index over past assessments have resulted in only modest gains in the explanatory power of the model, and there is considerable unaccounted variance in catch rates remaining. Gillnet catch rates were also evaluated for the first time, and it was found that catch rates from that gear type may also have utility as an age-disaggregated index of abundance.

RÉSUMÉ

Au titre de l'évaluation du cadre d'examen de la goberge (*Pollachius virens*), nous avons évalué l'utilité d'indicateurs d'abondance provenant des pêches commerciales et nous avons conclu que les taux de capture aux engins mobiles devraient continuer d'être utilisés comme indice d'abondance. Les indices par âge indiquent un certain accord dans l'interprétation de l'abondance des classes d'âge, qui semble étayer l'utilisation courante des taux de capture des pêches commerciales dans un mode désagrégé par âge. Toutefois, nos tentatives en vue de raffiner l'indice d'après des évaluations antérieures n'ont donné que des gains modestes dans la capacité d'explication du modèle; en outre, il reste une importante variance non expliquée dans les taux de capture. Nous avons aussi évalué les taux de capture aux filets maillants pour la première fois et nous avons établi qu'ils pourraient être utiles aussi comme indice d'abondance désagrégé par âge.

INTRODUCTION

In the absence of reliable fishery-independent indices of abundance for pollock in 4VWX5Zc (Scotian Shelf, Bay of Fundy and the Canadian portion of Georges Bank), there has been considerable effort in past assessments devoted to describing trends in commercial fishery catch rates as indicators of abundance. As part of the Framework Assessment of pollock conducted by the Marine Fish Division of the Maritimes Region in 2003, the utility of commercial catch rates as an indicator of abundance was reviewed. The history of approaches is provided here, along with some enhancements that increase the explanatory power of the model. The model is also recomputed to provide indices for the newly defined western Scotian Shelf management unit in Divs. 4X and the Canadian portions of 5Y and 5Z (Neilson et al. 2003). The implications of interactions between factors included in the model are discussed. A possible new index for the gillnet fishery for pollock is proposed. Finally, we evaluate the prospects for defining a fishery-derived index of abundance for pollock in the newly-defined eastern Scotian Shelf management unit (4VW).

Catch rates, however, have been subject to criticism as an index of abundance due to factors such as changes in technology (Kimura 1981), management measures (Worthington *et al.* 1998) or environmental conditions (Perry and Boutillier 2000) that can potentially influence the proportionality between catch rates and stock abundance. For schooling species such as tunas, catch rate analysis has been shown to sometimes provide misleadingly optimistic interpretations of stock abundance (Clark and Mangel 1979). Given that pollock frequently exhibit schooling behaviour, such observations are of concern. In the context of the periodic framework assessment of pollock, it is therefore important to carefully assess both the strengths and limitations of commercial fishery catches as indices of abundance.

HISTORY OF USAGE OF CATCH RATE INFORMATION IN THE ASSESSMENTS

Commercial fishery catch rates have featured prominently in Canadian assessments of pollock (Table 1). Since 1977, the majority of Canadian assessments have reported catch rates, typically for stern otter trawlers. The earlier assessments typically made no attempt to report standardized catch rates using approaches such as that of Gavaris (1980), rather providing the series of nominal CPUE values for a particular set of months and gear type. The use of standardized catch rate series, although attempted from time to time in the past, became the usual practice in 1997 and has since persisted. In general, early assessments which did not employ a standardization approach tended not to report catch during the December-March period, since it was thought catch rates during the period when fish were highly aggregated for spawning might be misleading. Prior to 1997, authors have tended to report the catch rates of the larger tonnage class vessels, as these vessels were dominant in the fishery at that time. Observer Program data typically was the source of such data.

More recently, however, the role of the Tonnage Class 4 vessels and larger has been greatly diminished in the fishery to the point that in 1999, the assessment moved towards reporting TC 1-3 catch rates only. Also in that year, the population model was reduced in geographic scope to NAFO Div. 4X and 5Zc; correspondingly, the abundance index was derived from that area only.

DESCRIPTION OF THE PREVIOUS MODEL, UPDATED TO 2002

Catch and effort data (stern otter trawlers, Tonnage Classes 2-3) from the Departmental ZIFF database were used. The data for 1989 were omitted from the analyses, since this was the year when a combined cod-haddock-pollock quota was attempted for areas 4X5 (Mohn *et al.* 1990), and anomolously high pollock catch rates were observed. Trips were selected which had directed pollock catches (when pollock landings were equal to or greater than 50% of the total landings by weight) and where effort (hours fished) and catch are both greater than zero and grouped to the sub-trip level from 1982 to 2002. For the final data input into STANDAR, catch and effort data were grouped to the trip level. Factors in the catch rate standardization included vessel, year, month, tonnage class, NAFO unit area and mesh type (square *vs* diamond). In instances prior to and including 1993 where the mesh type field was blank, it was assumed to be diamond. In 1994, all such records were deleted. In 1995, if the mesh type field was blank, it was assumed to be square mesh. We included NAFO unit areas 4Xm, 4Xo, 4Xp, 4Xq, 4Xr, 4Xs and 5Zj only (Fig. 1) in the analyses, as other areas did not have sufficient data to warrant inclusion. Even though area 5Yb was considered to have sufficient data, it was excluded, since there is thought to be landings incorrectly attributed to that area in the past. Also, based on examination of fishing patterns by month for all tonnage classes, catch rates during the May through October period were judged sufficiently similar to be combined into one level for the analysis of seasonal effects on catch rates.

The catch rate standardizations were computed using the APL software known as STANDAR. The results of the multiplicative analyses are shown in Appendix 1 and the overall standardized CPUE series in shown on Fig. 2. As with previous analyses of catch rates for this resource, the amount of variation in observed catch rate explained by the model was comparatively low (17%). However, all main effects were found to be significant (p<0.01) with the exception of mesh type, which was marginally less than the critical F value at p=0.05. The coefficients for factor levels generally followed patterns that were expected and intuitive (ie. increasing catch rate with increasing tonnage class, and highest monthly catch rates observed in January (Fig. 3), coincident with the peak of spawning as indicated from ichthyoplankton records (Neilson et al. 2003). On the other hand, the pattern of coefficients for catch rates by Unit Area were not as expected, with higher coefficients in 4Xs compared with 5Zj, for example.

POSSIBLE ENHANCEMENTS TO THE BASE MODEL

For the Framework Assessment, we explored several possible enhancements to the current approach that uses main effects only. The approach used in Neilson et al. (1999) and described in the previous section used an unweighted regression of catch and effort. However, inspection of the pattern of residuals indicates a pattern of increasing variance with decreasing catch or effort (Fig. 4). We corrected the problematic distribution of residuals by weighting each CPUE record by the effort in subsequent main effects models. The resulting pattern of residuals in the model fit is also shown on Fig. 4.

A further significant change was the consideration of vessel experience in the model. As part of the data selection process, for a vessel to be included in the model, we stipulated that the vessel had to have pollock directed catches (at least one trip with pollock weight equal to or greater than 50% of total catch weight) in a minimum (not necessarily consecutive) of five years during the series extending from 1982 to 2002. CFV was also included as a factor in the analysis. Among other changes we propose to the main effects approach, we noted that Unit Areas 4Xl and 5Zm were associated with very small catches of pollock recently and were dropped. Unit Area 5Yb was again included in the model, given that the suspected misreporting occurred in one year only (1984) and significant number of records of catch and effort were available for that area. Finally, the results of the first Framework Assessment Meeting suggested that pollock caught in the easternmost Unit Areas in 4X (4Xm,n) were slower growing than pollock in the remainder of the newly defined management unit. For the purposes of defining an abundance index that best reflects the population dynamics of pollock within the management unit and to be consistent with the recommendations from the first Framework Assessment Meeting (Neilson *et al.* 2003), we elected to delete the catch rate observations from 4Xm and n.

The results of the base main effects model (weighted regression) are shown in Appendix 2, and the impact of replacing Tonnage Class with CFV is shown in Appendix 3 (enhanced approach). Tables 2 – 3 provide details of the cross-tabulations of counts of catch rate data, by main effects. As indicated by those tabulations, observations of catch and effort are available for most levels of month and area in each year. The relative contribution of some areas or months to the catch effort data has changed over time. For example, the easternmost Unit Area 4Xo has very few records in recent years (Table 3). Fig. 5 shows the standardized catch rate series for both the base and enhanced approaches. Both series show very similar trends. Fig. 6 shows the enhanced approach along with the nominal data. The catch rate standardization moderates an anomolously high nominal catch rate increase from 2001 to 2002.

Fig. 7 shows the coefficients associated with different factor levels for the enhanced approach. The pattern of highest catch rates in January seen earlier (Fig. 3) is retained, but a second period of high catch rates is observed in June and July. The coefficients by area present are closer to expectations than the results shown in Fig. 3 (updated approach of Neilson et al. (1999)), with 4Xp, 4Xq and 5Zj being the areas associated with the highest catch rates. The weighted regression approach and the pre-selection of vessels with at least five years experience in the fishery increased the explanatory power of the model ($r^2 = 0.233$). Using the same input data, the enhanced approach (replacing TC with CFV) resulted in a further gain ($r^2 = 0.316$) but with a loss of degrees of freedom associated with vessels (df = 161) compared with Tonnage Class (df = 1).

INTERACTIONS BETWEEN FACTORS

Interactions between main effects were explored with a derivation of STANDAR which is web-based S-Plus statistical software available on the Maritimes Region Virtual Data Centre. This approach extends the least squares method to include interaction terms, and uses analysis of deviance to conduct statistical tests and diagnostics. The fitting and prediction methods remain identical to STANDAR. To clarify, if we run the same model on the same data in both applications, we expect the same predicted catch rates. For a main effects model, the only potential difference between applications would be determination of significant effects, such that model formulation might not follow the same path. To ensure comparability with the main effects results produced using STANDAR presented earlier, we independently ran some main effects models using the two sets of software and established that the results obtained were similar. We then explored two-way interaction terms using the main effects model presented in Appendix 3 as our starting point, but without weighting by effort. This approach attempts to account for confounding differences in annual catch rate trends with levels of the other factors in the model. Inclusion of interactions increased the explanatory power of the model to 37%, with most of this increase due to interactions of month and area with year. However, this model was characterized by too many singularities to produce estimates of the annual catch rates, largely due to the large number of vessels (175) in the model.

To circumvent this problem, we applied a more selective filter on vessel experience for inclusion in the model. We increased the minimum experience criterion from any 5 years within 1982 to 2002 directing on pollock, to 10 consecutive years directing. This reduced the vessels in the data from 175 to 48. Data loss and associated aliasing (empty or sparsely filled cells in the design matrix) further necessitated the removal of December-January and 1987-88 catch/effort data from the model. Examination of coefficients during preliminary modelling indicated that 4Xp could be combined with 4Xq, and 4Xr could be combined with 5Yb. As this approach differs from that represented by the main effects model presented in Appendix 3, we ran parallel main effects and interaction models using this revised dataset and ensured that consistent results were obtained. The interaction model could not produce a single mean estimate for the time series, but specific predictions were possible for various month-area combinations. We took the mean of all possible predictions from the interaction model as a proxy for the model mean. This will misrepresent the overall catch rate series to the extent that model components are not proportionately reflected by the achieved predictions.

Model results are presented in Appendix 4, and plots of the annual catch rates are shown in Fig. 8, along with the main effects model results presented in Appendix 3. While we were unable to provide model predictions for some years in the case of the interactions model, the two series give broadly similar trends, but the year by year comparisons often indicate lack of agreement whether the CPUE series is increasing or decreasing. We further note that the 2001 to 2002 increase is more moderate in the interactions model compared with the main effects. A subset of predictions from the interaction model over a representative range of months and areas are shown in Fig. 9. Area-specific patterns appear comparable from month to month. The recent increase in catch rates seems to be broadly reflected across the majority of month-area combinations.

A POTENTIAL NEW INDEX FROM THE GILLNET FISHERY FOR POLLOCK

A standardized catch rate series was developed for the 1990-2002 Western Scotian Shelf, Gulf of Maine and Bay of Fundy (4Xopqrs5Yb5Z) gillnet fishery following a similar approach to the mobile gear fishery described earlier. In this instance, a simpler filter on vessel experience of any five years directing since 1986 proved adequate to achieve a stable model. Catch per unit effort was determined as the tons per gillnet sheet aggregated by subtrip. The 1994 data were excluded from analysis due to problems processing that year's fishing logs. Following a similar line of development for the mobile gear catch rate series, we present both main effects and interactions models, with year, month, area, tonnage class, and vessel treated as model factors.

We spoke to several gillnet fishermen in the course of developing this approach. We were interested in their views as to when logbook information was more rigorously reported by fishermen, and if they thought the approach of using information from the gillnet fishery was generally sound. One fisherman who fished the lower Bay of Fundy area commented that the fishery was generally constrained in time, and his time on the water might amount to 6-8 weeks. However, given that the model attempted to adjust for monthly differences in catch rates, he thought the approach had some promise. The second fishermen fished on the edge of Georges Bank. He noted that his location, timing and gear characteristics had not changed appreciably over the past 10 years or so, and he thought catch rates could be indicative of abundance. Finally, a third fishermen who fished more towards the eastern portion of NAFO Div. 4X agreed that the catch rate information might be useful but cautioned that a minority of logbook data could not be trusted. However, he noted that the quality of information in the logbooks had increased appreciably in recent years.

A major decision affecting the use of the gillnet series is when the series should start. Table 4 illustrates that the data between 1986 and 1994 typically covered a low proportion of 4X5 gillnet landings. After 1995, the proportion of gillnet landings with effort improved. Table 5 shows how the distribution of landings with effort by unit area was biased towards certain unit areas in years such as 1994. Finally, it was noted that dockside monitoring came into effect in 1996 for the gillnet fleet, and it is considered that the DMP initiative markedly increased the quality of information in the logbooks (J. Hansen, Senior Groundfish Advisor, pers. comm.). Given these considerations, we suggest that a series starting in 1995 would be the best option, as this period appears to represent a time when the data were considered accurate by fishermen and the data were consistently recorded by the Department. However, as an alternative, we also provide the results for a longer series, starting in 1990 (but excluding 1994).

A preliminary main effects model using tonnage class as a factor was compared to a main effects model using vessel as a factor. Both models gave similar predicted catch rates, but the model with vessel as a factor explained considerably more of the variance than the model with tonnage class as a factor, so we proceeded with vessel as a factor in subsequent modelling. Examination of coefficients from preliminary interaction modelling indicated that May and June, July and August, 4Xr and 4Xs, and 4Xq and 5Yb, were similar enough to be combined. During this preliminary modelling we also eliminated December-March catches as they resulted in model singularities that precluded predictions. Parallel interaction and main effects models (Appendix 5) demonstrate that most of the explained variance in the models is associated with differences between boats. The explanatory power of the gillnet models is comparable to the OTB results (29 and 38% for the main effects and interactions models, respectively). The main effects and interactions CPUE series track each other from 1995-2000 (Fig. 10). We were unable to achieve a model prediction for 1995 and 1996 using the short time series of data in the interactions model. The longer time series did allow predictions (Fig. 11), but the values appeared to be anomolous. The interactions model results implied that catch rates were constant over the past three years, but the main effects model indicated a decrease from 2001 to 2002.

The prediction from the interaction model is the overall model mean, which represents a data-weighted mean prediction for the model as a whole. This is an improvement over the model achieved for the mobile gear fishery, as it is not vulnerable to biased subsetting of predictions. An attempt to capture the differences between months and areas, responsible for the interactions, is presented in Fig. 12. Most of the year:month interaction appears related to a general increasing trend evident from fishing earlier in the year (June) that is not reflected by catch rates later in the year, which either plateau or decline slightly. Much of the year:area interaction seems attributable to the more extreme trends exhibited by 5Z catch rates relative to other areas.

Using the results from the main effects modelling for the otter trawlers and gillnet fleets, we disaggregated the overall CPUE series by dividing the catch at age for the fleet component in 4X5Zc by the standardized effort for the fleet. We obtained standardized effort by dividing the annual landings by the fleet component by the catch rate in that year (Table 6). Referring to the otter trawler age specific indices, both strong and weak cohorts can be tracked across years in the matrix. Comparing with the shorter gillnet series, some concurrence of the interpretation of strong and weak year-classes can be found, although there are year-age combinations when the indices give divergent signals.

CATCH RATE INDICES FOR THE EASTERN MANAGEMENT UNIT?

Landings by year and unit area are shown in Tables 7 and 8, for otter trawlers (TC1-3) and gillnet vessels, respectively, in the proposed eastern management unit (4VW). Landings have diminished to the point that use of commercial catch rates as indicators of abundance is not feasible at present.

CONCLUSIONS AND RECOMMENDATIONS

We recommend that the mobile gear catch rates continue to be used as an index of abundance. The age specific indices provided in Table 6 indicate some consistency in the interpretation of year-class strength that appears to support the current use of commercial fishery catch rates in an age-disaggregated mode. We do note, however, that our attempts to refine the index over past assessments has only resulted in modest gains in the explanatory power of the model, and there is considerable unaccounted variance in catch rates remaining.

Previous assessments have suggested that inclusion of interaction terms in the model could improve model fit. This document represents the first in-depth examination of the use of interactions models for the pollock assessment. They have provided insight into the robustness of the conclusions of the main effects models by allowing examination of discrete combinations of important factors such as area and season. Such detailed examination allows us to comment, for example, that the large interannual increase in the catch rates from 2001 to 2002 in the mobile gear main effects analysis seems supported by most of the specific predictions we examined (Fig. 9), but the scale of the increase appears suspect. The interactions modelling approach presented some challenges, however. As indicated earlier, a more selective filter was necessary to reduce the number of vessels in the model from 175 to 48. Even then, we were unable to achieve model predictions in some years. Overall, the nature of interactions in the gillnet model may be sufficiently gradational for major fishery months (July-September), as opposed to contradictory, that main effects modelling may remain adequate to represent the catch rate time series. We therefore consider that the gillnet catch rate series has some promise as indices of abundance. We recommend that the series be made available for possible inclusion in the development of the Assessment Framework for pollock.

During the modelling exercise we encountered problems associated with the input data that may compromise results:

1. To apply weighted regression required some ad hoc auditing of the data when it became apparent that misplaced decimal places in the effort field resulted in some outliers driving the model (this was the weighting variable). More attention should be given to screening the input, as simply eliminating impossible values may not be adequate.
2. We have been restricted to using summarized subtrip effort because the set-specific effort data from the logs is not being captured by the ZIF database (the set-specific effort data exists in the log database, but is summarized to subtrip when loaded into ZIF).

Future directions being considered for modelling methods include:

1. The effort-weighted regression approach applied to the main effects model for the mobile gear fishery should be explored for the gillnet fishery, and extended to interaction modelling.
2. Prior standardization of vessels for model fitting. This would facilitate less problematic interaction modelling. As well, it may provide a better filtering mechanism for index vessels (consistent comparability of vessels in datasets).
3. Weighting the input data proportionately to the fishery where imbalances may be important.

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Table 1. History of the usage of commercial fishery catch rates in DFO pollock assessments. Not all assessments listed, rather only those that showed a different usage of commercial fishery catch rates.

Year	Areas Included	Years, Months Included	Direction	Tonnage Classes	Data Source	Method	Indices Used in Population Model?
1977	4VWX, SA 5	1964-1976 (all months)	10% or 50% pollock by weight, per trip	51-500 GRT USA vessels	USA Commercial Landings	Nominal CPUE (catch/day, for different levels of direction)	No
1980	4VWX, SA 5&6	1972-1978 (June to August)	50 or 75% pollock by weight	500-999, 150-499, 0-50, 51-100 GRT	Canadian and USA Commercial Landings	Chikuni for 500-999 GRT CDN, nominal CPUE otherwise	No
1981	4VWX, SA 5	1972-1980	50% pollock by weight, per trip	TC 4 (150-499 GRT), 5 (500-999 GRT)	Canada Commercial Landings	Nominal CPUE	Separate VPAs presented, tuned with TC 4 or 5 catch rates
1982	4VWX, SA 5	1970-1981	50% pollock by weight, per trip	TC 4 (150-499 GRT), 5 (500-999 GRT), also USA GN	Canada and USA Commercial Landings	Multiplicative (Gavaris 1980)	VPA tuned using median smoothed TC 5 catch rates
1983	4VWX, SA 5	1974-1982 (various month combinations)	50% pollock by weight, per trip	TC 5	Canada, Commercial Landings	Nominal CPUE reported for different month combinations	VPA tuned using TC 5 catch rates
1985	4VWX, SA 5	1974-1984 (various month combinations)	50% pollock by weight, per trip	TC 5	Canada, Commercial Landings, first documentation of Observer Program Data	Nominal CPUE reported for different month combinations	VPA tuned using TC 5 catch rates (from commercial fishery data
1987	4VWX, SA 5	1974-1986, June to August	Main species for the trip	TC 5	Canada, Commercial Landings, Observer Program Data (reported not used)	Nominal CPUE	VPA tuned using age disaggregated CPUE attempted for the first time but not used in final advice (commercial fishery data). RV also used.
1988	4VWX, SA 5	1974-87 for standardized, April to November 1970-1987	Main species	All TCs for standardized, TC 5 for nominal	Canada, Commercial Landings, Observer Program Data (reported, not used as index)	Nominal CPUE, but standardized analyses also attempted but rejected due to suspicions about reliability of TC 1-3 data	Both summer survey index and commercial catch rates used in calibration.
1989	4VWX, SubDiv. 5Zc (1st ref to 5Zc)	April to November, Commeri1974-1988 Observer 82-88	Main species	TC 5	Canada, Commercial Landings, Observer Program Data (reported, not used as index)	Nominal CPUE	No (RV survey only used)
1990	4VWX, SubDiv. 5Zc	April to November, Commercial 1974-1989 Observer 82-89	Main species	TC 5	Canada, Commercial Landings, Observer Program Data (reported, not used as index)	Nominal CPUE	No (RV survey only used)
1994	4VWX, SubDiv. 5Zc	Observer 82-93, April to November	Main species by set.	TC 5	Observer Program	Nominal CPUE	Yes (RV indices dropped)
1995	4VWX, SubDiv. 5Zc	April to November, Commercial 1974-1994 Observer 82-94	Main species, >50% by weight, by set or trip.	TC 5	Canada, Commercial Landings, Observer Program Data	Nominal CPUE	Yes, no other indices used
1996	4VWX, SubDiv. 5Zc	April to November, Commercial 1974-1994 Observer 82-94	Main species, >50% by weight, by set or trip..	TC 5	Canada, Commercial Landings, Observer Program Data	Nominal CPUE, standardized approach attempted with index vessels (not used in model)	Yes, no other indices used.
1997	4VWX, SubDiv. 5Zc (5Yb excluded)	Commercial 1982-1996 Observer 82-96	Main species, >50% by weight, by set or trip.	All Tonnage classes	Canada, Commercial Landings (TC 1-3), Observer Program Data (TC 4+)	Standardized analyses (factors were month, TC, year, mesh type and unit area), main effects model	Yes, no other indices used.
1999-02	4VWX, SubDiv. 5Zc (5Yb excluded)	Commercial 1982-1999+	Main species, >50% by weight, by trip.	TC 1-3	Canada, Commercial Landings (TC 1-3) TC 4+ component much reduced.	Standardized analyses, as before	Yes (note that in this year, population model done for 4X5 area only)

Table 2. Cross tabulation of number of trips by month and year used in the enhanced main effect catch rate model.

Count of POK_WT	MONTH												
YEAR	1	2	3	4	5	6	7	8	9	10	11	12	Grand Total
1982		12	5	3	55	21	57	20	23	9	1		206
1983	4	6	5	11	55	76	58	11	16	5	3	1	251
1984	2		6	22	46	65	84	19	8	19	11		282
1985	3	4	21	60	27	122	101	8	10	15	3		374
1986	4	12	28	31	94	34	13	12	5	4			237
1987	70	19	22		139	47	1	1	1				300
1988	11	4	7	24	30	14	39	1	2		1		133
1990	9	5		4	13	56	58	21	15	32	15	9	237
1991	35	68	40	139	126	158	176	90	120	82	47	17	1098
1992	20	29	15	89	223	111	212	174	134	69	38	25	1139
1993	12	5	36	43	171	189	251	144	82	6	18	10	967
1994	3	19	29	54	110	92	133	86	42	43	20	40	671
1995	7	14	19	33	38	98	88	40	36	26	13	4	416
1996	9	10	16	24	31	50	42	27	30	47	22	15	323
1997	2	36	44	63	64	99	83	53	54	18	20	9	545
1998	14	46	52	61	78	111	135	67	55	30	15		664
1999		5	17	22	25	53	83	40	16	7	3	1	272
2000	8	23	21	7	27	25	30	17	5	5	2	8	178
2001	8	1	26	16	35	26	31	10	4	3	3	1	164
2002	7	3	11	13	51	51	19	1	9	6	3		174
Grand Total	228	321	420	719	1438	1498	1694	842	667	426	238	140	8631

Table 3. Cross tabulation of number of Trips by Unit Area and year used in the enhanced main effect catch rate model.

Count of POK_WT	AREA							
YEAR	4Xo	4Xp	4Xq	4Xr	4Xs	5Yb	5ZEj	Grand Total
1982	15	18	96	56	4	15	2	206
1983	46	15	136	25	2	12	15	251
1984	43	15	149	24	1	40	10	282
1985	79	12	215	44	3	18	3	374
1986	80	7	94	36	3	4	13	237
1987	114	63	104	10		3	6	300
1988	58	18	46				11	133
1990	41	24	103	26	2	11	30	237
1991	172	123	220	290	198	32	63	1098
1992	202	105	227	310	204	48	43	1139
1993	129	115	210	271	150	58	34	967
1994	72	56	103	197	101	39	103	671
1995	24	42	152	92	54	25	27	416
1996	28	47	110	48	36	32	22	323
1997	29	83	236	80	54	33	30	545
1998	9	203	218	66	70	43	55	664
1999	4	45	78	70	54	16	5	272
2000	5	55	65	18	22	4	9	178
2001	1	50	66	14	16	6	11	164
2002	3	46	88	1	8	8	20	174
Grand Total	1154	1142	2716	1678	982	447	512	8631

Table 4. Tabulation of CPUE records available for use in the standardized model of gillnet catch rates.

Year	N	Mean CPUE	Std Dev	CV	% of total 4X5 GN Landings with Effort
1986	40	9.41	6.83	72.59	4.6
1987	39	3.83	2.95	77.03	1.6
1988	79	4.63	4.55	98.36	4.3
1989					
1990	175	3.24	2.87	88.45	5.7
1991	203	1.89	1.97	104.12	5.4
1992	374	1.03	1.08	105.26	6.9
1993	271	1.57	1.57	99.79	11.5
1994	19	1.86	0.93	49.97	1.1
1995	609	1.53	1.37	89.30	32.8
1996	424	1.20	1.22	102.35	32.5
1997	719	1.41	1.19	84.41	38.1
1998	1151	1.76	1.76	99.74	60.9
1999	738	1.06	1.05	99.17	46.3
2000	686	1.76	1.31	74.49	63.4
2001	594	1.73	1.23	71.27	51.5
2002	450	1.59	1.13	70.81	41.7

Table 5. Distribution of records of CPUE by the gillnet fleet in Div. 4X5 by unit area and year.

				Unit Area				
	5Yb	**5Zj**	**4Xo**	**4Xp**	**4Xq**	**4Xr**	**4Xs**	Total
1986		3	37					40
1987		2	35				2	39
1988		22	32	3		22		79
1990	30		103	8	14		20	175
1991	52	4	89	2	8	1	47	203
1992	131	29	93	2	79	7	33	374
1993	66	81	31	22	55	11	5	271
1994		19						19
1995	55	81	73	152	195	44	9	609
1996	60	9	63	58	140	58	36	424
1997	96	13	48	133	352	47	30	719
1998	136	66	111	151	536	103	48	1151
1999	23	72	57	106	323	96	61	738
2000	32	73	42	163	326	29	21	686
2001	12	45	45	113	326	39	14	594
2002	7	33	40	96	255	13	6	450
Total	700	552	899	1009	2609	470	332	6571

Table 6. Comparison of age disaggregated indices from otter trawlers (Enhanced approach, Appendix 3), compared with gillnet indices for vessels operating in the same area (Appendix 5).

	Age	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*average*
	3	0.0109	0.0234	0.0200	0.0102	0.0310	0.0189	0.0055	0.0051	0.0038	0.0338	0.0385	0.0204	0.0185
	4	0.0296	0.0519	0.0662	0.0260	0.0445	0.0644	0.0323	0.0195	0.0297	0.0239	0.0688	0.0638	0.0434
	5	0.0271	0.0283	0.0438	0.0589	0.0549	0.0403	0.0513	0.0269	0.0345	0.0282	0.0394	0.0663	0.0417
OTB	6	0.0237	0.0105	0.0123	0.0285	0.0280	0.0209	0.0189	0.0211	0.0178	0.0120	0.0220	0.0191	0.0196
	7	0.0064	0.0026	0.0030	0.0106	0.0083	0.0104	0.0041	0.0036	0.0051	0.0035	0.0059	0.0051	0.0057
	8	0.0026	0.0007	0.0007	0.0039	0.0017	0.0010	0.0007	0.0006	0.0006	0.0006	0.0014	0.0008	0.0013
	9	0.0011	0.0005	0.0002	0.0014	0.0005	0.0003	0.0001	0.0001	0.0001	0.0001	0.0003	0.0002	0.0004
	10	0.0006	0.0003	0.0000	0.0003	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0001

above average indices that follow a cohort
below average indices that follow a cohort

		1995	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*average*
	3	0.0069	0.0016	0.0076	0.0028	0.0019	0.0224	0.0042	0.0027	0.0063
	4	0.0361	0.0241	0.0663	0.0337	0.0251	0.0511	0.0909	0.0527	0.0475
Gillnet	5	0.1044	0.0702	0.1579	0.1302	0.0724	0.1333	0.1686	0.1634	0.1250
	6	0.1284	0.1062	0.1446	0.2249	0.0966	0.1087	0.1225	0.1179	0.1312
	7	0.0807	0.0793	0.0456	0.0878	0.0566	0.0574	0.0406	0.0444	0.0616
	8	0.0206	0.0177	0.0163	0.0183	0.0088	0.0114	0.0050	0.0065	0.0131
	9	0.0060	0.0034	0.0008	0.0061	0.0026	0.0026	0.0017	0.0023	0.0032
	10	0.0013	0.0003	0.0001	0.0011	0.0002	0.0000	0.0004	0.0004	0.0005

GN Indices show lack of agreement with OTB
GN Indices show agreement with OTB

Table 7. Distribution of pollock landings (t) taken by otter trawlers (Tonnage Class 2-3) in the proposed eastern management unit (4VW) along with 4Xmn.

YEAR	4Vb	4Vc	4Vn	4Vu	4Wd	4We	4Wf	4Wg	4Wh	4Wj	4Wk	4Wl	4Wm	4Wu	4Xm	4Xn	4Xl	Grand Total
1982									90	4	57	73		2	11	511		748
1983						3			64		9	66				545		688
1984		94				14			304	0	206	104			60	1525		2307
1985		58				35			10		55	31		2	73	1237		1502
1986	39	107	78	25	1				66		14	26		59	55	1454		1924
1987	12	5	46	5					12	11	86	1			96	1090		1365
1988	11	33	45	11		23			11		24			11	100	328		598
1989	48	135	40	27		23	11	9	36	149	83	125		29	46	1034		1795
1990	62	59	5				7		0	10	213	53		5	15	353	5	787
1991	0	1	7				1	1	34		492	212	2		114	2190		3053
1992	0	20	4			2		8	74	1	468	466	42		413	2723		4221
1993	9	15				0		1	1		8	1			28	1484		1546
1994		0	6						7		26	2			13	876		929
1995			2								2	24			37	315		380
1996			0								38	4	1		39	308		390
1997	1								1		88	16			33	399		538
1998			6		0				2		10	492			22	1146		1679
1999	0	0							28		447	3			11	370		860
2000										0	25				0	36		62
2001		0									56	38				22		116
2002		0									1	1				59		60
Grand Total	182	528	238	69	1	102	19	18	740	176	2409	1736	46	108	1166	18003	5	25546

Table 8. Distribution of pollock landings (t) taken by gillnet vessels (all tonnage classes) in the proposed eastern management unit (4VW) along with 4Xmn.

YEAR	4VNn	4VSc	4VSu	4Wd	4We	4Wh	4Wk	4Wl	4Wm	4Wu	4Xm	4Xn	Grand Total
1995		18	35	36		28	22	6		82	7	103	337
1996		14	3	27		11	15	19		10	15	72	187
1997		18	66	3	1	87	8	12		32	112	96	437
1998	1	13	32	10	16	55	15	47		7	93	39	326
1999			4			32	56	6		0	91	85	274
2000							26	4		4	41	24	99
2001			3				20	50	2	10	86	69	240
2002							16	1		0	32	18	67
Grand Total	1	64	143	75	16	213	178	145	2	145	477	507	1966

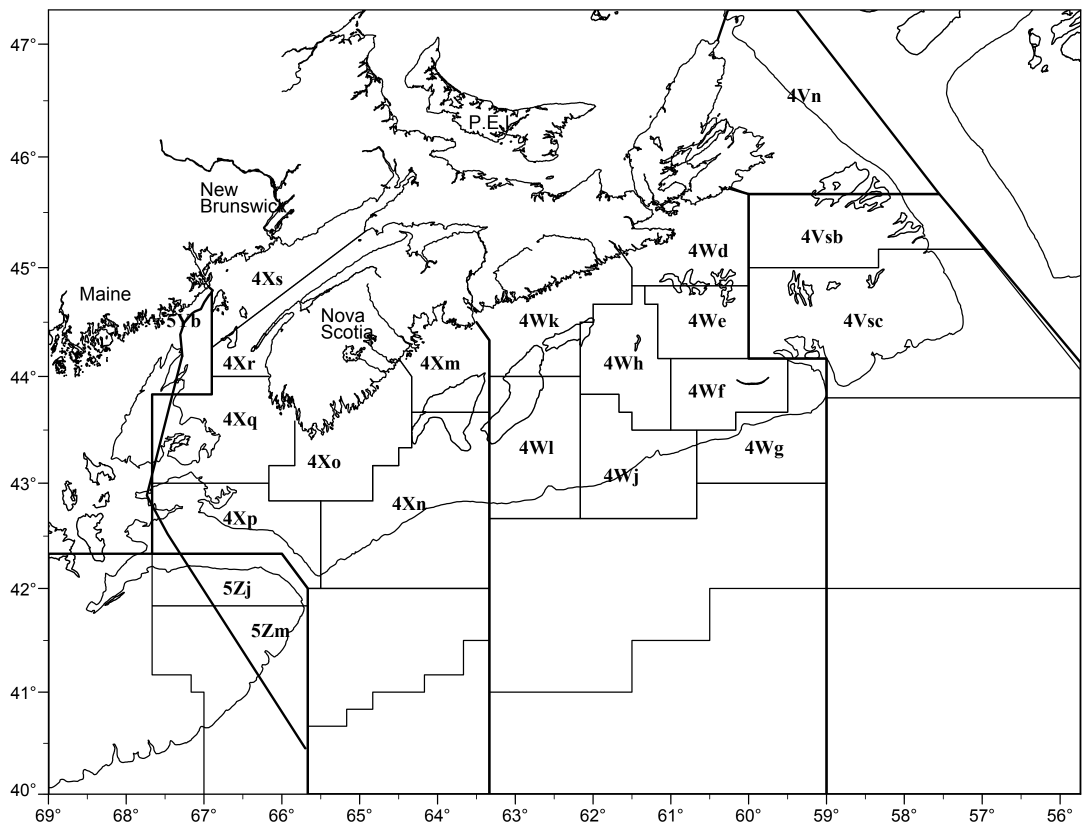


Fig. 1. Location of Statistical Unit Areas.

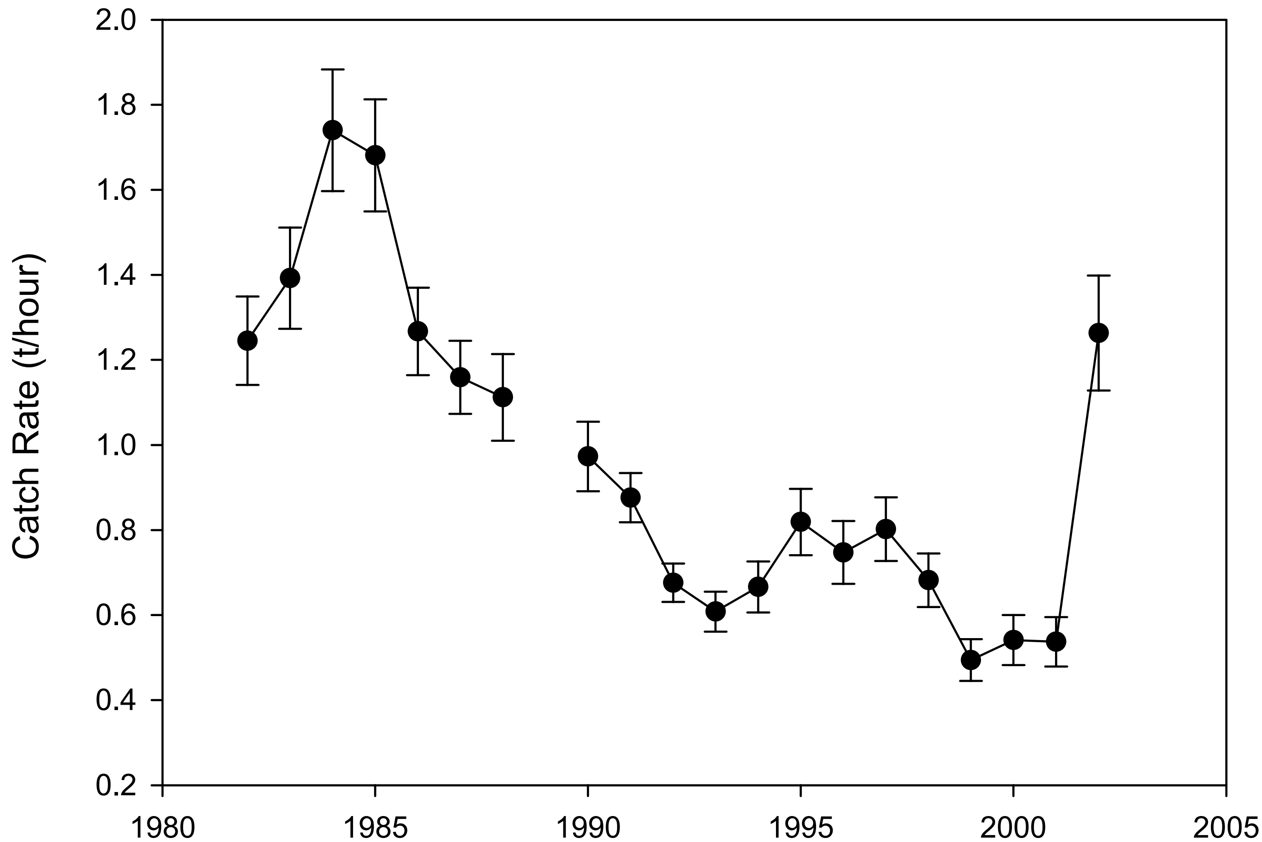


Fig. 2. Commercial fishery catch rates for mobile gear vessels of Tonnage Class 2-3, operating in NAFO Divs. 4X and 5Zc, 1982 to 2002 (Appendix 1). The data are standardized using the approach of Neilson et al. (1999), and the means are shown plus/minus one standard error.

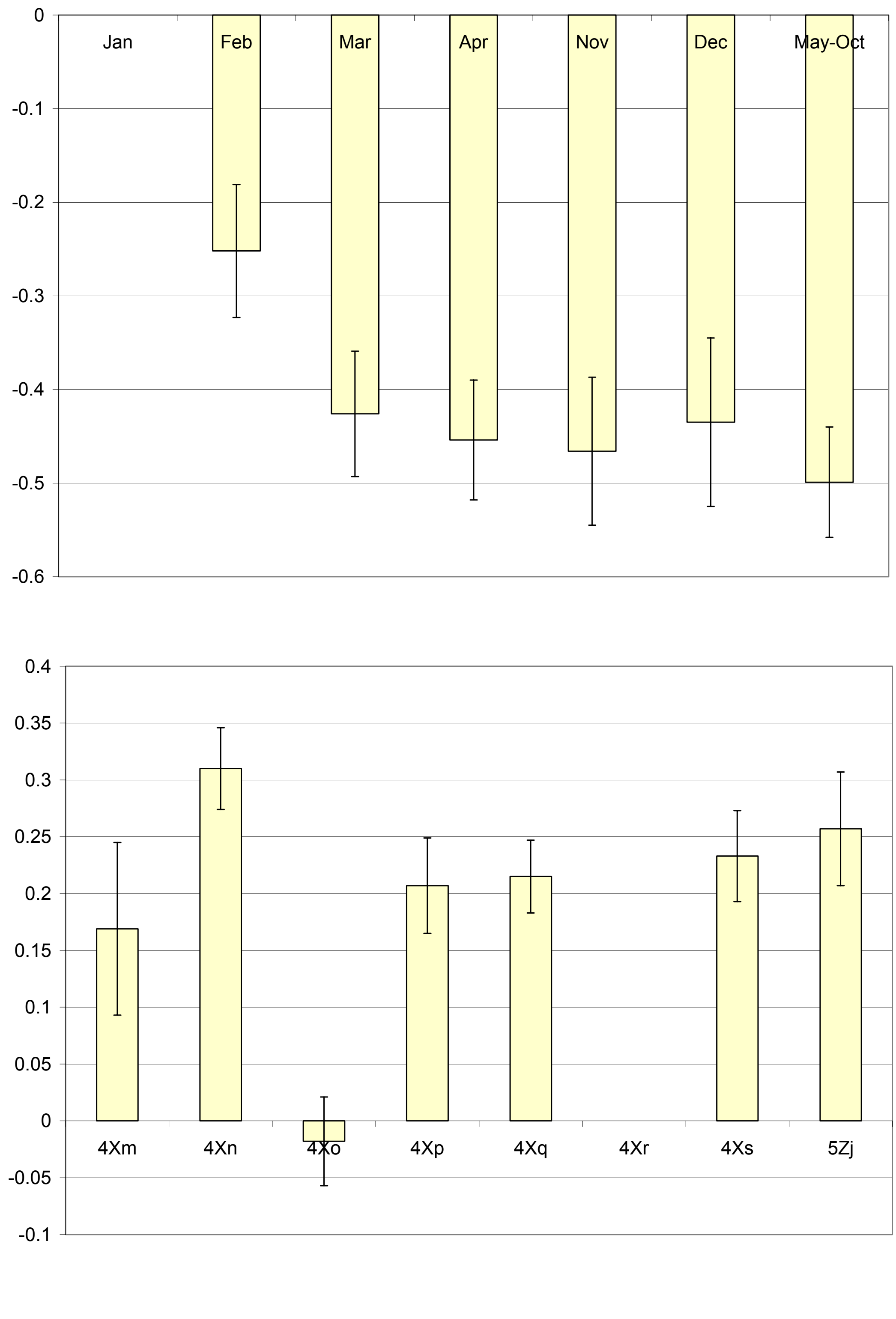
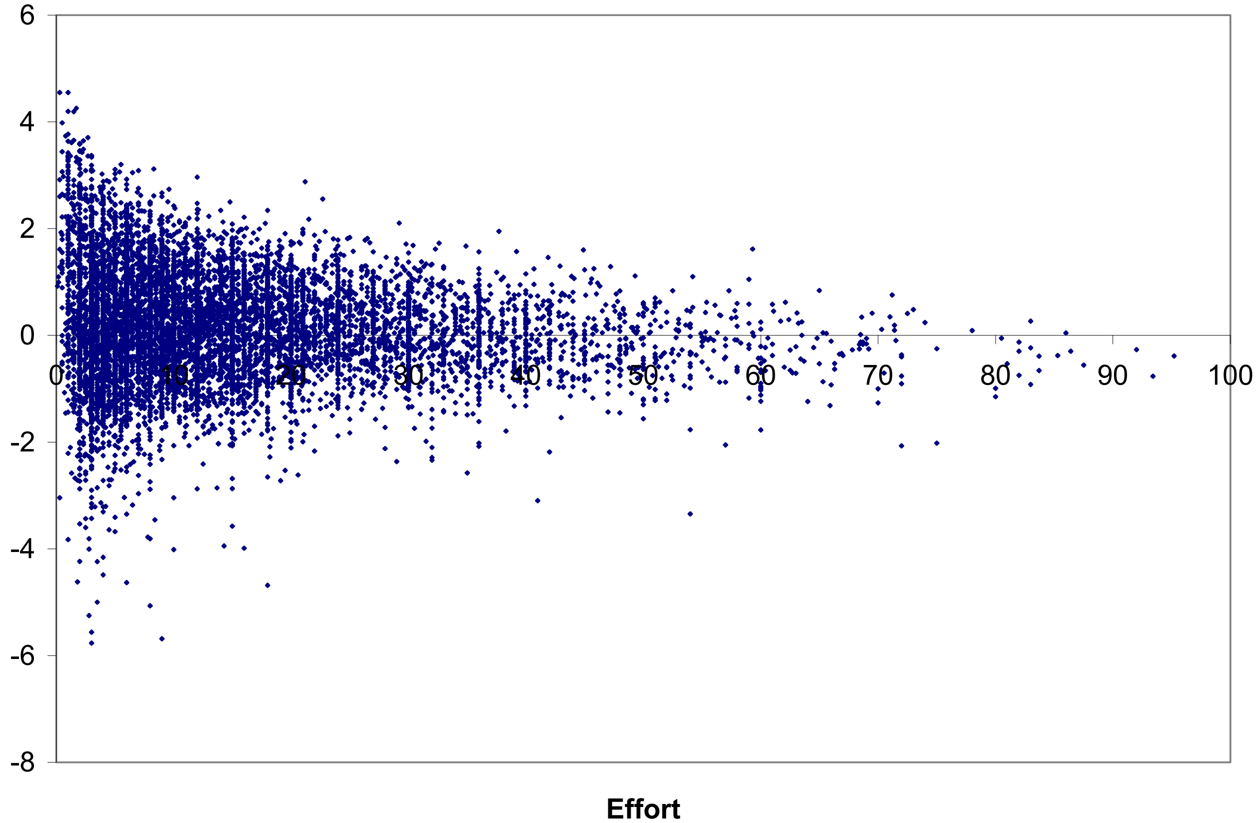


Fig. 3. Relative powers for the main effects of month (top) and unit area (bottom) in the base catch rate standardization model (Appendix 1). The standards selected were January and 4Xr.



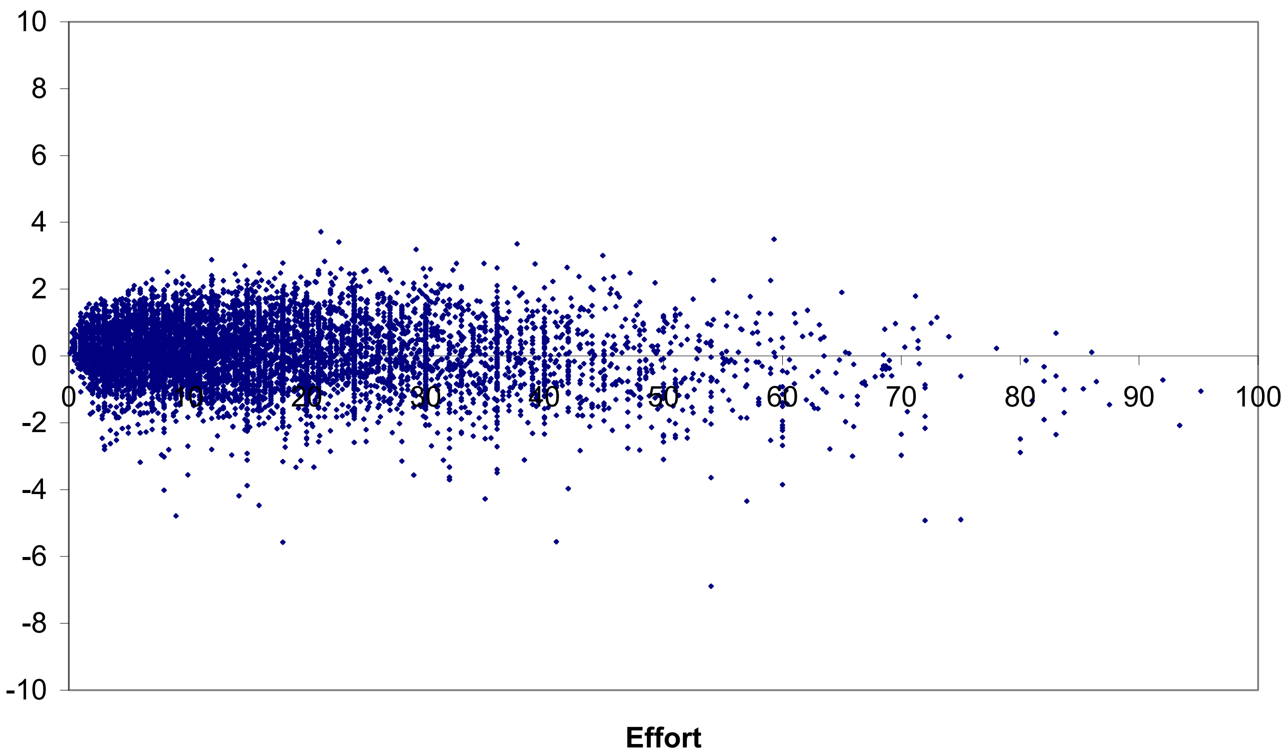


Fig. 4. Base model pattern in residuals from the fitting of catch and effort for the unweighted regression (top) and effort weighted regression (bottom).

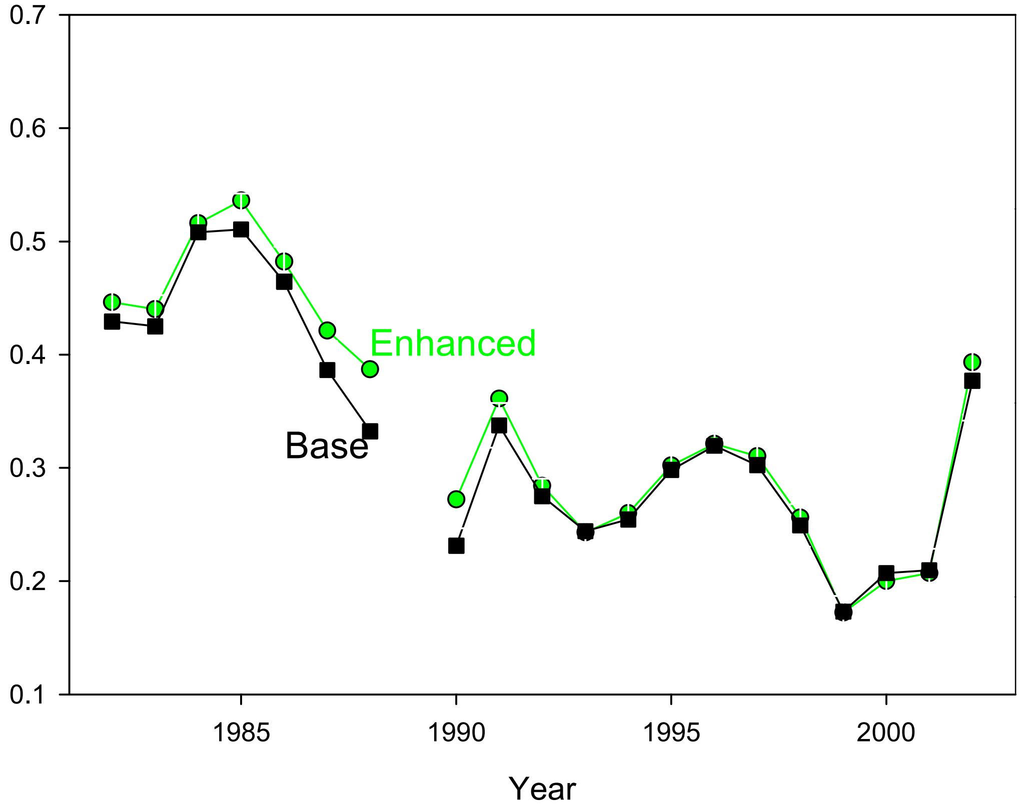


Fig. 5. Commercial fishery catch rates for mobile gear vessels of Tonnage Class 2-3, operating in NAFO Divs. 4X and 5Zc, 1982 to 2002. The base approach is that used in Neilson et al. (1999), updated to 2002 and using an effort-weighted regression (square symbols, Appendix 2), and the enhanced approach replaces Tonnage Class with Vessel (circle symbols, Appendix 3).

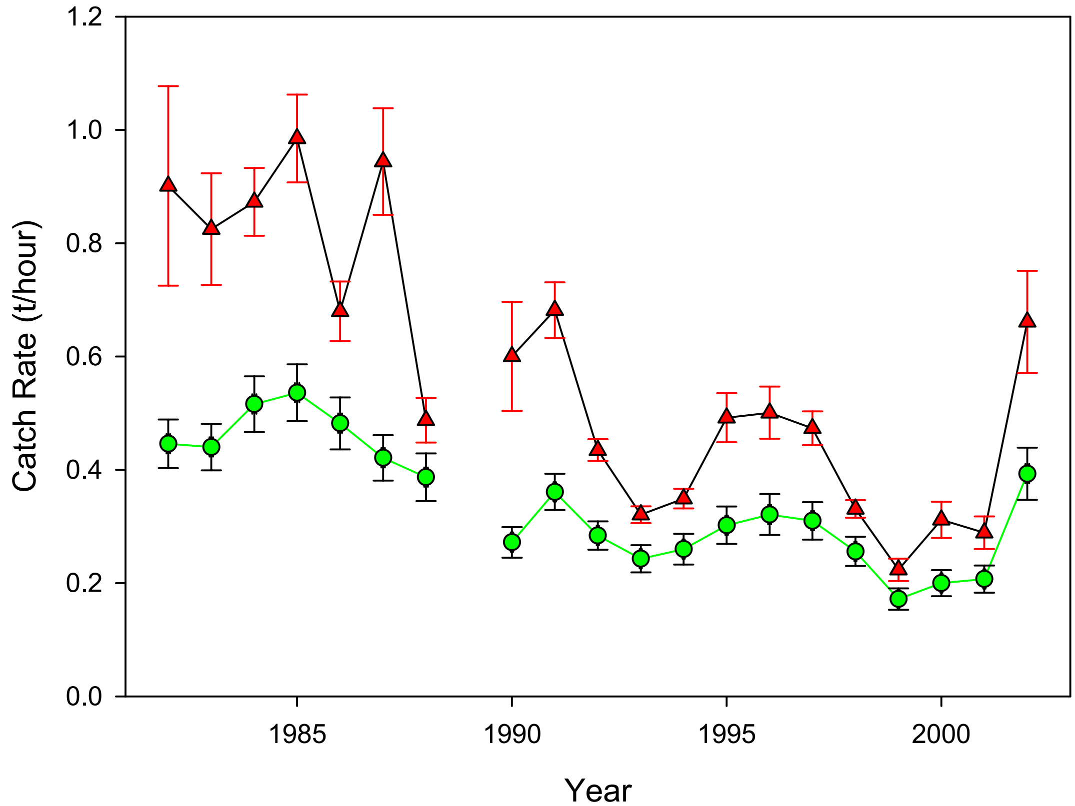


Fig. 6. Commercial fishery catch rates for mobile gear vessels of Tonnage Class 2-3, operating in NAFO Divs. 4X and 5Zc, enhanced main effects approach (Appendix 3), means shown plus/minus one standard error (lower series, circle symbols).. For comparison, the nominal data are also shown (top series, triangle symbols).

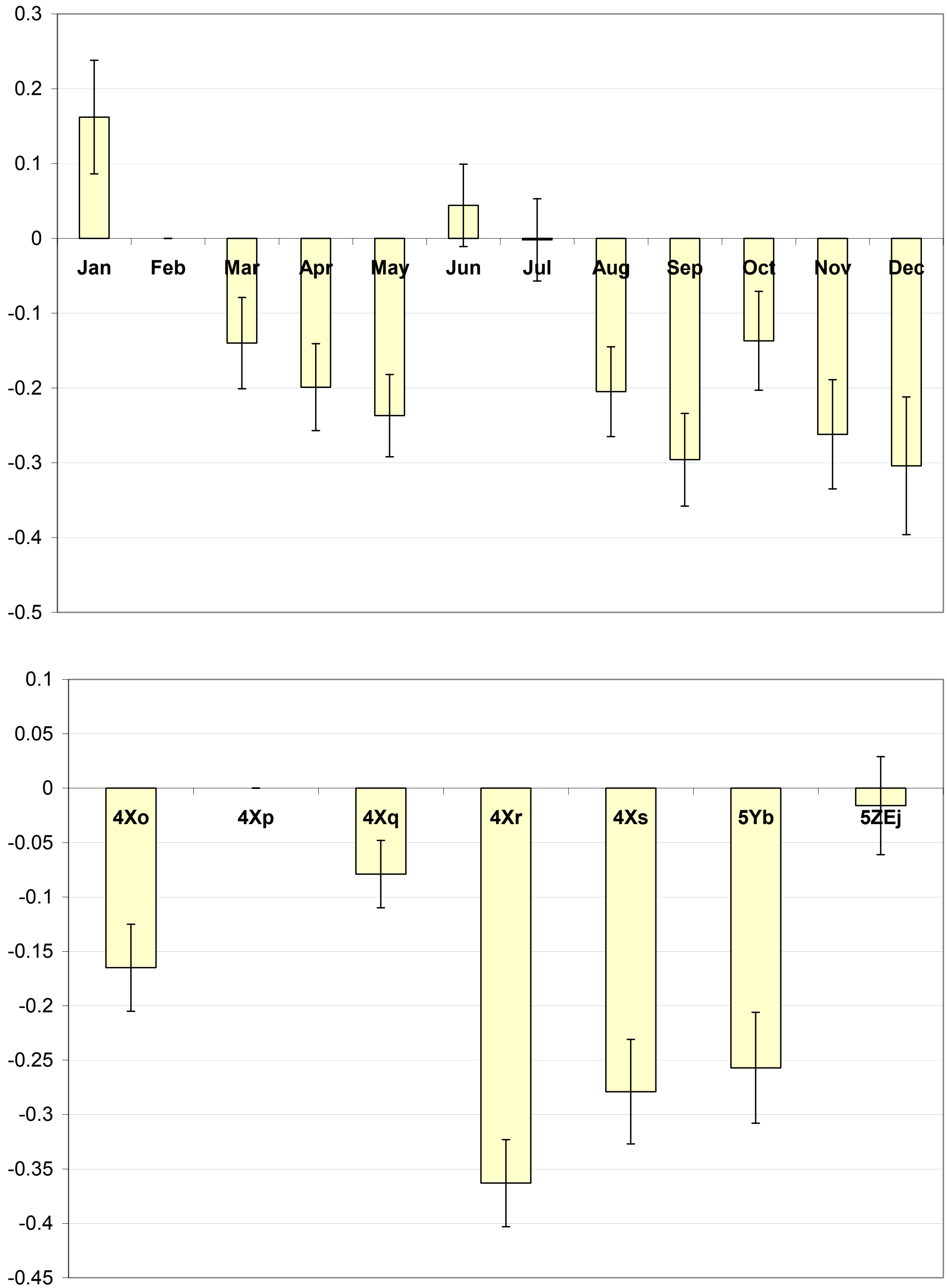


Fig. 7. Coefficients associated with different factor levels in the Enhanced main effects approach OTB catch rate standardization (Appendix 3). Coefficients from Base model (weighted) showed a similar pattern. Standards chosen were February and 4Xp.

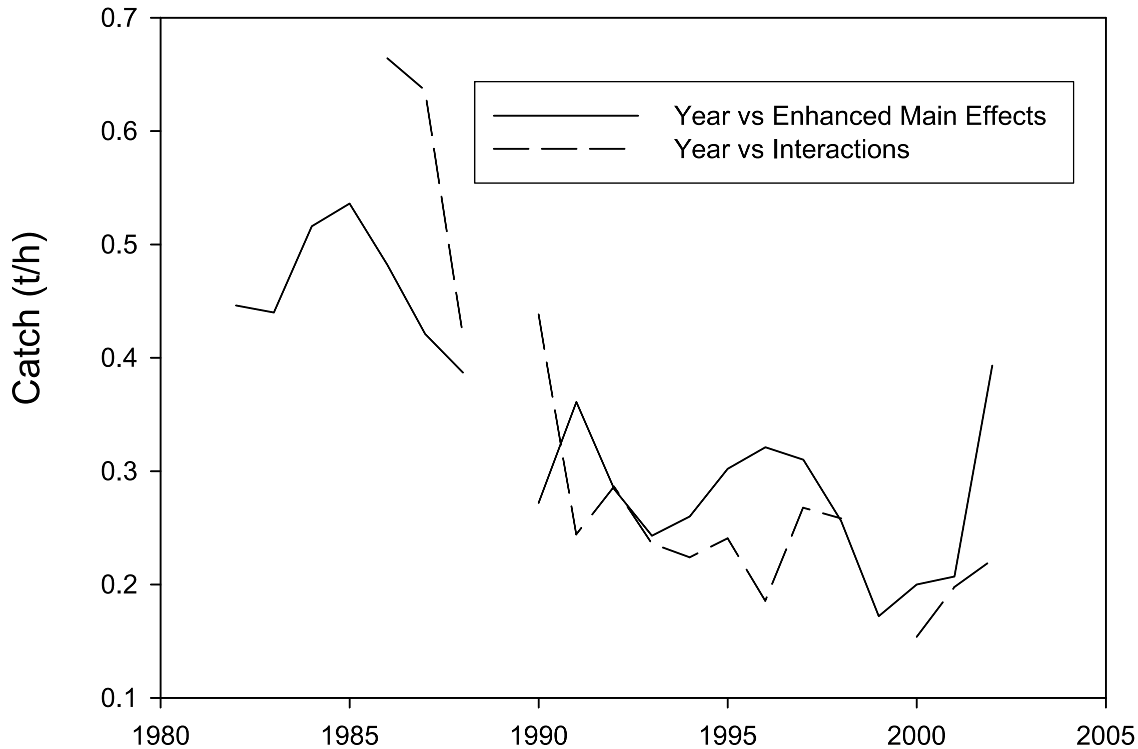


Fig. 8. Comparison of the predicted CPUE obtained from the main effects OTB model described in Appendix 3 and the interactions OTB model described in Appendix 4.

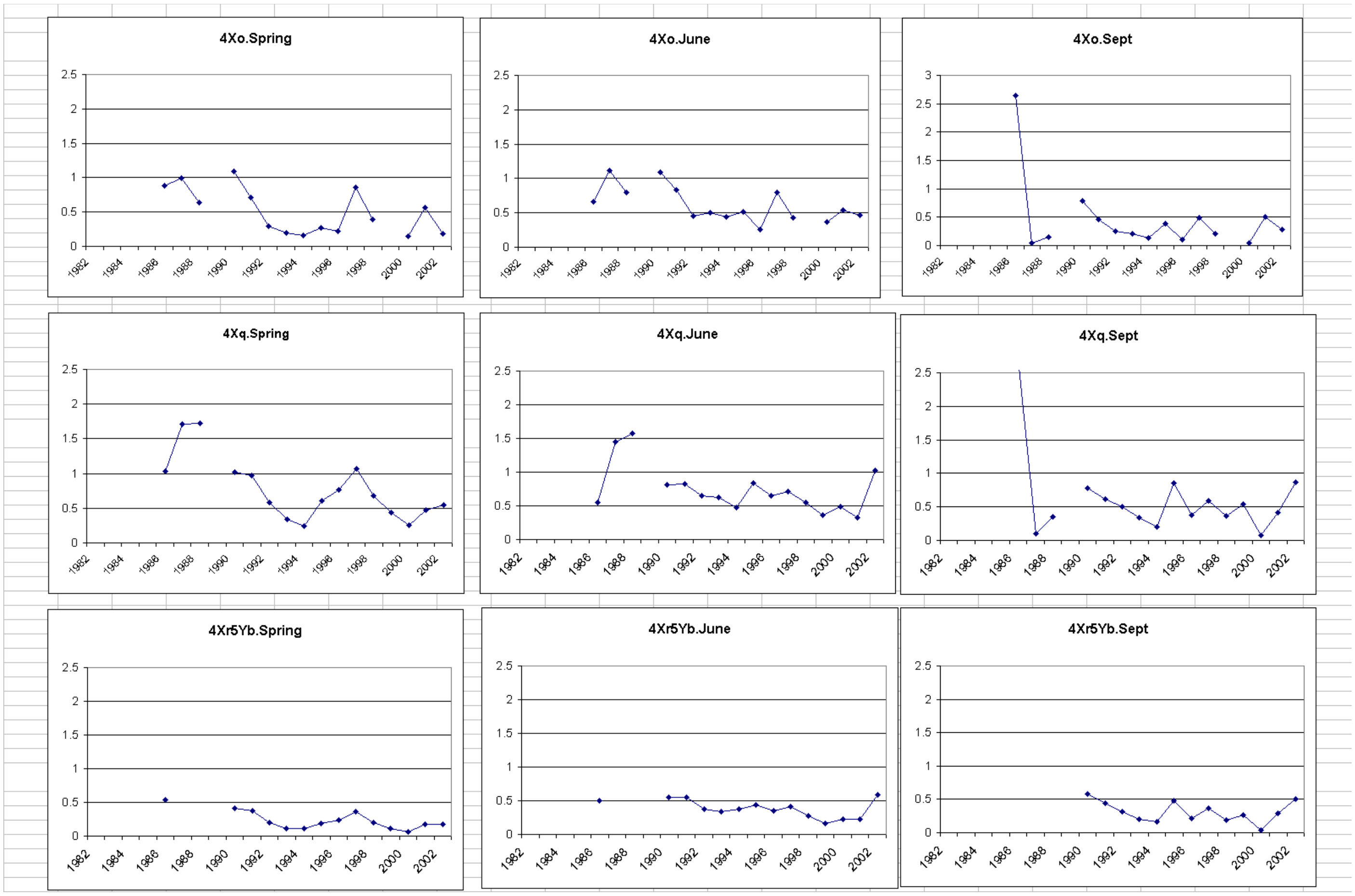


Fig. 9. Predictions from the interactions OTB CPUE model described in Appendix 4 for various combinations of area and month.

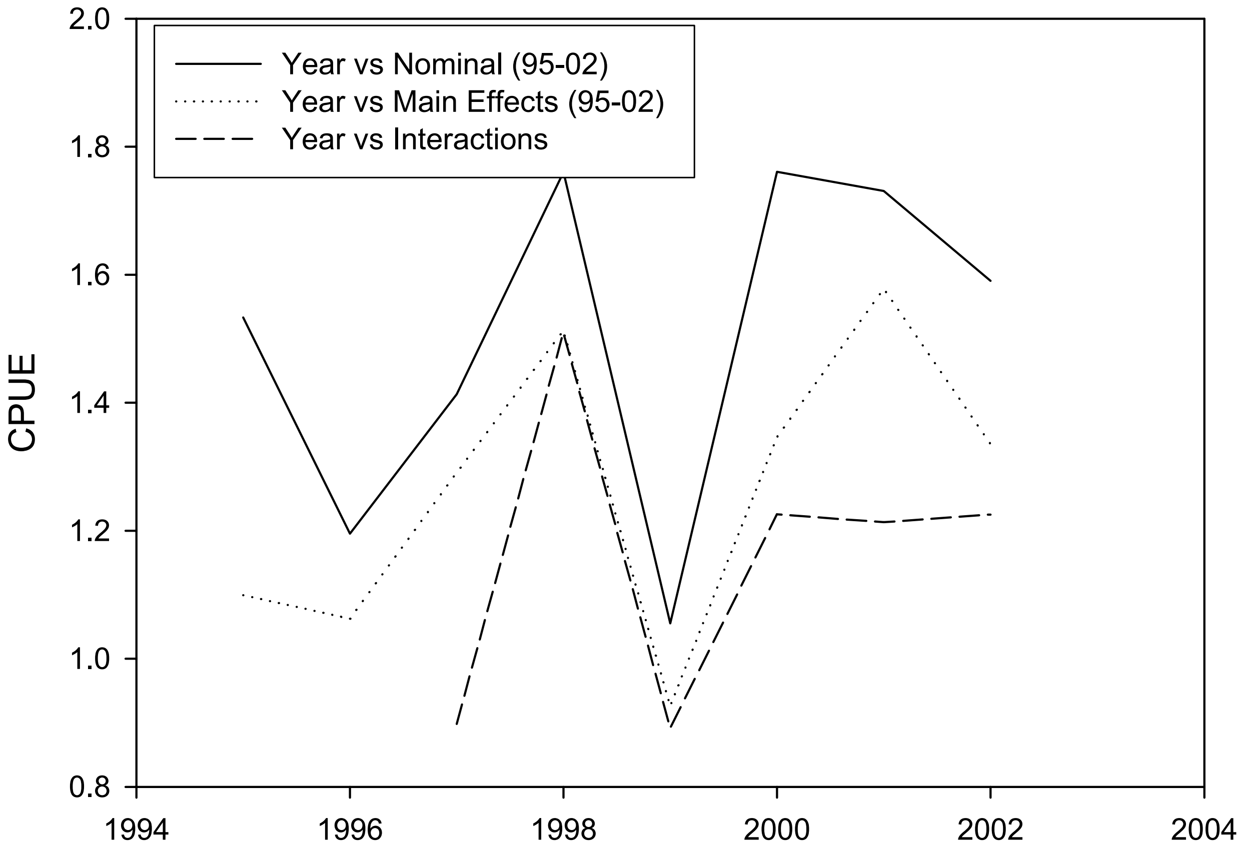


Fig. 10. Comparison of gill net catch rates (both main effects and interactions models, 1995 to 2002) compared with nominal catch rates.

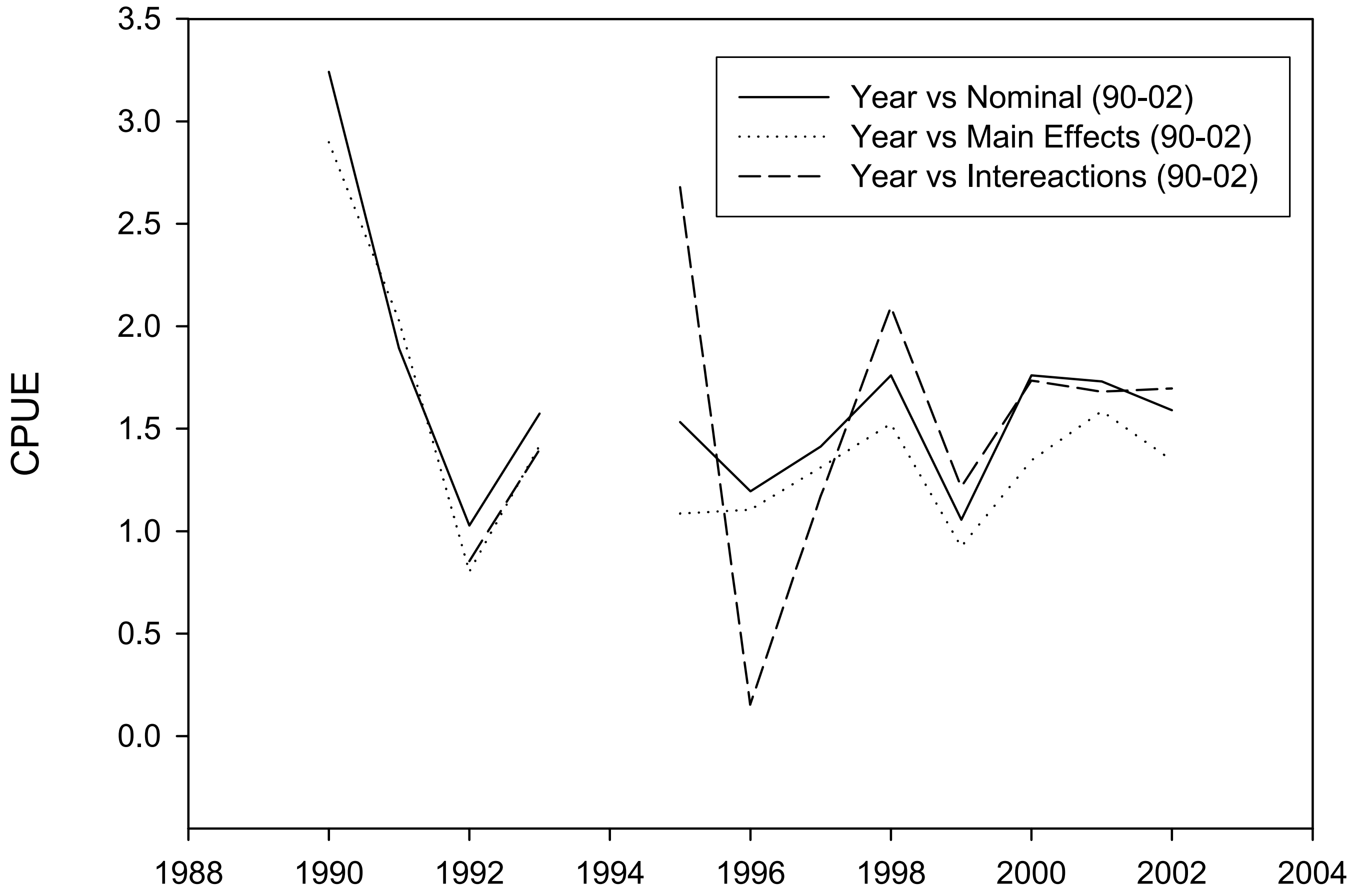


Fig. 11. Comparison of gill net catch rates (both main effects and interactions models, 1990 to 2002) compared with nominal catch rates.

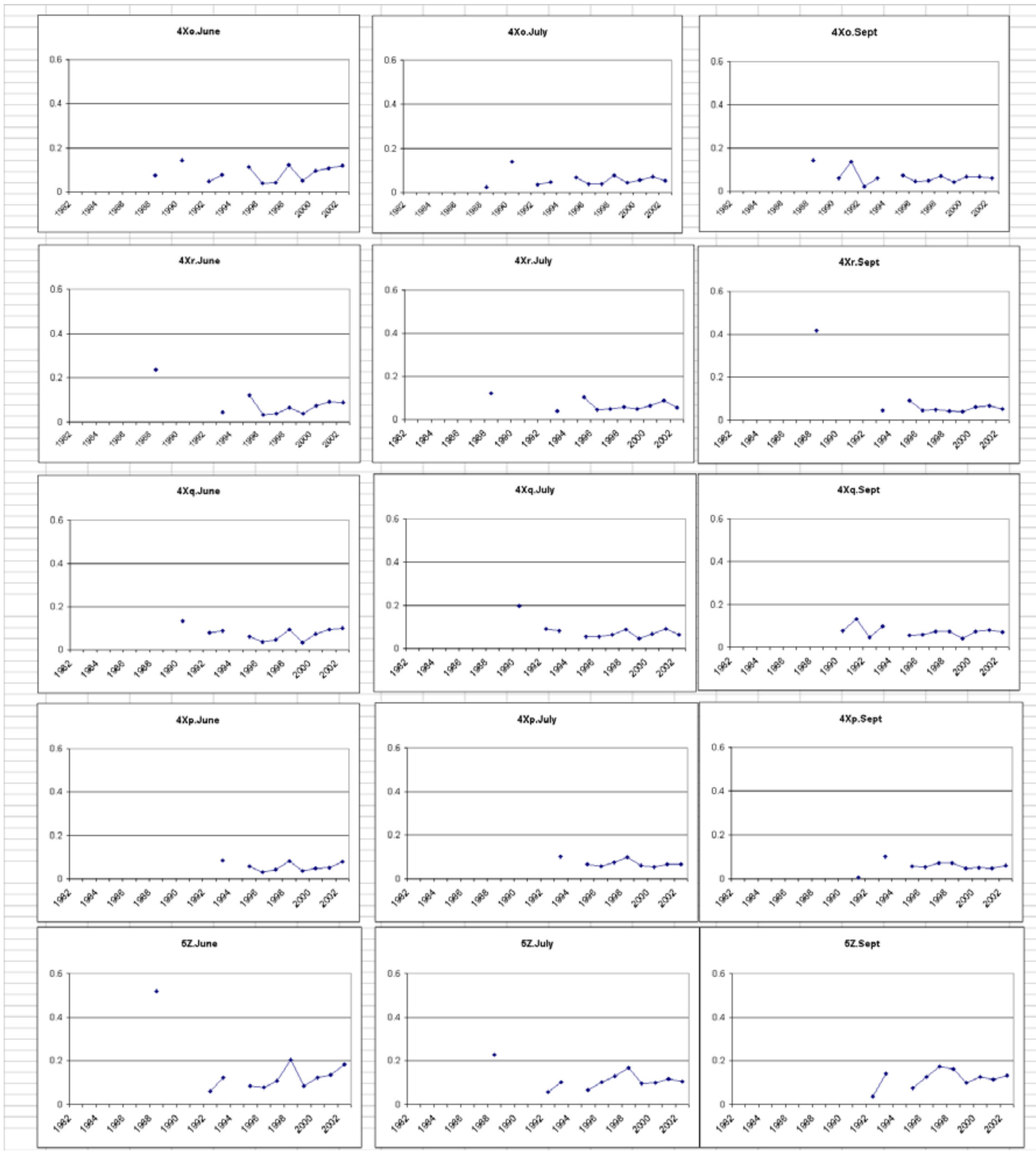


Fig. 12. Predictions from the interactions CPUE model for gillnets described in Appendix 5 for various combinations of area and month. A single high value in 5Z 1988 is not plotted to avoid compression of the scale in the plots.

Appendix 1

TC 2-3 Pollock Catch Rate Standardization
Using Method from Last Full Assessment

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R............. 0.406
MULTIPLE R SQUARED..... 0.165

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	1.690E4	1.690E4	
REGRESSION	34	2.394E3	7.040E1	66.046
Year	19	8.915E2	4.692E1	44.020
Tonnage Class	1	8.060E2	8.060E2	756.119
Month	6	9.203E1	1.534E1	14.390
Area	7	1.467E2	2.095E1	19.655
Mesh Type	1	3.703E0	3.703E0	3.474
RESIDUALS	11366	1.212E4	1.066E0	
TOTAL	11401	3.141E4		

REGRESSION COEFFICIENTS

CATEGORY	VARIABLE	COEFFICIENT	STD. ERROR	NO. OBS.
1982	INTERCEPT	¯0.311	0.083	11401
3				
1				
4Xr				
D				
1983	1	0.112	0.080	330
1984	2	0.335	0.076	421
1985	3	0.300	0.073	497
1986	4	0.017	0.077	394
1987	5	¯0.072	0.073	530
1988	6	¯0.112	0.089	236
1990	7	¯0.246	0.079	348
1991	8	¯0.353	0.062	1583
1992	9	¯0.611	0.062	1629
1993	10	¯0.717	0.072	1123
1994	11	¯0.624	0.086	658
1995	12	¯0.417	0.091	461
1996	13	¯0.510	0.095	367
1997	14	¯0.439	0.089	611
1998	15	¯0.601	0.087	765
1999	16	¯0.923	0.095	377
2000	17	¯0.831	0.105	232
2001	18	¯0.838	0.105	225
2002	19	0.017	0.102	270
2	20	¯0.589	0.021	3636
2	21	¯0.252	0.071	516
3	22	¯0.426	0.067	763
4	23	¯0.454	0.064	1174
11	24	¯0.466	0.079	347
12	25	¯0.435	0.090	224
13	26	¯0.499	0.059	8012
4Xm	27	0.169	0.076	218
4Xp	28	0.207	0.042	1279
4Xo	29	¯0.018	0.039	1352
4Xn	30	0.310	0.036	1976
4Xq	31	0.215	0.032	3009
4Xs	32	0.233	0.040	1086
5Zj	33	0.257	0.050	577
S	34	¯0.103	0.055	4543

PREDICTED CATCH RATE

	LN TRANSFORM		RETRANSFORMED			
YEAR	MEAN	S.E.	MEAN	S.E.	CATCH	EFFORT
1982	¯0.3107	0.0069	1.245	0.104	3684	2960
1983	¯0.1987	0.0073	1.392	0.119	4442	3191
1984	0.0245	0.0068	1.740	0.143	6657	3825
1985	¯0.0103	0.0062	1.681	0.132	7811	4645
1986	¯0.2933	0.0067	1.267	0.103	4459	3520
1987	¯0.3826	0.0055	1.159	0.086	3605	3110
1988	¯0.4223	0.0085	1.112	0.102	1370	1232
1990	¯0.5567	0.0071	0.973	0.082	1708	1755
1991	¯0.6632	0.0044	0.876	0.058	8666	9893
1992	¯0.9220	0.0045	0.676	0.045	7793	11524
1993	¯1.0277	0.0060	0.608	0.047	4924	8100
1994	¯0.9351	0.0082	0.666	0.060	2629	3946
1995	¯0.7282	0.0092	0.819	0.078	2328	2843
1996	¯0.8202	0.0100	0.747	0.074	1790	2397
1997	¯0.7493	0.0089	0.802	0.075	3462	4317
1998	¯0.9120	0.0087	0.682	0.063	5123	7516
1999	¯1.2341	0.0099	0.494	0.049	1518	3075
2000	¯1.1413	0.0119	0.541	0.059	945	1747
2001	¯1.1486	0.0119	0.537	0.058	1035	1927
2002	¯0.2934	0.0115	1.263	0.135	2448	1938

Appendix 2

TC 2-3 Pollock Catch Rate Standardization
Base Approach (Weighted Regression, Five Year Experience in Fishery)

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R............. 0.460
MULTIPLE R SQUARED..... 0.212

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	1.829E4	1.829E4	
REGRESSION	38	1.771E3	4.662E1	60.783
Year	19	5.634E2	2.965E1	38.663
Month	11	1.356E2	1.233E1	16.074
Tonnage Class	1	5.936E2	5.936E2	773.973
Area	6	9.059E1	1.510E1	19.687
Mesh Type	1	2.262E¯1	2.262E¯1	0.295
RESIDUALS	8592	6.589E3	7.669E¯1	
TOTAL	8631	2.665E4		

REGRESSION COEFFICIENTS

CATEGORY	VARIABLE	COEFFICIENT	STD. ERROR	NO. OBS.
1982 2 2 4Xp D	INTERCEPT	¯1.107	0.069	8631
1983	1	¯0.011	0.060	251
1984	2	0.175	0.059	282
1985	3	0.180	0.056	374
1986	4	0.082	0.064	237
1987	5	¯0.108	0.066	300
1988	6	¯0.263	0.079	133
1990	7	¯0.650	0.068	237
1991	8	¯0.250	0.054	1098
1992	9	¯0.464	0.053	1139
1993	10	¯0.589	0.064	967
1994	11	¯0.545	0.077	671
1995	12	¯0.379	0.081	416
1996	13	¯0.304	0.085	323
1997	14	¯0.365	0.077	545
1998	15	¯0.568	0.076	664
1999	16	¯0.962	0.084	272
2000	17	¯0.763	0.095	178
2001	18	¯0.752	0.095	164
2002	19	¯0.131	0.094	174
3	20	¯0.144	0.064	420
4	21	¯0.176	0.060	719
5	22	¯0.214	0.057	1438
6	23	0.058	0.057	1498
7	24	¯0.029	0.057	1694
8	25	¯0.209	0.062	842
9	26	¯0.268	0.064	667
10	27	¯0.073	0.069	426
11	28	¯0.228	0.077	238
1	29	0.159	0.079	228
12	30	¯0.238	0.097	140
3	31	0.537	0.019	6040
4Xo	32	¯0.286	0.038	1154
4Xq	33	¯0.097	0.032	2716
4Xr	34	¯0.272	0.038	1678
5Yb	35	¯0.220	0.051	447
5ZEj	36	0.000	0.047	512
4Xs	37	¯0.175	0.044	982
S	38	¯0.029	0.054	4028

PREDICTED CATCH RATE

	LN TRANSFORM		RETRANSFORMED			
YEAR	MEAN	S.E.	MEAN	S.E.	CATCH	EFFORT
----	----	----	----	----	-----	------
1982	¯1.1071	0.0048	0.484	0.033	2497	5161
1983	¯1.1177	0.0045	0.479	0.032	3418	7139
1984	¯0.9323	0.0045	0.576	0.039	4561	7913
1985	¯0.9273	0.0041	0.579	0.037	5885	10158
1986	¯1.0252	0.0048	0.525	0.036	2464	4692
1987	¯1.2154	0.0049	0.434	0.030	2011	4632
1988	¯1.3703	0.0069	0.371	0.031	793	2135
1990	¯1.7572	0.0052	0.253	0.018	1118	4427
1991	¯1.3572	0.0036	0.377	0.023	5132	13612
1992	¯1.5714	0.0036	0.304	0.018	4434	14570
1993	¯1.6966	0.0050	0.268	0.019	3463	12907
1994	¯1.6520	0.0066	0.280	0.023	2647	9442
1995	¯1.4861	0.0071	0.331	0.028	2085	6302
1996	¯1.4109	0.0081	0.356	0.032	1547	4339
1997	¯1.4719	0.0068	0.336	0.028	2994	8921
1998	¯1.6748	0.0062	0.274	0.022	3825	13956
1999	¯2.0689	0.0079	0.185	0.016	885	4793
2000	¯1.8701	0.0092	0.225	0.021	643	2856
2001	¯1.8590	0.0098	0.228	0.022	687	3019
2002	¯1.2385	0.0095	0.423	0.041	1161	2743

Appendix 3

TC 2-3 Pollock Catch Rate Standardization
Enhanced Approach (Weighted, Five Year Experience, CFV replaces Tonnage Class)

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R............. 0.556
MULTIPLE R SQUARED..... 0.309

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	1.829E4	1.829E4	
REGRESSION	198	2.585E3	1.306E1	19.064
Vessel	161	1.408E3	8.743E0	12.764
Year	19	4.235E2	2.229E1	32.539
Month	11	1.502E2	1.365E1	19.932
Area	6	8.409E1	1.401E1	20.461
Mesh Type	1	2.688E¯1	2.688E¯1	0.392
RESIDUALS	8432	5.775E3	6.849E¯1	
TOTAL	8631	2.665E4		

REGRESSION COEFFICIENTS

CATEGORY	VARIABLE	COEFFICIENT	STD. ERROR	NO. OBS.
1065 1982 2 4Xp D	INTERCEPT	¯1.146	0.097	8631
1983	162	¯0.013	0.059	251
1984	163	0.147	0.058	282
1985	164	0.184	0.056	374
1986	165	0.078	0.064	237
1987	166	¯0.057	0.065	300
1988	167	¯0.141	0.081	133
1990	168	¯0.494	0.068	237
1991	169	¯0.211	0.054	1098
1992	170	¯0.451	0.053	1139
1993	171	¯0.607	0.065	967
1994	172	¯0.537	0.077	671
1995	173	¯0.388	0.081	416
1996	174	¯0.328	0.086	323
1997	175	¯0.362	0.079	545
1998	176	¯0.553	0.078	664
1999	177	¯0.953	0.085	272
2000	178	¯0.798	0.097	178
2001	179	¯0.763	0.096	164
2002	180	¯0.125	0.095	174
3	181	¯0.140	0.061	420
4	182	¯0.199	0.058	719
5	183	¯0.237	0.055	1438
6	184	0.044	0.055	1498
7	185	¯0.002	0.055	1694
8	186	¯0.205	0.060	842
9	187	¯0.296	0.062	667
10	188	¯0.137	0.066	426
11	189	¯0.262	0.073	238
1	190	0.162	0.076	228
12	191	¯0.304	0.092	140
4Xo	192	¯0.165	0.040	1154
4Xq	193	¯0.079	0.031	2716
4Xr	194	¯0.363	0.040	1678
5Yb	195	¯0.257	0.051	447
5ZEj	196	¯0.016	0.045	512
4Xs	197	¯0.279	0.048	982
S	198	¯0.034	0.054	4028

PREDICTED CATCH RATE

	LN TRANSFORM		RETRANSFORMED			
YEAR	MEAN	S.E.	MEAN	S.E.	CATCH	EFFORT
1982	¯1.1458	0.0094	0.446	0.043	2497	5602
1983	¯1.1584	0.0089	0.440	0.041	3418	7763
1984	¯0.9992	0.0091	0.516	0.049	4561	8836
1985	¯0.9615	0.0087	0.536	0.050	5885	10976
1986	¯1.0674	0.0090	0.482	0.046	2464	5110
1987	¯1.2024	0.0092	0.421	0.040	2011	4774
1988	¯1.2869	0.0120	0.387	0.042	793	2051
1990	¯1.6402	0.0096	0.272	0.027	1118	4112
1991	¯1.3569	0.0080	0.361	0.032	5132	14209
1992	¯1.5972	0.0081	0.284	0.025	4434	15612
1993	¯1.7524	0.0097	0.243	0.024	3463	14252
1994	¯1.6833	0.0111	0.260	0.027	2647	10173
1995	¯1.5340	0.0117	0.302	0.033	2085	6904
1996	¯1.4738	0.0125	0.321	0.036	1547	4825
1997	¯1.5076	0.0113	0.310	0.033	2994	9653
1998	¯1.6984	0.0107	0.256	0.026	3825	14921
1999	¯2.0993	0.0120	0.172	0.019	885	5159
2000	¯1.9439	0.0130	0.200	0.023	643	3210
2001	¯1.9084	0.0137	0.207	0.024	687	3311
2002	¯1.2705	0.0136	0.393	0.046	1161	2957

Appendix 4

TC 2-3 Pollock Catch Rate Standardization
Interaction Model (tons/hr, Ten Consecutive Year Experience)

ffort unit	ubtrip tons/hr
idex	en consecutive years directing
iitial terms	'EAR,MONTH,AREA, [CFV]

lote: YEARs 1986-2002, excluding 1989
lote: AREA modelled as 4Xo,4Xp,4Xq,4Xr5Yb,4Xs,5Z
lote: MONTHs February/March/April combined.
lote: CFV modelled as main effect only. The intent is to remove vessel effects, not interpret them.

NTERACTION MODEL

	Df	Deviance	Resid. Df	Resid. Dev	F Value	Pr(F)
NULL	NA	NA	4519	5135.242	NA	NA
cfv	34	517.4179	4485	4617.824	18.68637	0.000000e+000
yland	15	348.6338	4470	4269.191	28.53912	0.000000e+000
mland	9	164.5061	4461	4104.684	22.44409	0.000000e+000
AREA	5	105.9094	4456	3998.775	26.00919	0.000000e+000
yland:mland	117	279.9389	4339	3718.836	2.937919	0.000000e+000
yland:AREA	67	182.5382	4272	3536.298	3.345349	0.000000e+000
mland:AREA	41	90.57283	4231	3445.725	2.712542	2.896125e-008

power	0.814
dispersion	32.9

Appendix 5

Gillnet Pollock Catch Rate Standardization
Interaction Model (tons/net, Five Year Experience)

ffort unit ubtrip tons/net
ıdex ve years directing
ıitial terms 'EAR,MONTH,AREA, [CFV]
lote: YEARs 1988-2002, excluding 1989 and 1994
lote: AREA modelled as 4Xo,4Xp,4Xq,4Xr,4Xs,5Yb,5Z
lote: MONTHs November/December/February/March removed.
lote: CFV modelled as main effect only. The intent is to remove vessel effects, not interpret them.

Gear Count Interaction Model

	Df	Deviance	Resid. Df	Resid. Dev	F Value	Pr(F)
NULL	NA	NA	4749	3383.49	NA	NA
cfv	50	687.1167	4699	2696.373	29.47044	0.000000e+000
yland	12	210.9437	4687	2485.429	37.69739	0.000000e+000
AREA	6	54.85267	4681	2430.577	19.60526	0.000000e+000
mland	6	18.59492	4675	2411.982	6.646132	5.171351e-007
yland:mland	66	140.6107	4609	2271.371	4.568781	0.000000e+000
yland:AREA	55	123.7768	4554	2147.594	4.82617	0.000000e+000
mland:AREA	33	39.41063	4521	2108.184	2.561094	2.472671e-006

ispersion 0.466
ower 37.7

Gear Count Main Effects Model

	Df	Deviance	Resid. Df	Resid. Dev	F Value	Pr(F)
NULL	NA	NA	4749	3383.49	NA	NA
cfv	50	687.1167	4699	2696.373	26.63594	0.00000e+000
yland	12	210.9437	4687	2485.429	34.07163	0.00000e+000
AREA	6	54.85267	4681	2430.577	17.71961	0.00000e+000
mland	6	18.59492	4675	2411.982	6.006902	2.85896e-006

ispersion 0.516
ower 28.7

PREDICTION AS THE MODEL MEAN (Interaction Model) - # Nets

	YEAR	Catch	Predicted.Mean.CPUE	Variance	Standardized.Effort
1986	1986				
1987	1987				
1	1988				
1989	1989				
1990	1990	2994.54	2.835754	6.738532	1.055994e+003
1991	1991				
1992	1992	2442.141	0.8533	0.410835	2.861997e+003
1993	1993	2285.122	1.396821	1.297915	1.635944e+003
1994	1994				
1995	1995	1523.757	2.67919	8.189454	5.687379e+002
1996	1996	717.714	0.154193	0.520395	4.654634e+003
1997	1997	1376.146	1.170761	0.394837	1.175429e+003
1998	1998	2762.329	2.094689	3.528558	1.318730e+003
1999	1999	1020.037	1.216463	0.561282	8.385269e+002
2000	2000	1406.678	1.734432	2.297433	8.110309e+002
2001	2001	1347.035	1.679516	2.110605	8.020375e+002
2002	2002	1110.433	1.69692	2.165087	6.543815e+002

PREDICTION AS THE MODEL MEAN (Main Effects) - # Nets

	YEAR	Catch	Predicted.Mean.CPUE	Variance	Standardized.Effort
1986	1986				
1987	1987				
1988	1988	2251.123	2.622329	5.192977	858.4441
1989	1989				
1990	1990	2994.54	2.89903	6.411261	1032.9454
1991	1991	2286.741	2.030025	2.935772	1126.4598
1992	1992	2442.141	0.802522	0.108943	3043.085
1993	1993	2285.122	1.416811	0.867061	1612.8634
1994	1994				
1995	1995	1523.757	1.08574	0.037583	1403.4277
1996	1996	717.714	1.104561	0.051167	649.7733
1997	1997	1376.146	1.310423	0.298702	1050.1539
1998	1998	2762.329	1.52435	1.245147	1812.1359
1999	1999	1020.037	0.923547	0.034816	1104.4781
2000	2000	1406.678	1.345307	0.533883	1045.6189
2001	2001	1347.035	1.585451	1.45043	849.6226
2002	2002	1110.433	1.345534	0.536819	825.2728

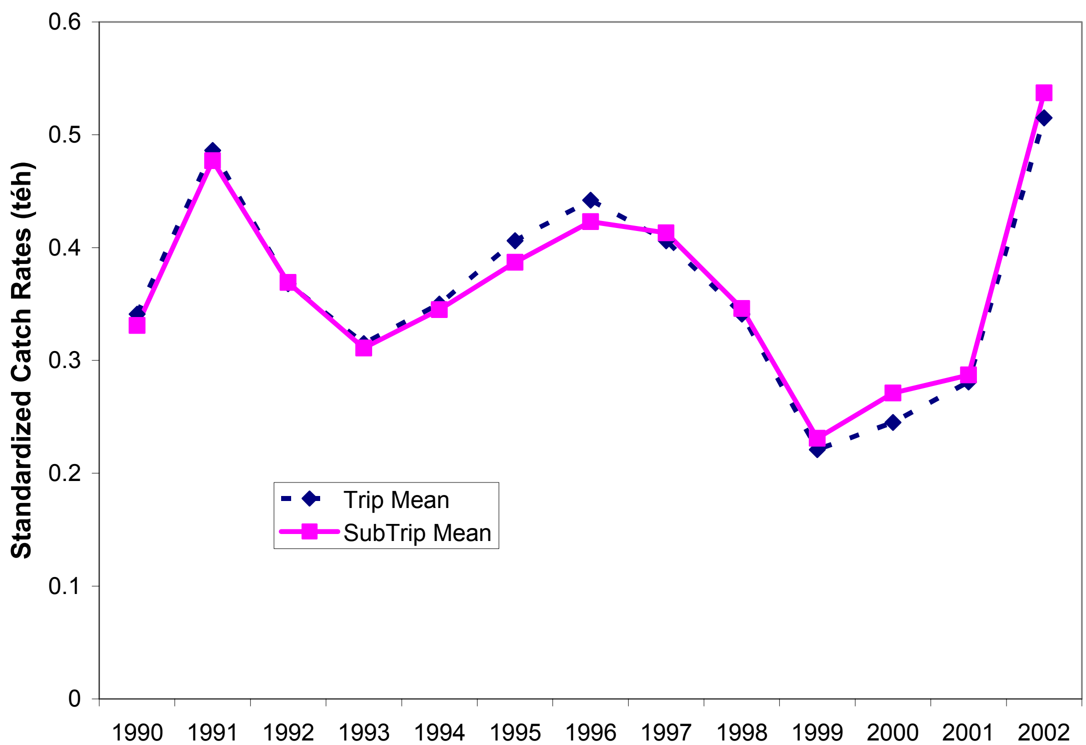
Appendix 6

Authors' Responses to Reviewers' Suggestions

The questions listed below represent the authors' interpretation of the most significant or potentially influential comments that were raised during the review of the working paper. Furthermore, this document contains those responses considered feasible by the authors to provide within the constraints of available resources, and allowing for timely completion of the Research Document as part of the Framework Assessment Process. As such, this Appendix is not meant to be an exhaustive response to all questions raised during the review. A complete listing of all questions and concerns may be found in the draft Proceedings of the Framework Assessment, circulated to participants in the June 16-18 Framework Assessment Meeting.

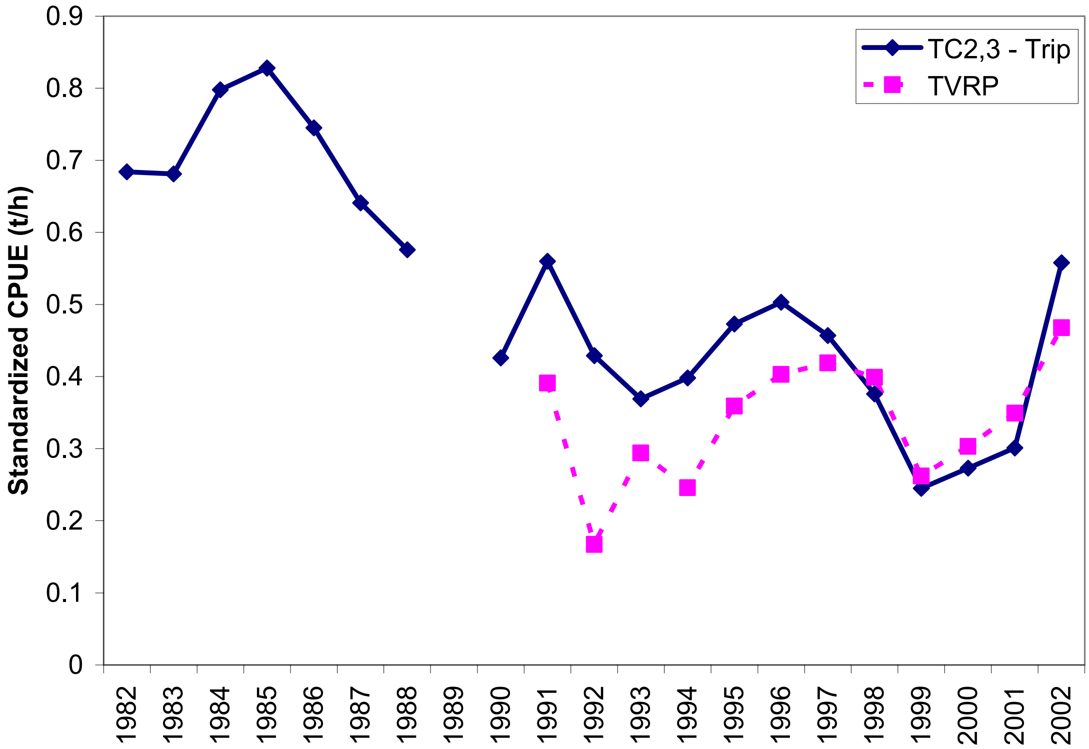
Q1. **What is the impact of subtrip versus trip level aggregation upon the interpretation of the catch rate series?**

A1. Given the slight differences in the series illustrated below, we concluded that using either level of aggregation for the catch and effort data had no appreciable effect on the trend in standardized catch rates. However, the data available from 1982 to 1988 are summarized to the trip level only. To ensure a consistent approach in the time series, we will employ the trip level of aggregation throughout.



Q2. **The Temporary Vessel Replacement Program (TVRP) included vessels that targeted pollock extensively compared to the rest of the mobile gear fleet. Would selection of the subset of vessels involved in TVRP fishing provide a better measure of trends of pollock abundance?**

A2. The TVRP data series began in 1991. We obtained records of vessels fishing under the TVRP from Statistics Branch and completed a standardized analysis. Following the recommendations of the review, we selected a subset of vessels that had significant landings of pollock and a number of consecutive years in the fishery. The two series are shown below. As can be seen, the TVRP series track the TC2-3 series reasonably well. In 1991 and 1992, relatively few data were available. Both series will be made available for consideration in the final meeting of the pollock framework.

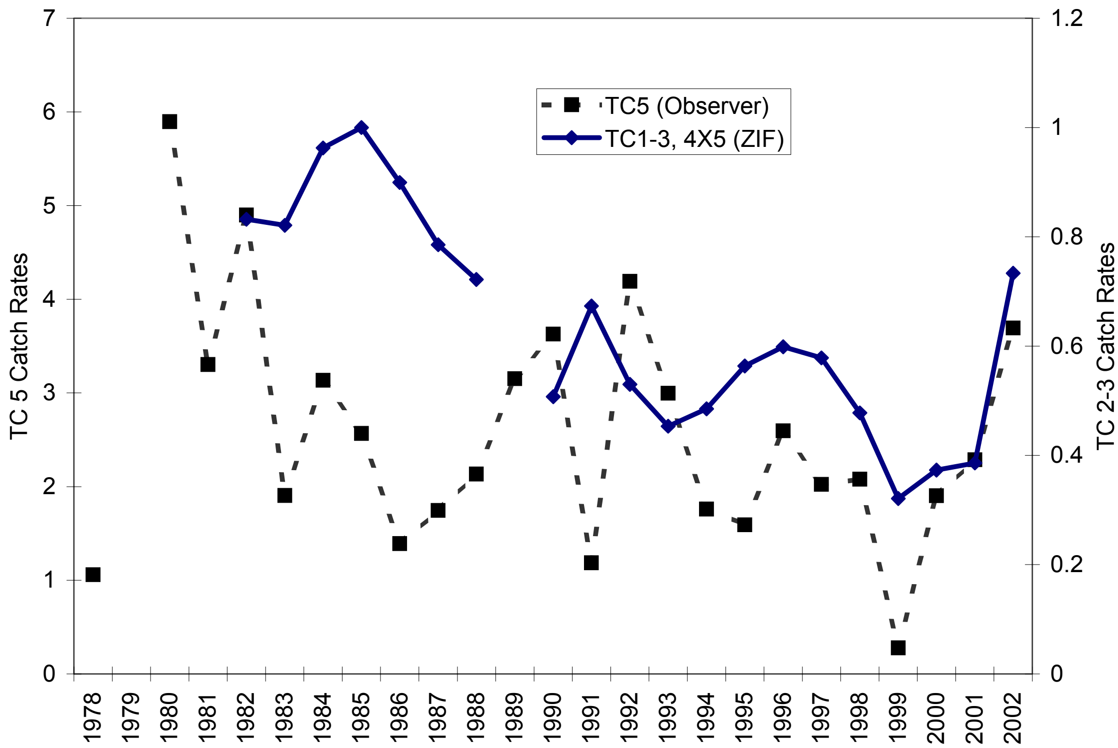


Appendix Table 1. Catch in tons of pollock by mobile gear vessels (TC1-3) participating in the TVRP, 1991 – 2002.

	Year											
Vessel	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
1	97											
2		42										
3								214				
4		174				1	2					2
5				6								
6									13		5	19
7											2	
8	178	132	180	24								
9								92				30
10	60	40										
11									83	121	175	149
12	5											
13				10								
14							200	198	43	49	11	125
15	43											
16							124					
17	15	114										
18		102										
19	4	149	172	6		17		490	19			
20	17											
21				59	141	159	222	65				
22										85	81	83
23					57	92	222	363	124			
24											4	74
25	300	70										
26					70							
27							19	20		10		
28								11				
29		28										
30												19
31	74											
32												96
33								85				
34	543	371	188	118	22	3	13	9	4			
35							30	2				
36		122										
37	12											
38	23	61	91									
39	40	90		7			19					
40				27								
41		71	28									
42							100					
43		103					9	124				
44		200	158	73		63	278	503	106		7	30
45							135	108				
46	411											
47			174	329	153	317	283					
48						59	136	328				
49					2							
50							84	76				
51									205	147		362
52									5			
53							26	218				

Q 3. Larger mobile gear (TC5+) have had a history of fishing on Georges Bank (5Zj) and have a relatively high level of observer coverage. Could such catch/effort data provide an index of abundance on Georges Bank that would augment the TC2-3 series?

A 3. Catch rate information (data aggregated to the set level) from the Observer Program (TC 5 in 5Zj) are summarized below, along with the TC2-3 series presented in this Research Document. The TC5 data were standardized with year and month included as factors in the model. The resulting model of catch rates explained only a low proportion of observed variance in catch rates (r^2 = 0.079).



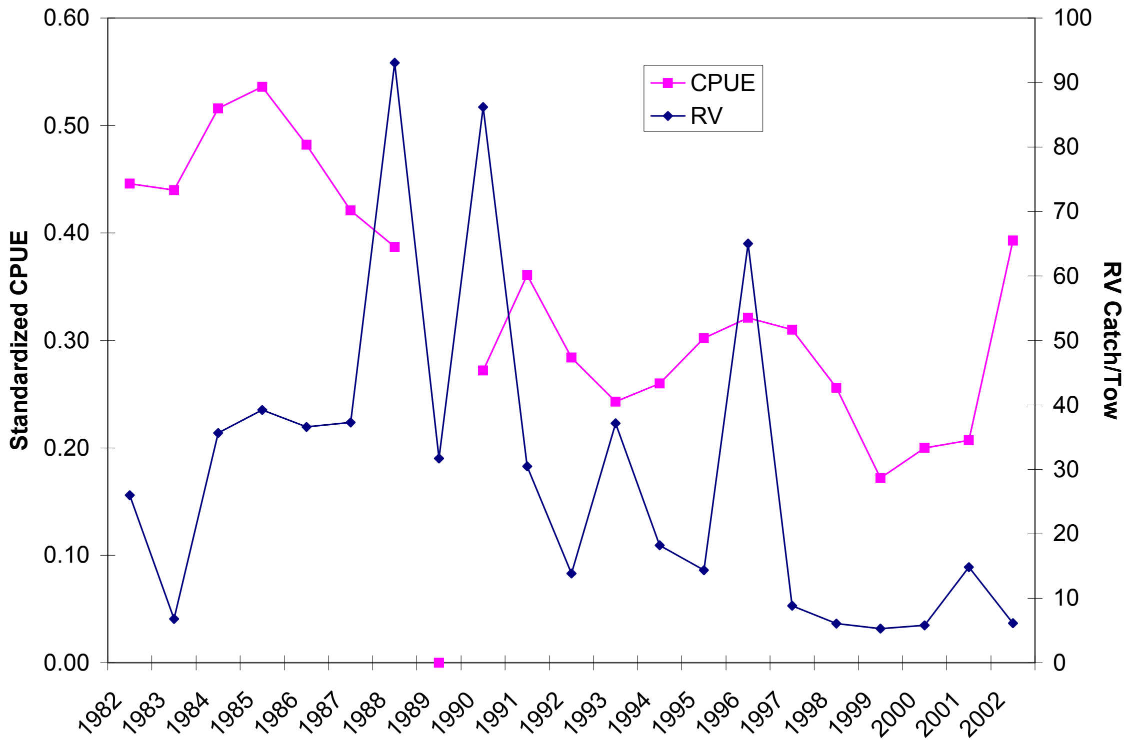
The catch rate series from the Observer Program shows show strong interannual variability. At least in part, such variation may be due to the low catches in certain years by this fleet. For example, in 1999, the fleet caught only 66 t. As the table below shows, in recent years only 1-3 vessels have contributed to the series. Given these considerations, we do not recommend including this series as an index of abundance in the population model.

Appendix Table 2. Catch in tons of pollock by large mobile gear vessels (TC 5) fishing on Georges Bank (5Zj), 1982 – 2002.

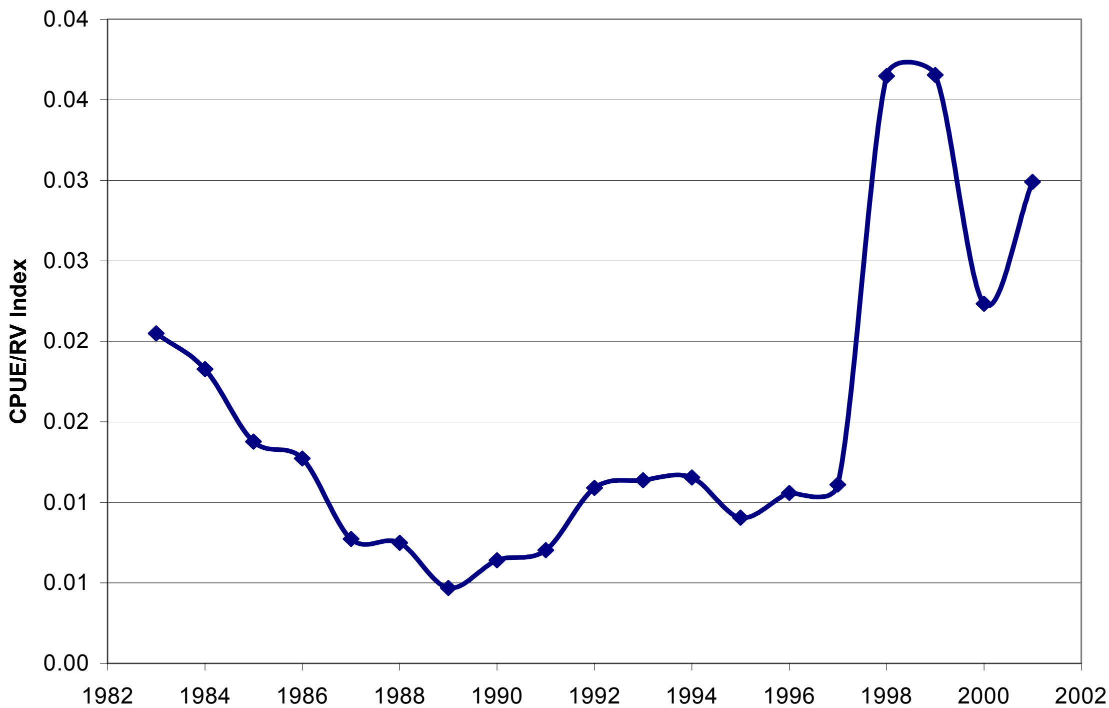
	YEAR																				
CFV_NUMBER	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
1	29																				
2	8	36																			
3			29																		
4		50				51															
5		15				18		105													
6	185	162	8					134		82	36	419	175	144	251	157	150		228	340	356
7	96	141	119		35			1			11										
8	112	28	20					24													
9	130	10	37					87			12										
10	6	22	32					13			7	25									
11	7																				
12	13																				
13	220	24	99	50					82	69	275										
14	245	17	99						69	0	127										
15									36	6	146										
16						86						113									
17	112								52	63	97										
18												216	267				18	2		103	
19												292	187								
20		81										397	318		112	11	152	64			
21	225	183				56		32		8		127		32		100	0				
22	219					55	61	114			65	283									
23	137	270				92		1		20	206	158			33						
24	217							17		2	66	180									
25	214	167																			
26	256	272		70					125	81	217	420	69	6	182	2			7		68
27																				1	
Total	2431	1480	443	120	35	360	61	527	363	330	1266	2630	1017	182	578	270	320	66	235	443	424

Q 4. Are commercial fishery catch rates a reflection of resource concentration rather than an index of abundance?

A 4. As suggested during the meeting, this possibility was examined by plotting the commercial fishery CPUE and the RV survey indices (catch/tow in weight) in a comparable area and comparing the ratio of the two. The two series for the Unit Areas 4Xopqrs are shown in the figure below:



The ratio of the two smoothed series are represented in the figure below:



As can be seen, the last four years in the series are considerably higher than earlier values. This is consistent with the possibility that the resource is spatially more concentrated, and the fleet has been able to maintain or increase catch rates recently but the overall population abundance remains low as indicated from the surveys. Given this possibility, the use of this abundance index in future population models and interpretations of increasing biomass in recent years should be qualified.

Q5. While there was agreement that the gillnet catch rate information showed promise, it was noted that the measure of CPUE (catch/net) was possibly biased as a high proportion of fishermen were entering an arbitrary value of 40 nets fished. It was recommended that the CPUE calculations use catch/day instead.

Also, it was recognized that different fleets could fish in a fleet-specific manner, and it was suggested that the available catch/effort data be disaggregated into fleet components and "fleet" be explored as a factor in the catch rate standardization.

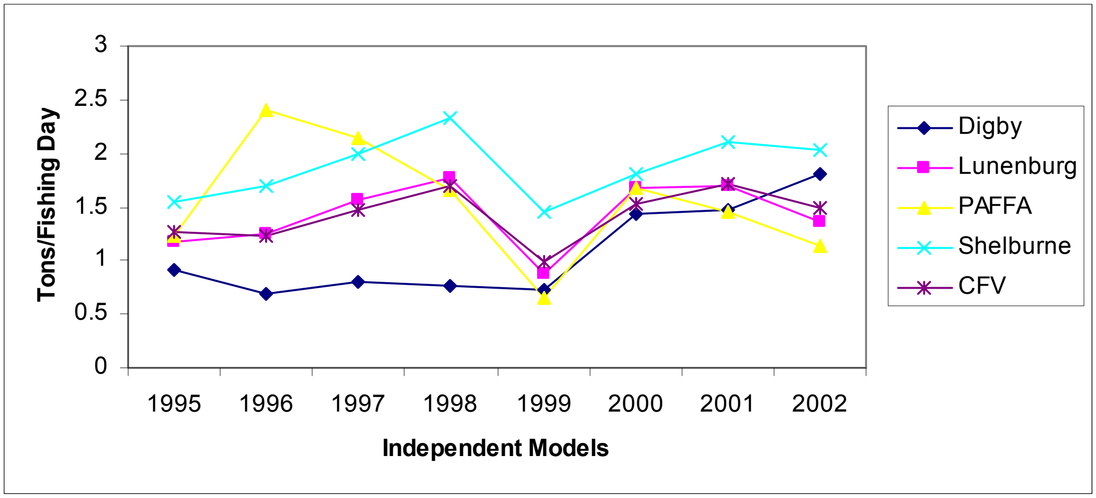
A5. We completed the calculations using the new response variable of catch per day and obtained results that were comparable to the results presented during the meeting. We then introduced a new factor that represented the five fleets. One of the five (Lunenburg A-16) was poorly represented in the data series (see text table below), so we deleted it.

	Metric.tons	Number.cases	
Digby	516.7	528	
Lunenburg A-15	1057.4	814	
Lunenburg A-16	22.5	24	too little data, and only seen 1996-1999
PAFFA	354.3	213	
Shelburne	2689.8	993	

The addition of the factor "fleet" is significant in the analyses presented below. Overall, the model accounts for 35% of the observed variation in catch rates.

ANOVA						
	Df	**Deviance**	**Resid. Df**	**Resid. Dev**	**F Value**	**Pr(F)**
NULL	NA	NA	2079	1199.557	NA	NA
AREA	6	286.1758	2073	913.3808	126.2186	0
yland	7	76.03079	2066	837.35	28.74308	0
fleet	3	55.34868	2063	782.0013	48.82338	0
mland	6	4.694478	2057	777.3068	2.070513	0.05366156

We also modeled the trend in catch rates for the four fleets independently and compared them with the fleet aggregated approach (labeled CFV), shown in the following figure.



Generally speaking, the Lunenburg and Shelburne series track each other well. The PAFFA (Prospect Area Fulltime Fishermen's Association) series digresses early in the series but follows a similar trend to Lunenburg and Shelburne from 1998 to 2002. The Digby series appears to be following an increasing trend that is more apparent than for the other series.

The fleets fish different unit areas within the western management unit for pollock (see below).

Appendix Table 3. Distributions of gillnet landings (t) by Unit Area and Fleet, 1995-2002.

	Digby	Lunenburg	PAFFA	Shelburne
4Xo		40	11	118
4Xp	1	127	128	135
4Xq	81	520	72	275
4Xr	134	50		13
4Xs	2		1	
5Yb	114	8		3
5Z				247

However, given that area is already included as a factor in the main effects model and the generally slight differences between the predicted catch rates by fleet compared with the fleet aggregated approach, we conclude that the fleet-aggregated main effects model is an adequate representation of gillnet catch rates in 4X5 (less 4Xmn).