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Pollock Stock Status in the Canadian Maritimes: A Framework Assessment

État du stock de goberge aux Maritimes : examen du cadre d'évaluation

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ABSTRACT

In 2003 and 2004, the Maritimes Region of the Department of Fisheries and Oceans undertook a Framework Assessment of pollock (*Pollachius virens*). Such assessments are meant to be a comprehensive review of the biology, stock structure, the fishery, abundance indices, current assessment methodology and approaches for determining acceptable harvest levels. The results of the final (April 6-8, 2004) meeting of the Framework Assessment are described here, and the specifications of a population model and assessment methodology are provided in detail. Given the relative importance of the fishery in the western half of the management unit and the availability of indices of abundance, the population model focuses on that area. The review provides a consensus opinion on the best available approach for the provision of harvest advice for the pollock resource.

RÉSUMÉ

En 2003 et 2004, la Région des Maritimes du ministère des Pêches et des Océans a entrepris un examen du cadre d'évaluation de la goberge (*Pollachius virens*). Les examens du genre se veulent être complets et portent sur la biologie, la structure des stocks, la pêche, les indices d'abondance, les méthodes d'évaluation courantes et les approches permettant d'établir des niveaux de prises acceptables. Le présent document décrit les résultats de la dernière réunion d'examen du cadre d'évaluation de la goberge, qui a eu lieu du 6 au 8 avril 2004, ainsi que les caractéristiques détaillées d'un modèle de la population et de la méthodologie d'évaluation. Étant donné l'importance relative de la pêche de cette espèce dans la moitié ouest de l'unité de gestion et la disponibilité d'indices d'abondance, le modèle de la population cible ce secteur. Cet examen offre une opinion unanime sur la meilleure approche disponible pour formuler des avis en matière de pêche de cette ressource.

INTRODUCTION

This document contains a synthesis of new knowledge concerning the population dynamics of pollock (*Pollachius virens*) in Canadian Maritime waters. As part of a Framework Assessment of pollock, the population structure of pollock, indices of abundance and summaries of the fishery catch, and finally, the model and associated assumptions for evaluating status of the resource were considered in a sequential manner during three meetings of Departmental and external scientists, fisheries managers and members of the fishing industry (Stephenson, in prep.). The Framework Assessment process is meant to be a periodic intensive review of the methodology for conducting resource assessment within the Region, and is conducted outside of the timeframe of the typical annual stock assessments. Once a Framework Assessment is agreed upon, it is intended to provide the foundation for future annual assessments for a period of about five years.

This document focuses on the optimal means to describe the current status of the pollock resource within the constraints of the available data. The final (April 6-8, 2004) meeting of the Framework Assessment reached a consensus on the best available approach for the provision of harvest advice for the pollock resource, and the detailed specifications of the consensus approach are given here. To provide context for the development of the population model, some of the main conclusions from the previous two meetings of the Framework Assessment process are also summarized below.

STOCK STRUCTURE

Previous assessments of this resource have considered that the management unit is comprised of 4VWX5Yb and 5Zc. The review of stock structure conducted as part of the Framework Assessment (Neilson *et al*. 2003a) examined data relevant to the stock structure of pollock including commercial fishery spatial distribution, research vessel surveys, spatial distribution of various stages of the life history, somatic growth rates, meristic and morphometric data and mark-recapture information. The Proceedings of the meeting (Stephenson, in prep.) indicated that there were sufficient grounds to suggest that future stock assessments separately deal with the eastern and western stock components of pollock on the Scotian Shelf. However, it was noted that the available data do not allow a precise resolution of the boundary between the eastern and western components. There was general consensus that on pragmatic grounds, the line defining the boundary between the eastern and western components could be the 4X/4W boundaries. It was noted, however, that unit areas 4Xm and 4Xn show affinity with the slower-growing eastern component, and calculation of the catch at age and abundance indices should reflect this.

The review also concluded that the current eastern and northern boundaries with NAFO Divs. 4T and 3Ps appear appropriate and should be retained. The boundary of the stock to the south in SA 5 appears less clear, however. The International Boundary will continue to be recognized as the limit of the management unit, based on operational considerations, until the transboundary ramifications are examined.

In light of these conclusions, the data presented here include landings and indices from 4Xopqrs, 5Zc and 5Yb for the western component (Fig. 1), and 4VW and 4Xmn for the eastern component (Fig. 1). Given the relative importance of the fishery in the western component and the availability of indices of abundance, the population model focuses on that area.

THE FISHERY

Landings and the Canadian TACs since 1982 are shown in Table 1 and Fig. 2. for the former management unit. Canadian landings peaked at 45000 t in 1987; since then, landings have sharply decreased, and in recent years have been less than 10,000 t. The TAC was not always attained, although for a period of five consecutive years in the late 1980s, the TAC was either met or exceeded. Recently, the contribution to total landings made by the eastern component has become comparatively small (Fig. 3). In part, this has been due to management measures that have had considerable impact on the fishery in recent years. For example, the cod management unit in 4VsW has been closed since September 1993, thus restricting opportunities for pollock fishing on the eastern Shelf.

Only Canada and the USA have landings of pollock from the western component since 1982 (Table 2). Following the convention established in Annand et al. (1989), 60% of all USA landings from 1982 to 1984 in statistical unit areas 5Zjm were assumed to be from NAFO Sub-Division 5Zc. The USA reported landings from statistical Unit Areas 4Xp and q from 1982 to 1992. Prior to the revision of NAFO Sub-area 4 and 5 in 1986 to coincide with the International Boundary (NAFO 1986), we assumed that all USA landings attributed to 4Xp and 4Xq from 1982-1984 occurred within the new management unit, and were included in this assessment. However, USA landings in 4Xp and 4Xq from 1985 to 1992 were erroneously included in this Framework evaluation, but given the relatively small tonnages involved, their effect is considered negligible.

The Canadian fishery landings have generally peaked in June and July (Table 3), although from time to time, high landings are observed during winter (e.g. December in 1988). Statistical Unit Areas 4Xp and 4Xq (near the mouth of the Bay of Fundy, Fig. 1) now are the most significant areas for the Canadian fishery, along with the Canadian portion of Georges Bank (Table 4, Fig. 4). In the 1980s, 4Xo supported a significant fishery. However, that fishery declined markedly in 1995. As indicated in Table 4, Canadian landings not attributed to a particular Unit Area (4Xu) were significant, particularly in the 1990s.

Pollock are primarily caught with otter trawl (Gross Registered Tonnage less than 150 t (OTB 1-3) are referred to as small mobile gear and otter trawlers greater than 150 t are referred to as large mobile gear (OTB 4+)), gill nets and longline. The OTB 1-3 component has been the largest single contributor to the overall Canadian fishery removals (Table 5, Fig. 5), followed by the gillnet component. In some previous years, the OTB 4+ components has made substantial contributions to total landings, but in recent years the numbers of active vessels within this gear category has been much reduced and landings have declined accordingly. For example, the number of TC 4+ vessels operating in the management unit has declined from 44 in 1982 to 3 in 2002.

SAMPLING AND CATCH/WEIGHT AT AGE

Details of sampling adequacy are provided in Clark et al. (in prep.). The level of commercial fishery sampling was relatively low in the 1970s in Div. 4X, thus the assessment presented here starts at 1982 when the level of sampling improved to reflect the fishery more accurately. To construct the catch at age, data for the western component were aggregated to the trimester level by gear type and tonnage class. Area 4Xu was prorated over the western component by allocating the proportion of landings attributed to 4Xmn versus the remaining unit areas in 4X.

Commercial fishery samples were selected for the proposed management unit and paper records examined to determine the location of fishing. Any sampled trip that did not fish entirely within the western component was excluded. Samples were aggregated on a trimester basis for OTB 1-3, OTB 4+ and when possible for gillnet and longline. If not enough data were available for any of the gear sectors then an annual aggregation was employed. Age-length keys were constructed on a trimester basis. The catch at age was adjusted to include US landings taken in NAFO Sub-Division 5Zc and statistical Unit Areas 4Xp and 4Xq between 1982 and 1992. The age composition was assumed to be similar to the Canadian catch at age during those years and the Canadian catch at age was adjusted to reflect these increased landings.

The catch in the western component is comprised primarily of fish of ages 3-7 in recent years (Fig. 6). The total catch at age for the western component and for the various gear sectors in Tables 6-10. The catch at age matrix shows internal consistency, and strong and weak cohorts can be tracked from year to year. For example, the 1979 cohort has been identified as a very strong cohort in past assessments for the combined eastern and western components. That year-class remained noteworthy until 1988 at age 9 (Fig. 6). In 2002, the 1997 cohort at age 5 is stronger than the three immediately preceding cohorts.

In recent years, the proportion of older fish by number in the catch is lower than that observed in the 1980s. In particular, ages 6 and older make up a smaller proportion of the catch compared with the averages from 1992 to 2001 and from 1982-1991 (Fig. 7). This difference is particularly apparent when comparing the 2002 catch at age to the 1982 to 1991 period.

The trend in the commercial fishery weight at age for the western component is shown in Fig. 8 and Table 11. The series reached minima in 1993-94, and have been generally increasing for ages 5 and 6 but remain below the highest values observed for the series. Ages 3 and 4 also reached minima in 1993-94, but have remained at those low levels. Comparable information from the research vessel surveys is also shown in Fig. 8, and similar trends are indicated.

INDICES OF ABUNDANCE

The second meeting of the Framework Assessment identified several potential indices of abundance that are described in more detail below.

Mobile Gear Catch Rates

Neilson et al. (2003b) presented a standardized series of mobile gear catch rates in the management unit. During the peer review of the indices of abundance (Stephenson in prep, 2004), there was concern that the recent increase in the index could have resulted from changes in resource and fishery distribution rather than changes in abundance. If, for example, the observed contraction of the range of the fishery reflected a greater density within a smaller area occupied by the resource, the conclusion that higher catch rates from that smaller area reflected an increase in abundance would be incorrect.

To address this possibility, we first determined how the fishery distribution had changed over time by mapping the catch of the fishery over 10’ squares (Fig. 9). A reduction of fishing activity in unit area 4Xo (Fig. 1) is apparent. We then established four geographic zones of 4X within which catch rates appear to be behaving in a similar fashion (Fig. 10). The approach of calculating a single standardized catch rate series with statistical unit area included as one of the factors makes the assumption that catch rate trends are varying proportionately over statistical unit areas, an assumption that appears to be somewhat violated. An alternative approach is to combine the distinct catch rates trends from the four zones, weighting each by the area it represents (Table 12). Since the fishery had moved away from the 4Xo area, observations of catch rates were missing for 1998 to 2002. Following the suggestion of Walters (2003), we replaced the 4Xo cells in recent years with either zeros or the lowest observed in the series (Table 12). No data are presented for 1989, because of a management measure that greatly impacted commercial fishery catch rates (Mohn et al. 1990).We combined the four series using an area-weighted approach, with the weights calculated as the number of productive 10’ squares in that area in 1992 (a year of high landings, Fig. 9) divided by the total number of productive 10’ squares in all areas in 1992.

The resulting catch rate series are shown in comparison with the original series in Fig. 11. The replacement of the recent values in 4Xo had little impact on the perception of a rapid increase in the catch rates in 2002. However, the area-weighted approach indicates that the extent of population decline from the mid-1980s was somewhat greater than that suggested by the single standardized catch rate approach. We elected to use the area-weighted CPUE series in the population model, since there was concern about changes in fishery and population distribution. Of the two possibilities for filling recent cells in 4Xo, we elected to use the approach that filled the cells with zeros. This choice appears justifiable, based on the decline in survey catch per tow in 4Xo compared with the rest of the western component (Fig. 12). The age disaggregated (ages 3-9) catch rates that result are shown in Fig. 13 and Table 13.

Gillnet Catch Rates

Neilson et al. (2003) presented a catch rate series for gillnet vessels operating in the western component. The age disaggregated series (ages 3-10) is shown in Fig. 14. In general, the age composition varies little from year to year and there is no indication of either strong or weak year-classes. Preliminary population modeling indicated that this relatively short series was not informative of population trends, and as a consequence, this index was not given further consideration.

Research Vessel Survey Indices

Carruthers et al. (2003) reviewed available survey pollock information and concluded, contrary to recent assessments, that the summer DFO research vessel survey results may be a useful index of abundance, at least in an age-aggregated form. The presence of strong year effects continues to complicate interpretation and will pose a challenge for analysis with models. The trend in RV total catch/tow has been declining since the late 1980s (Table 14, Fig. 15).

We also examined the survey length composition information and found that consistent with the trends in the commercial catch at age, there are proportionately fewer larger (older) fish in the 2002 survey catch compared with the 10-yr average (Fig. 16). However, there was indication of significant recruitment of 20-cm pollock in 2000. These fish represent one year old fish (1999 year-class). In general, observed modes in the survey length frequency distributions do not agree well with the fishery mean lengths at age (Fig. 16).

ESTIMATION OF CURRENT POPULATION STATE

It was assumed that there is general confidence that the landings were accurately reported. We also concluded that sampling was adequate to characterize the age composition of the fishery. The catch at age therefore was considered informative with respect to reconstructing the population history. The catch rates derived from a selected pollock-directed subset of the OTB TC 1-3 fishery and bottom trawl survey abundance indices showed general concordance with respect to abundance trends, year-class strengths and mortality rates. However, the bottom trawl survey results displayed high variability and the fishery catch rates showed hyperstability (Walters 2003), meaning that decreases in population abundance are not being represented by proportionate decreases in the commercial fishery catch rates. While those caveats were recognized, both indices of abundance were considered suitable for estimation of status.

The initial VPA trials included runs where the two abundance indices were used separately (both in age-aggregated and age-disaggregated form) since initial examination of “smoothed” trends suggested that the RV showed a more pronounced decline. Results from the initial trials confirmed that a linear relationship between the catch rate information and the population over the entire time period from 1982 to 2002 was not supported. Residual diagnostics for CPUE suggest substantial lack of fit with severe time trends in residuals consistent with the suspicion that CPUE is hyperstable. Residual diagnostics for the RV formulation also indicate time-trended residuals, but the pattern is somewhat less severe. The initial results also indicated that the age-structure for the RV survey indices provided information and stability to the model. Finally, it was noted that the initial years of the survey indices appeared not to fit the model predictions well.

Participants in the review of the initial results noted that on the basis of a retrospective analysis, model formulations using single indices of abundance displayed a severe retrospective pattern. It was suggested that use of both the RV and commercial CPUE indices of abundance could moderate the retrospective pattern. The review participants also noted that several ages could be estimated in the population model, rather than only one age as was presented initially.

After consideration of these preliminary investigations, the consensus recommendation of the review committee of the final workshop of the pollock Framework Assessment was reflected in the following ADAPT formulation:

Observations

$C_{a,y}$ = catch at age for a = 2 to 12 and y = 1982 to terminal year.
$I_{1,a,y}$ = bottom trawl survey for a = 3 to 8 and y = 1984 to terminal year (initial two years excluded)
$I_{2,a,y}$ = catch rates for a = 3 to 8 and y = 1982 to terminal year.
Both the bottom trawl survey and catch rates are related to the middle of year VPA abundance.

Parameters

$\theta_{a,y}$ = ln abundance for a=4 to 10 in y=terminal year +1.
$\kappa_{1,a}$ = ln bottom trawl survey catchability for a = 3 to 8 (ages 9 and 10 excluded because of frequent zeroes).
$\kappa_{2,a}$ = ln catch rate catchability for a = 3 to 8 (ages 9 and 10 excluded because of frequent zeroes).
$\beta_{2,a}$ = power for catch rate catchability relationship for a = 3 to 8.

Model Structural Assumptions

- Natural mortality was assumed to be 0.2 for all ages and years.
- Abundance at ages 11, 12 and 13 in the terminal year and at age 13 for years 1995 until the terminal year was assumed to be a small number (1000).
- Fishing mortality on age 12 for 1982 to 1993 was assumed to be equal to the population number weighted average fishing mortality on ages 9, 10 and 11.
- The biomass for ages 4+ is considered a proxy for spawning biomass.
- Ages 2 and 3 were assigned fixed values based on recent observed recruitment.

Error Model

- Catch at age error was assumed negligible compared to the index error.
- Error on the *ln* index observations was assumed to be independent and identically distributed.

Estimation

Parameters were obtained by minimizing the objective function:

$$\sum_{i,a,y}\left(I_{iay} - \hat{I}_{iay}[\theta,\kappa]\right)^2$$

where $\hat{I} = \kappa' N$ for the bottom trawl survey
and $\hat{I} = \kappa' N^{\beta}$ for catch rates
and $\kappa = \ln \kappa'$.

This generic framework is intended to provide guidance for upcoming assessments of this stock. It is noted, however, that certain year-classes may be problematic in the future and estimation may not always be possible.

Population Model Results

The consensus formulation and ADAPT results are provided in Appendix One.

The model fit for the two included indices compared with the predicted population is shown in Figs. 17 and 18 for the commercial fishery CPUE and RV indices, respectively. While there is still evidence of time-trended residuals, the pattern is less severe than those displayed in the initial model formulations. The trends in fishing mortality for ages 4-9 and 6-9 are shown in relation to the fishery landings in Table 15 and Fig. 19. Two groups of ages are shown, given the changing patterns of ages represented in the recent population. Fishing mortality for ages 4-9 reached a maximum in 1998 and has declined since then, but remains above the reference level, whose derivation is described in the next section. The fishing mortality for ages 6-9 increases and diverges unexpectedly from the pattern for ages 4-9 in the terminal year suggesting that the mortality estimate for ages 6-9 is highly variable due to the low numbers represented in the population at those ages. Biomass trends for ages 2+ and 4+ indicate that the population biomass was at its highest level in

1984 then steadily declined until 1999 (Table 16 and Fig. 20). Biomass has been rebuilding since then but remains at a low level compared with 1984. The trends in age-2 recruitment indicate a period of low recruitment from 1994-1996 (Fig. 21), with improved recruitment in the following three years.

To assess the stability of the consensus model, a retrospective analyses was completed (Fig. 22). Through the first four years of the retrospective analyses, the model produced consistent estimates of fishing mortality and biomass. However, the addition of the 1996 RV survey value resulted in a significant change in the trend in fishing mortality and biomass. The 1996 survey index (Fig. 15) was associated with a rapid increase in all ages compared with the 1995 value, indicating that the survey index for that year was suspect.

CHARACTERIZATION OF PRODUCTIVITY TO DETERMINE HARVEST STRATEGY REFERENCE POINT

Yield per recruit analysis was coupled with stock-recruitment patterns to evaluate age structured productivity and to derive a fishing mortality reference point. The value of F_{ref} = 0.2 was considered a practical limit fishing mortality threshold (Fig. 23). When stock biomass is depleted, exploitation may be further constrained to achieve rebuilding. Historically, the chance of good recruitment has been higher when the adult biomass is greater than a B_{ref} = 30,000 t threshold (Fig. 23). This reflects the biomass below which reduced production and recruitment was observed. This biomass reference point is based on a limited biomass range during a period of high exploitation and does not take into account that production in this stock may have been higher prior to 1982.

PROCEDURE FOR PROJECTION

For short term projections, catch and stock weights at age and partial recruitment to the fishery should be averaged over a recent period of stable patterns if there are no trends over time. If trends are detected, suitable measures to reflect the most recent patterns should be applied. Alternative TAC tactics are evaluated through risk analysis. The risk of F exceeding F_{ref} = 0.2 should generally be neutral to risk averse (less than 50%) and the risk of biomass decline ($\Delta B < 0$) should be neutral to risk averse (less than 50%) when biomass is less than B_{ref} = 30,000t. The further biomass is below 30,000t, the decisions should be more risk averse. These risk evaluations are conditioned on the model assumptions.

POLLOCK ON THE EASTERN SCOTIAN SHELF

While most of the fishery now occurs within the western component, there remains a need to provide advice on the status of the resource on the eastern component. Fig. 24 shows the trend of RV indices from the western component compared with the biomass estimates from 4Xmn and 4VW (the eastern component), and such data are shown on a proportional basis in Fig. 25. The proportion of biomass from the western component has averaged about half of the total, with about 25% each coming from 4VW and 4Xmn.

Such resource distributions, while approximate, allow some guidance on exploitation levels on the eastern component. For annual assessments, it may be feasible to have a quantitative assessment based on the western component as completed here, then use the RV survey to extrapolate an approximate TAC, keeping in mind the lower growth rates of fish in the eastern component and the apparent higher natural mortality in the survey estimates of Z.

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Table 1. Pollock landings (t) by country for the former management unit (4VWX5Zc). The TAC was provided on an April 1 to March 31 basis since 2000, and the landings are reported on a calendar year basis.

	Canada	Japan	France[2]	Cuba	USSR (Russia)	USA	Other	Total	TAC
1982	38029	3	44	84	297	840		39297	55000
1983	32749	6	22	261	226	1324		34588	45000
1984	33465	1	46	123	97	1691	1	35424	53000
1985	43300	17	77	66	336			43796	53000
1986	43249	51	77	387	564		4	44332	40000
1987	45330	82	28	343	314			46097	43000
1988	41831	1		225	1054			43111	43000
1989	41112	1		99	1782			42994	43000
1990	36178			261	1040			37479	38000
1991	37931	38		459	1177			39605	43000
1992	32002	72	9	1015	1006			34104	43000
1993	20253			644	176			21073	21000
1994	15240			10				15250	24000
1995	9781			58				9839	14500
1996	9145			129	6			9280	10000
1997	11927			64				11991	15000
1998	14371			9	1			14381	20000
1999	7738			6				7744	13400
2000	5672							5672	10000
2001	6318							6318	10000
2002	7090							7090	10000

Table 2. Pollock landings (t) for the western component (4Xopqrs, 5Yb and 5Zc).

	Canada	USA	Total
1982	18518	1107	19625
1983	16465	1854	18319
1984	15347	2272	17619
1985	19511	152	19663
1986	17520	234	17754
1987	16460	102	16562
1988	17899	60	17959
1989	13724	35	13759
1990	15595	213	15808
1991	18602	68	18670
1992	16639	57	16696
1993	14410		14410
1994	10836		10836
1995	7144		7144
1996	6441		6441
1997	9759		9759
1998	10534		10534
1999	4760		4760
2000	4768		4768
2001	5400		5400
2002	6485		6485

Table 3. Pollock landings (t) by month in the western component, (4Xopqrs, 5Yb and 5Zc). Unit Area 4Xu is not prorated in this instance.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1982	766	667	258	196	1557	2809	3415	2511	2338	2098	1141	621	18377
1983	1149	816	481	555	1928	4668	3348	1685	1224	588	173	82	16696
1984	170	199	371	809	1506	3930	3872	1704	1362	1276	563	248	16010
1985	136	831	931	2120	1082	4640	5329	1963	1770	1191	379	240	20614
1986	1027	937	1002	493	2289	3039	3725	2766	2180	758	198	35	18449
1987	1515	812	830	111	2768	3823	2863	2017	1578	603	132	838	17889
1988	1141	583	273	536	1163	4313	5189	1420	1357	537	172	2562	19246
1989	704	1583	480	724	978	3826	1813	1384	1275	667	1336	321	15091
1990	259	257	54	176	1121	3239	3800	3127	2247	1332	564	933	17108
1991	1092	894	437	1288	1934	3456	3226	2200	1815	1397	747	693	19180
1992	436	636	237	830	1814	2925	3116	2450	1840	1590	829	237	16941
1993	1089	654	645	447	1204	2726	2743	1689	1188	565	904	630	14482
1994	41	245	229	547	810	1967	2973	1362	1071	911	482	489	11127
1995	106	217	206	476	323	2017	1420	257	1509	259	300	180	7269
1996	277	199	221	219	472	790	1230	919	546	609	389	605	6477
1997	56	459	508	688	598	1485	1921	1398	1215	665	562	284	9838
1998	285	624	807	710	953	1869	2194	1111	986	789	173	57	10558
1999	64	59	174	236	346	780	1111	826	666	215	180	112	4769
2000	135	272	301	96	317	735	850	684	554	506	185	140	4773
2001	231	46	417	224	414	775	1180	567	611	534	260	146	5406
2002	139	268	328	410	945	1346	1259	598	507	345	222	121	6488

Table 4. Pollock landings (t) by area in the western component, (4Xopqrs, 5Yb and 5Zc). Unit Area 4Xu is prorated in this instance.

	4Xo	4Xp	4Xq	4Xr	4Xs	4Xu	5Yb	5Zc	Total
1982	4781	1499	2675	2508	1345	183	925	4430	18347
1983	4337	1146	3635	1170	461	1319	1079	3301	16448
1984	3536	1189	4541	716	163	1933	2015	1199	15291
1985	6179	595	5718	1284	696	3275	853	911	19511
1986	7326	1073	2531	1046	1287	2066	654	1538	17520
1987	4734	2329	1893	508	1209	2571	1120	2096	16460
1988	3194	3417	3333	307	790	4110	345	2403	17899
1989	3619	3373	2334	332	374	1777	531	1385	13724
1990	3668	2523	2953	1042	693	2629	346	1740	15595
1991	4621	3745	2665	2465	2105	831	456	1715	18602
1992	4174	1528	2626	2175	1793	865	443	3036	16639
1993	2754	1985	2226	1605	941	337	368	4193	14410
1994	1860	1097	1213	1453	866	784	236	3327	10836
1995	429	1158	2552	676	393	683	250	1004	7144
1996	419	1478	1811	686	412	179	256	1200	6441
1997	446	1574	4030	1112	607	447	311	1231	9759
1998	437	3495	3134	564	469	153	425	1857	10534
1999	313	879	1372	648	380	37	135	996	4760
2000	257	1086	1531	264	249	47	136	1197	4768
2001	207	1191	1774	301	186	68	104	1569	5400
2002	201	1482	2628	189	159	52	157	1616	6485

Table 5. Pollock landings(t) by gear in the western component, (4Xopqrs, 5Yb and 5Zc). Unit Area 4Xu is prorated in this instance.

	Gillnet	OTB 4+	Longline	Misc	OTB 1-3	Grand Total
1982	2574	6782	2315	241	6435	18347
1983	2416	4307	1618	25	8081	16448
1984	1809	1623	1615	39	10204	15291
1985	3045	1246	2443	52	12725	19511
1986	4378	1928	4447	55	6712	17519
1987	4003	3465	2934	26	6032	16460
1988	3021	5904	1704	93	7177	17899
1989	4217	3558	1391	78	4480	13724
1990	4810	3027	2252	95	5411	15595
1991	3572	3884	2387	132	8627	18602
1992	3784	3135	2789	3	6928	16639
1993	3159	3983	2199	1	5067	14410
1994	2760	1703	2019	44	4310	10836
1995	2620	951	506	4	3062	7144
1996	1301	1733	605	3	2799	6441
1997	2312	1648	978	1	4820	9759
1998	3076	1323	621	21	5492	10534
1999	1431	546	494	5	2286	4761
2000	1796	516	278	5	2172	4768
2001	1776	564	291	1	2765	5398
2002	1621	559	229	1	4074	6484

Table 6. Total catch at age (000s) for pollock in the western component (4Xopqrs 5Yb and 5Zc).

	2	3	4	5	6	7	8	9	10	11	12
1982	91	1565	1339	375	1049	856	436	150	47	34	13
1983	40	1135	3534	770	163	286	266	127	54	16	17
1984	3	333	1656	2500	425	79	136	105	37	17	2
1985	4	181	580	1688	2006	307	35	95	94	59	28
1986	1	151	1313	1061	1245	822	83	35	35	39	14
1987	5	103	622	1608	876	780	487	68	17	15	28
1988	18	413	966	1102	1251	506	413	236	21	14	20
1989	93	387	1533	1128	575	462	147	129	65	6	7
1990	47	772	1095	1609	867	426	173	137	49	23	10
1991	58	1020	1913	1516	1404	349	158	56	49	25	10
1992	45	1221	2615	1611	658	306	121	94	59	14	11
1993	4	540	1953	2087	1123	312	91	27	10	7	6
1994	49	250	652	1283	1115	479	161	57	14	8	2
1995	19	239	507	908	651	283	61	17	3	1	1
1996	14	196	923	693	463	251	54	15	0	0	1
1997	6	150	894	1645	777	216	53	4	0	1	0
1998	7	230	836	1380	1273	309	47	16	2	1	0
1999	12	88	492	616	423	172	21	4	1	2	0
2000	81	553	384	564	304	132	26	6	1	0	0
2001	15	321	780	548	301	87	13	4	2	1	1
2002	7	182	752	1026	398	121	19	6	1	0	0

Table 7. OTB 1-3 catch at age (000s) for pollock in the western component, (4Xopqrs, 5Yb and 5Zc).

	2	3	4	5	6	7	8	9	10	11	12
1982	37	694	429	105	303	271	148	59	21	16	6
1983	16	666	1965	346	50	80	81	36	15	6	5
1984	3	165	922	1501	270	49	81	61	22	11	1
1985	3	108	386	1224	1407	202	17	44	44	26	10
1986	1	70	519	422	493	319	27	11	13	15	5
1987	4	49	294	638	314	277	170	25	5	5	8
1988	1	103	295	480	582	216	182	93	10	3	6
1989	17	256	798	414	177	110	27	21	9	1	0
1990	28	401	528	663	292	110	36	25	9	4	1
1991	14	364	1015	788	624	151	73	26	19	9	4
1992	22	667	1567	794	209	58	18	13	8	1	2
1993	0	251	983	842	315	69	21	7	3	1	2
1994	28	132	319	571	450	172	58	19	5	3	0
1995	18	191	292	449	264	95	21	4	2	1	0
1996	4	104	531	365	182	80	13	2	0	0	0
1997	5	92	552	952	336	79	14	1	0	0	0
1998	5	174	578	846	656	119	18	5	0	0	0
1999	9	60	339	361	196	54	6	1	0	0	0
2000	62	372	238	295	121	38	7	1	1	0	0
2001	14	279	516	274	128	30	5	2	1	0	0
2002	7	164	608	707	210	53	8	2	0	0	0

Table 8. OTB 4+ catch at age (000s) for pollock in the western component, (4Xopqrs, 5Yb and 5Zc).

	2	3	4	5	6	7	8	9	10	11	12
1982	45	750	780	191	436	281	115	34	12	8	3
1983	24	445	1203	235	64	106	82	34	14	2	4
1984	0	149	525	511	59	10	16	12	4	3	0
1985	1	57	74	109	121	21	4	5	7	3	1
1986	0	26	161	125	175	102	6	2	4	4	1
1987	1	46	173	363	196	140	88	16	4	4	8
1988	18	305	577	395	367	140	93	38	3	4	5
1989	76	124	546	333	108	87	27	20	10	2	1
1990	18	350	420	401	152	42	14	9	3	2	1
1991	41	573	512	302	226	48	20	6	7	3	1
1992	16	427	701	303	85	32	10	7	4	1	0
1993	4	218	631	634	254	59	11	4	2	2	2
1994	8	40	120	246	178	58	18	5	1	0	0
1995	0	30	101	151	80	28	6	1	0	0	0
1996	9	74	305	187	112	58	10	3	0	0	0
1997	1	33	180	316	112	33	4	0	0	0	0
1998	1	33	159	216	145	23	4	1	0	0	0
1999	2	16	71	82	42	13	2	0	0	0	0
2000	18	132	54	49	19	8	2	0	0	0	0
2001	0	35	132	54	18	5	1	0	0	0	0
2002	0	14	72	96	35	7	1	0	0	0	0

Table 9. Gillnet gear catch at age (000s) for pollock in the western component (4Xopqrs 5Yb and 5Zc).

	2	3	4	5	6	7	8	9	10	11	12
1982	0	4	53	48	186	168	82	26	5	3	1
1983	0	21	336	149	34	55	45	16	6	1	1
1984	0	6	84	215	51	14	32	25	9	3	1
1985	0	13	110	296	325	40	4	6	7	3	1
1986	0	6	231	275	346	212	18	4	2	4	1
1987	0	5	98	361	213	206	131	13	5	2	5
1988	0	4	62	130	159	80	87	77	7	6	7
1989	0	4	161	294	211	188	71	63	33	2	5
1990	0	9	101	401	310	190	78	62	19	8	3
1991	0	23	184	216	340	99	43	16	16	8	3
1992	0	14	99	288	255	145	57	39	25	6	6
1993	0	16	132	313	328	125	46	14	5	4	2
1994	1	3	19	137	297	185	64	25	5	3	1
1995	2	23	98	258	267	146	31	10	1	0	0
1996	0	3	41	95	126	83	20	5	0	0	0
1997	0	12	105	251	232	77	27	2	0	1	0
1998	0	6	61	260	408	140	19	7	1	0	0
1999	0	7	58	130	141	80	9	2	0	0	0
2000	0	33	72	181	142	77	15	4	0	0	0
2001	0	4	101	190	138	46	6	2	0	0	0
2002	0	3	62	200	137	52	8	3	1	0	0

Table 10. Longline and miscellaneous gear catch at age (000 s) for pollock in the western component, (4Xopqrs, 5Yb and 5Zc).

	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1982	9	118	77	32	124	135	91	31	9	8	3
1983	0	4	30	39	15	46	59	41	20	7	7
1984	0	13	125	274	45	6	8	8	2	1	0
1985	0	4	10	58	152	45	11	39	35	26	15
1986	0	49	402	239	230	190	31	18	15	16	8
1987	0	3	57	247	152	157	98	14	3	3	7
1988	0	1	32	97	143	70	50	28	2	1	2
1989	0	3	28	86	80	78	22	25	13	2	1
1990	0	13	46	144	112	84	45	40	18	9	5
1991	3	60	202	210	214	51	23	8	7	5	3
1992	7	113	248	226	109	72	36	34	23	6	3
1993	0	55	206	298	227	60	13	2	0	0	0
1994	11	74	193	329	190	63	21	9	3	1	0
1995	0	3	27	67	53	21	5	1	1	0	0
1996	1	16	46	45	42	31	11	5	0	0	0
1997	0	13	57	127	96	27	8	1	0	0	0
1998	1	17	38	58	64	27	6	3	1	0	0
1999	1	4	24	44	45	25	5	1	1	1	0
2000	2	16	20	38	22	9	2	1	0	0	0
2001	0	4	30	30	17	6	1	1	0	0	0
2002	0	1	10	24	17	9	2	1	0	0	0

Table 11. Mean weights at age (kg) for pollock in the western component, (4Xopqrs, 5Yb and 5Zc).

	Age 2	**Age 3**	**Age 4**	**Age 5**	**Age 6**	**Age 7**	**Age 8**	**Age 9**	**Age 10**	**Age 11**	**Age 12**
1982	1.047	1.532	2.589	3.454	4.131	4.632	5.433	5.919	7.165	7.961	9.640
1983	1.022	1.542	2.236	3.730	4.782	5.558	6.130	7.142	7.758	8.958	9.475
1984	1.057	1.847	2.596	3.312	4.440	5.813	6.492	6.641	7.106	7.685	10.209
1985	1.081	1.766	2.660	3.400	3.947	4.569	6.344	7.664	7.531	8.328	9.718
1986	0.826	1.701	2.496	3.322	4.190	4.811	6.109	6.988	7.506	7.668	9.066
1987	0.960	1.497	2.292	3.075	3.594	4.344	4.936	5.328	6.818	7.502	7.927
1988	1.231	1.594	2.302	3.176	3.898	4.289	5.094	6.021	7.231	8.343	8.633
1989	0.876	1.310	2.094	3.071	3.891	4.501	4.881	6.032	6.356	8.954	7.161
1990	0.573	1.268	2.067	2.913	3.684	4.806	5.870	6.430	7.032	7.700	9.872
1991	0.899	1.335	2.138	2.847	3.712	4.700	5.676	6.421	6.774	8.013	8.978
1992	1.057	1.301	1.875	2.680	3.597	4.731	5.606	6.300	7.043	8.379	9.433
1993	0.778	1.133	1.699	2.355	3.197	3.815	4.796	5.573	6.799	7.807	8.239
1994	0.843	1.302	1.649	2.240	3.156	3.877	4.339	4.984	6.418	6.229	8.014
1995	0.724	1.180	1.862	2.353	3.098	4.001	4.853	5.440	7.390	8.601	8.744
1996	0.940	1.389	1.852	2.413	3.116	3.719	5.237	6.305	8.457	9.484	11.280
1997	0.932	1.407	1.956	2.462	3.297	3.976	5.085	7.698	9.937	6.691	11.749
1998	0.862	1.096	1.707	2.342	3.117	4.177	5.103	5.578	8.515	8.728	11.919
1999	0.826	1.215	1.706	2.440	3.260	4.290	5.638	7.008	9.819	9.825	
2000	0.798	1.312	1.887	2.603	3.323	4.371	5.671	6.019	9.422	10.276	
2001	0.479	1.091	2.075	3.051	3.882	4.956	6.763	8.392	8.822	9.322	11.124
2002	0.296	0.979	1.669	2.644	3.879	5.038	6.594	7.224	9.014	11.303	11.518

Table 12. Individual standardized CPUE (t/hr) series (OTB 1-3) for four regions within the Western Component . Factors included in the catch rate standardization included year, month, CFV and mesh type (Neilson et al. 2003 b) . The calculation of area-weighted averages is also shown, with different treatment of 4Xo. The two series appearing on the bottom of the table represent the arithmetic average of the data presented in the upper of the table.

Fill 4Xo with zeroes

Year	4Xo	4Xp/5Zj	BOF	4Xq
1982	0.102	0.57	0.619	0.795
1983	0.178	0.885	0.653	0.735
1984	0.246	1.143	0.757	0.785
1985	0.249	0.501	0.632	0.926
1986	0.278	1.062	0.504	0.786
1987	0.257	0.844	0.584	0.561
1988	0.22	0.687		0.632
1989				
1990	0.274	0.275	0.446	0.49
1991	0.178	0.531	0.543	0.538
1992	0.122	0.56	0.443	0.358
1993	0.152	0.477	0.298	0.295
1994	0.093	0.413	0.419	0.248
1995	0.181	0.298	0.545	0.406
1996	0.213	0.591	0.477	0.397
1997	0.145	0.461	0.399	0.386
1998	0	0.451	0.252	0.311
1999	0	0.273	0.206	0.205
2000	0	0.387	0.224	0.221
2001	0	0.408	0.226	0.244
2002	0	0.616	0.385	0.472
Weights	0.17	0.27	0.29	0.28

Fill 4Xo with lowest observed values

Year	4Xo	4Xp/5Zj	BOF	4Xq
1982	0.102	0.57	0.619	0.795
1983	0.178	0.885	0.653	0.735
1984	0.246	1.143	0.757	0.785
1985	0.249	0.501	0.632	0.926
1986	0.278	1.062	0.504	0.786
1987	0.257	0.844	0.584	0.561
1988	0.22	0.687		0.632
1989				
1990	0.274	0.275	0.446	0.49
1991	0.178	0.531	0.543	0.538
1992	0.122	0.56	0.443	0.358
1993	0.152	0.477	0.298	0.295
1994	0.093	0.413	0.419	0.248
1995	0.181	0.298	0.545	0.406
1996	0.213	0.591	0.477	0.397
1997	0.145	0.461	0.399	0.386
1998	0.093	0.451	0.252	0.311
1999	0.093	0.273	0.206	0.205
2000	0.093	0.387	0.224	0.221
2001	0.093	0.408	0.226	0.244
2002	0.093	0.616	0.385	0.472
Weights	0.17	0.27	0.29	0.28

Year	Zeroes
1982	1.921
1983	2.300
1984	2.774
1985	2.202
1986	2.528
1987	2.164
1988	1.524
1989	
1990	1.480
1991	1.702
1992	1.399
1993	1.185
1994	1.102
1995	1.374
1996	1.626
1997	1.329
1998	0.913
1999	0.613
2000	0.749
2001	0.790
2002	1.324

Year	lowest observed
1982	1.921
1983	2.300
1984	2.774
1985	2.202
1986	2.528
1987	2.164
1988	1.524
1989	
1990	1.480
1991	1.702
1992	1.399
1993	1.185
1994	1.102
1995	1.374
1996	1.626
1997	1.329
1998	1.049
1999	0.750
2000	0.886
2001	0.927
2002	1.460

Table 13. Small mobile age-disaggregated catch rates in the western component, calculated using the area-weighted approach.

	3	**4**	**5**	**6**	**7**	**8**
1982	0.199	0.123	0.030	0.087	0.078	0.042
1983	0.184	0.543	0.096	0.014	0.022	0.022
1984	0.044	0.244	0.397	0.071	0.013	0.021
1985	0.019	0.067	0.212	0.243	0.035	0.003
1986	0.026	0.192	0.157	0.183	0.118	0.010
1987	0.018	0.105	0.228	0.112	0.099	0.061
1988	0.022	0.062	0.102	0.123	0.046	0.039
1989	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.109	0.144	0.181	0.080	0.030	0.010
1991	0.072	0.200	0.155	0.123	0.030	0.014
1992	0.135	0.317	0.160	0.042	0.012	0.004
1993	0.059	0.230	0.197	0.074	0.016	0.005
1994	0.033	0.079	0.144	0.115	0.045	0.015
1995	0.086	0.133	0.203	0.118	0.042	0.009
1996	0.060	0.308	0.212	0.106	0.047	0.007
1997	0.026	0.153	0.263	0.093	0.022	0.004
1998	0.019	0.090	0.142	0.112	0.020	0.003
1999	0.010	0.083	0.100	0.056	0.015	0.001
2000	0.122	0.082	0.102	0.043	0.014	0.003
2001	0.068	0.154	0.080	0.036	0.008	0.001
2002	0.028	0.173	0.239	0.073	0.018	0.003

Table 14. Summer DFO research vessel survey age-disaggregated numbers per tow in the western component.

	3	**4**	**5**	**6**	**7**	**8**
1984	0.545	0.951	3.308	0.913	0.097	0.284
1985	0.101	0.498	2.844	3.613	0.747	0.000
1986	1.468	1.929	1.599	3.027	1.821	0.072
1987	0.064	0.633	1.851	1.119	2.268	1.159
1988	1.651	2.277	6.218	5.278	4.043	1.984
1989	0.098	0.488	1.358	1.957	1.868	0.568
1990	15.197	6.864	10.383	2.456	0.619	0.755
1991	1.872	1.656	2.877	2.862	0.890	0.800
1992	0.364	0.989	1.341	1.061	0.223	0.143
1993	11.941	8.135	4.141	1.815	0.514	0.016
1994	0.301	1.086	2.306	1.980	0.784	0.219
1995	1.501	1.216	1.957	0.986	0.297	0.050
1996	1.142	12.519	10.772	3.475	1.531	0.133
1997	0.351	0.477	1.616	0.763	0.081	0.090
1998	0.126	0.306	0.616	0.609	0.143	0.000
1999	0.538	0.849	0.492	0.378	0.271	0.000
2000	0.480	0.439	0.795	0.216	0.000	0.029
2001	6.976	1.824	0.652	0.177	0.093	0.022
2002	1.583	0.731	0.580	0.200	0.106	0.024

Table 15. ADAPT results (consensus formulation) – Bias adjusted fishing mortality at age estimates, Western component pollock.

F Bias Adj(	2	3	4	5	6	7	8	9	10	11	12	13	4-9 F	6-9 F	Landings
1982	0.006	0.093	0.405	0.480	0.737	0.654	0.720	0.540	0.901	0.476	0.583	0.000	0.5546	0.690367	19625
1983	0.005	0.103	0.312	0.431	0.397	0.453	0.433	0.473	0.379	0.935	0.466	0.000	0.343827	0.43791	18319
1984	0.000	0.053	0.215	0.380	0.451	0.340	0.406	0.304	0.244	0.196	0.273	0.000	0.307336	0.403353	17619
1985	0.001	0.022	0.122	0.354	0.602	0.696	0.248	0.555	0.489	0.760	0.567	0.000	0.363413	0.599822	19663
1986	0.000	0.029	0.217	0.341	0.480	0.533	0.406	0.420	0.407	0.386	0.404	0.000	0.342599	0.494579	17754
1987	0.000	0.018	0.158	0.449	0.525	0.636	0.710	0.691	0.371	0.306	0.532	0.000	0.412863	0.603258	16562
1988	0.002	0.051	0.233	0.460	0.767	0.666	0.850	0.941	0.473	0.599	0.863	0.000	0.487376	0.771887	17959
1989	0.009	0.063	0.270	0.467	0.465	0.735	0.411	0.717	0.749	0.238	0.693	0.000	0.387358	0.554331	13759
1990	0.004	0.092	0.254	0.505	0.810	0.761	0.688	0.856	0.667	0.658	0.782	0.000	0.471036	0.785931	15808
1991	0.006	0.107	0.344	0.667	1.178	0.947	0.728	0.498	0.894	0.889	0.682	0.000	0.592326	1.057296	18670
1992	0.009	0.180	0.432	0.547	0.697	0.919	1.098	1.465	1.690	0.705	1.442	0.000	0.527425	0.828294	16696
1993	0.001	0.140	0.482	0.744	0.955	0.873	0.795	0.793	0.577	1.041	0.766	0.000	0.668709	0.924638	14410
1994	0.006	0.064	0.250	0.685	1.253	1.734	1.999	2.378	1.423	1.400	1.021	0.000	0.751707	1.456361	10836
1995	0.004	0.037	0.178	0.653	0.933	1.482	1.308	1.746	1.025	0.328	0.639	0.000	0.528652	1.093578	7144
1996	0.004	0.045	0.197	0.391	0.848	1.282	1.568	1.645	0.000	0.000	0.639	0.000	0.364525	1.019662	6441
1997	0.002	0.054	0.299	0.638	1.045	1.403	1.119	0.430	0.000	0.550	0.000	0.000	0.585875	1.109196	9759
1998	0.003	0.097	0.466	1.045	1.769	2.135	1.672	1.412	0.398	0.550	0.000	0.000	1.077725	1.827299	10534
1999	0.002	0.042	0.308	0.759	1.167	1.632	0.992	0.610	0.276	0.899	0.000	0.000	0.655682	1.268453	4760
2000	0.008	0.117	0.260	0.699	1.141	1.806	1.435	0.899	0.298	0.000	0.000	0.000	0.598053	1.31314	4768
2001	0.002	0.038	0.240	0.719	1.064	1.354	0.966	0.932	0.899	0.550	0.639	0.000	0.433763	1.115629	5400
2002	0.002	0.036	0.117	0.568	2.421	2.458	1.451	2.297	0.639	0.000	0.000	0.000	0.361143	2.387452	6485

Table 16. ADAPT results (consensus formulation) – Bias-adjusted biomass trends at age estimates. Western component pollock.

Beginning	2	3	4	5	6	7	8	9	10	11	12	13	2+	3 +	4 +
1982	4443	15720	7464	3050	8282	8516	4644	2230	560	742	282	0	55933	51490	35770
1983	2660	15744	24006	7486	2217	4117	4417	2297	1271	229	434	147	65025	62365	46621
1984	4055	6754	24618	25604	5213	1584	2684	2808	1340	812	88	257	75816	71761	65007
1985	2519	7437	12791	19413	17530	3008	1063	1720	1880	929	612	57	68957	66439	59002
1986	3285	4122	11879	13086	13489	9478	1440	744	869	1014	402	329	60136	56852	52730
1987	2065	4076	8823	13465	8104	7724	5091	848	415	469	579	253	51910	49846	45770
1988	4879	6356	6966	9292	8808	4458	3693	2293	379	256	303	357	48041	43162	36805
1989	4357	5226	13513	9837	5953	4051	2185	1523	832	250	118	130	47976	43619	38393
1990	3445	6339	7085	12358	5720	3767	1951	1452	715	364	189	63	43447	40002	33663
1991	3674	6544	8317	6962	7220	2578	1740	959	595	346	184	75	39194	35520	28976
1992	1857	6335	11215	8804	4574	2319	1010	788	523	227	135	91	37879	36022	29687
1993	2420	2548	6528	9242	5803	2159	861	300	163	87	102	30	30243	27824	25275
1994	2736	3091	3590	4834	4600	2199	811	327	119	75	27	47	22454	19718	16627
1995	1266	3460	4053	4233	3072	1402	392	107	31	29	17	10	18073	16806	13346
1996	777	2980	5902	4359	2386	1275	336	111	21	12	23	10	18190	17414	14434
1997	685	3084	5092	8180	3666	1088	371	80	25	19	13	10	22312	21627	18543
1998	1080	1656	2386	4859	4562	1389	280	121	54	24	11	10	16432	15352	13696
1999	1495	1427	2423	2104	1837	841	176	57	34	34	11	10	10448	8953	7526
2000	3086	3846	2229	2433	1378	639	181	64	35	28	11	10	13941	10855	7009
2001	2199	4992	5945	2880	1584	514	124	49	27	24	25	10	18374	16175	11182
2002	1568	3464	8793	5762	1598	622	153	50	20	12	13	10	22066	20498	17034
2003	1485	2489	5824	12171	4659	170	65	37	5	11	12	10	26937	25452	22964

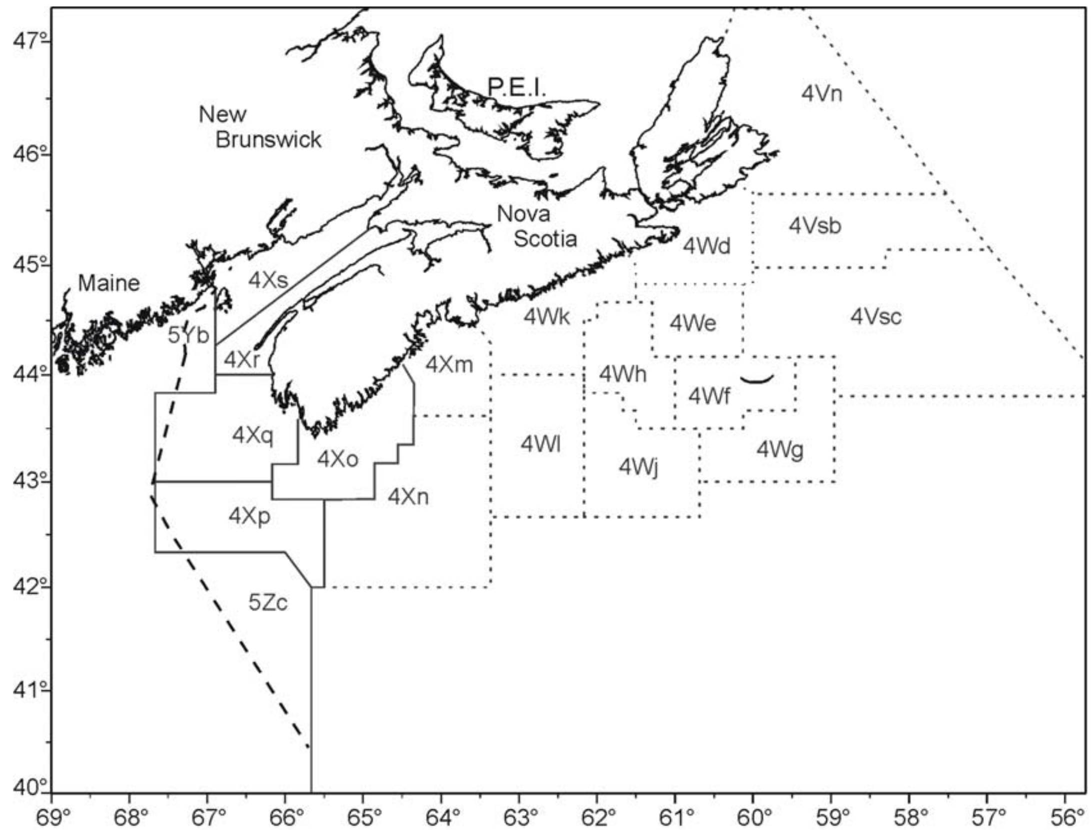

Fig. 1. Statistical Unit Areas in the Scotian Shelf, Bay of Fundy and the Canadian portion of NAFO Subarea 5. Those Unit Areas forming the western component of pollock on the Scotian Shelf, Bay of Fundy and Georges Bank are outlined as solid lines, and those comprising the eastern component are shown dashed lines.

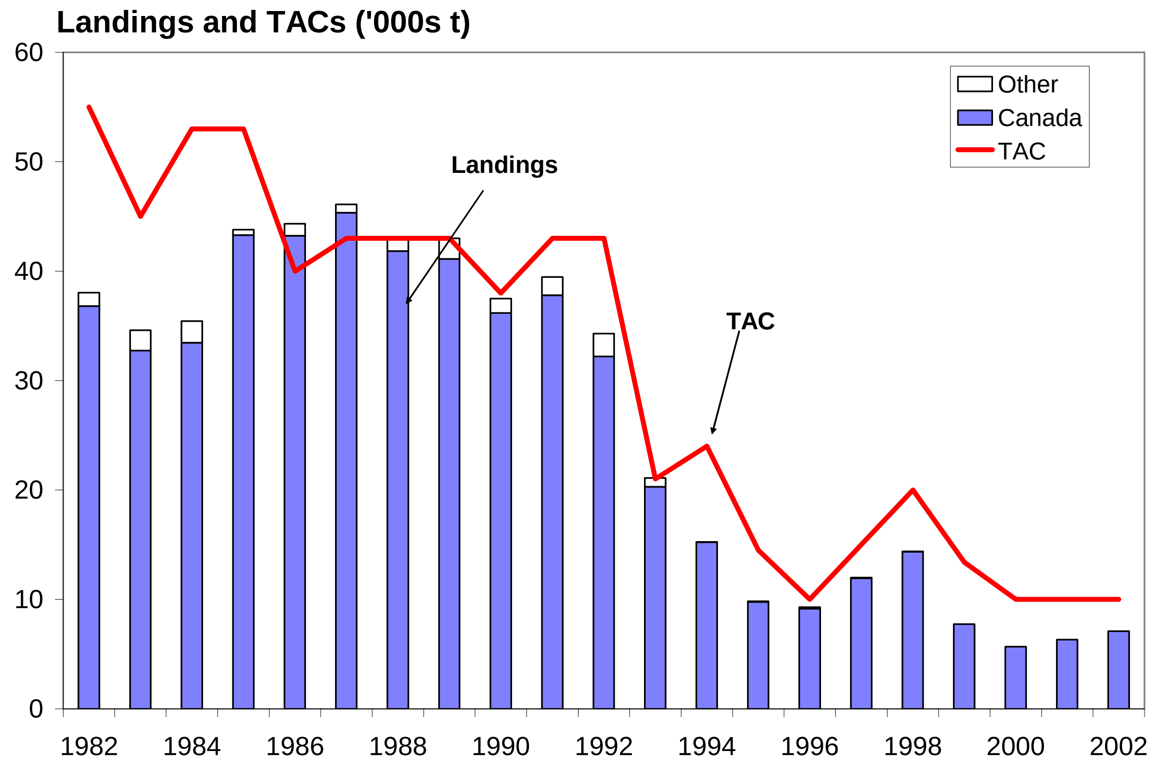

Fig. 2. Landings of 4VWX5Zc pollock, shown with respect to the Canadian Total Allowable Catch.

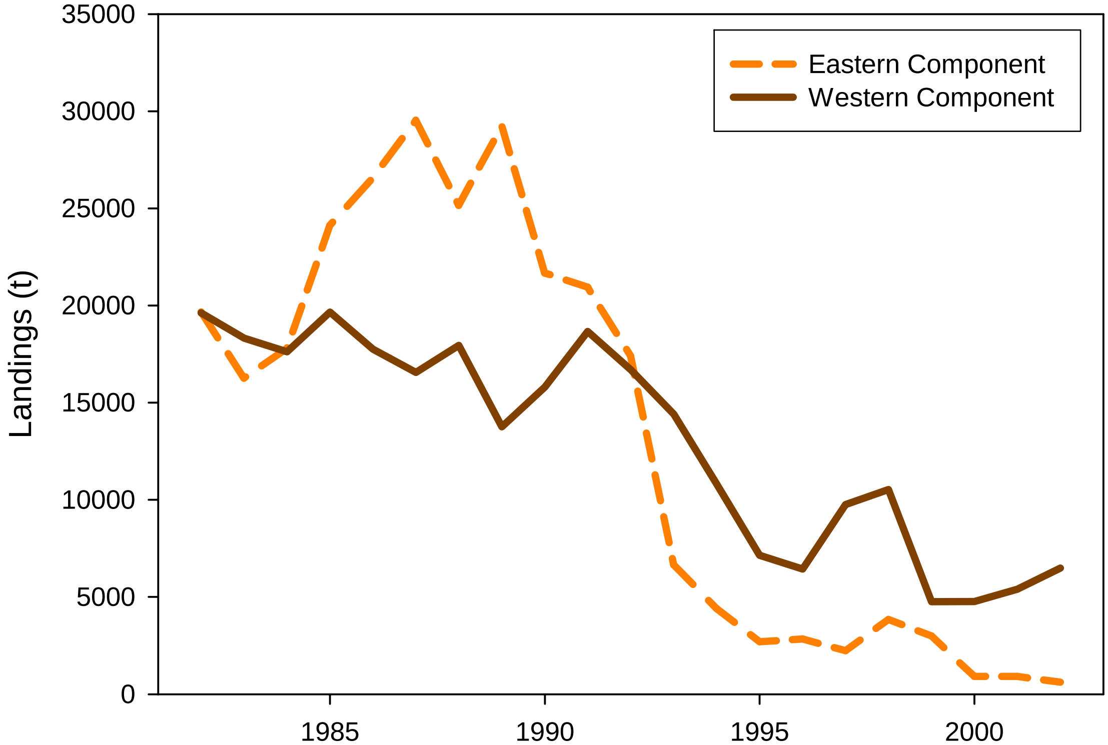

Fig. 3. Landings of pollock from the eastern and western components, 1982-2002.

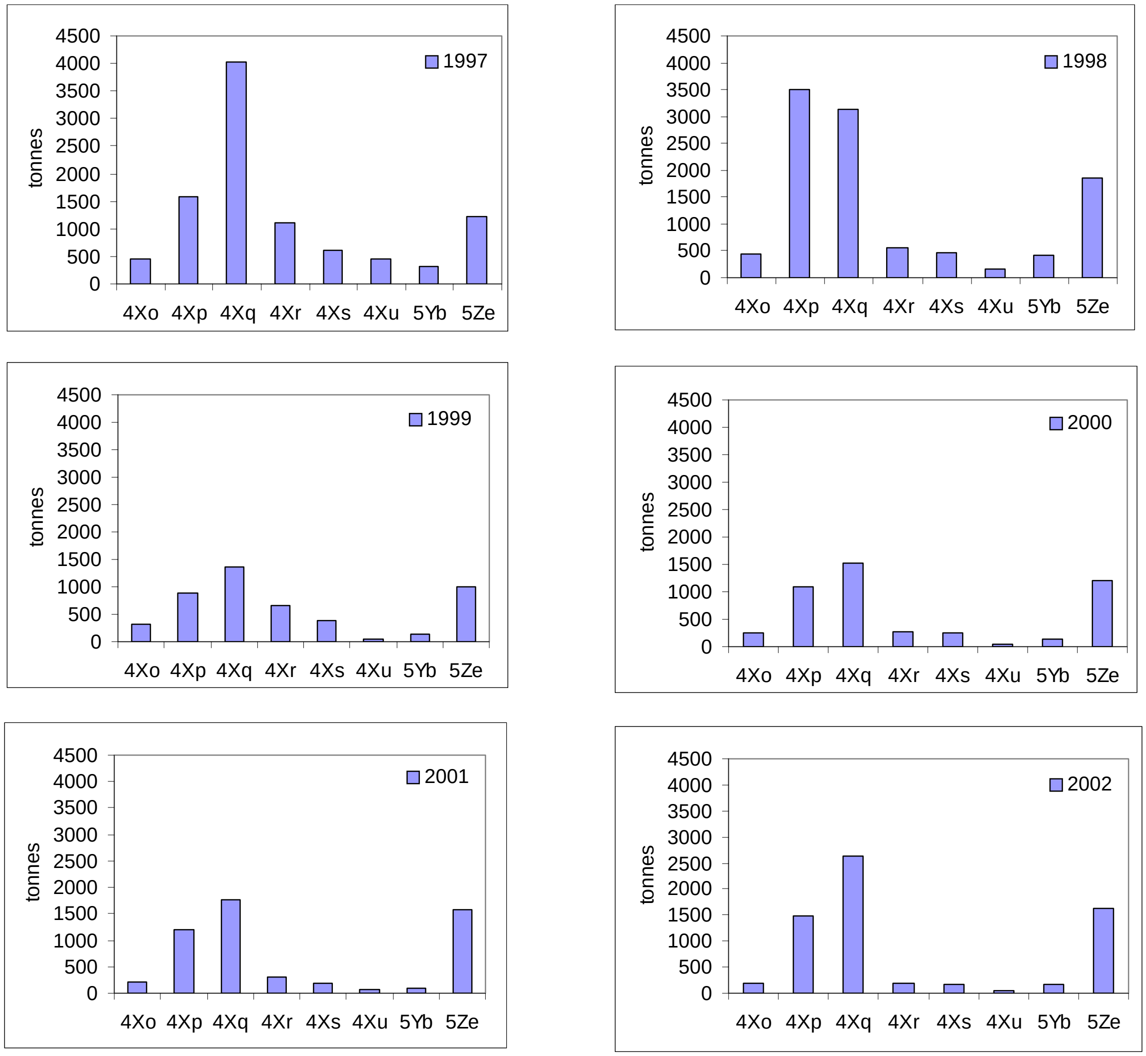

Fig. 4. Pollock landings(t) by statistical Unit Area, 1996-2002 (western component).

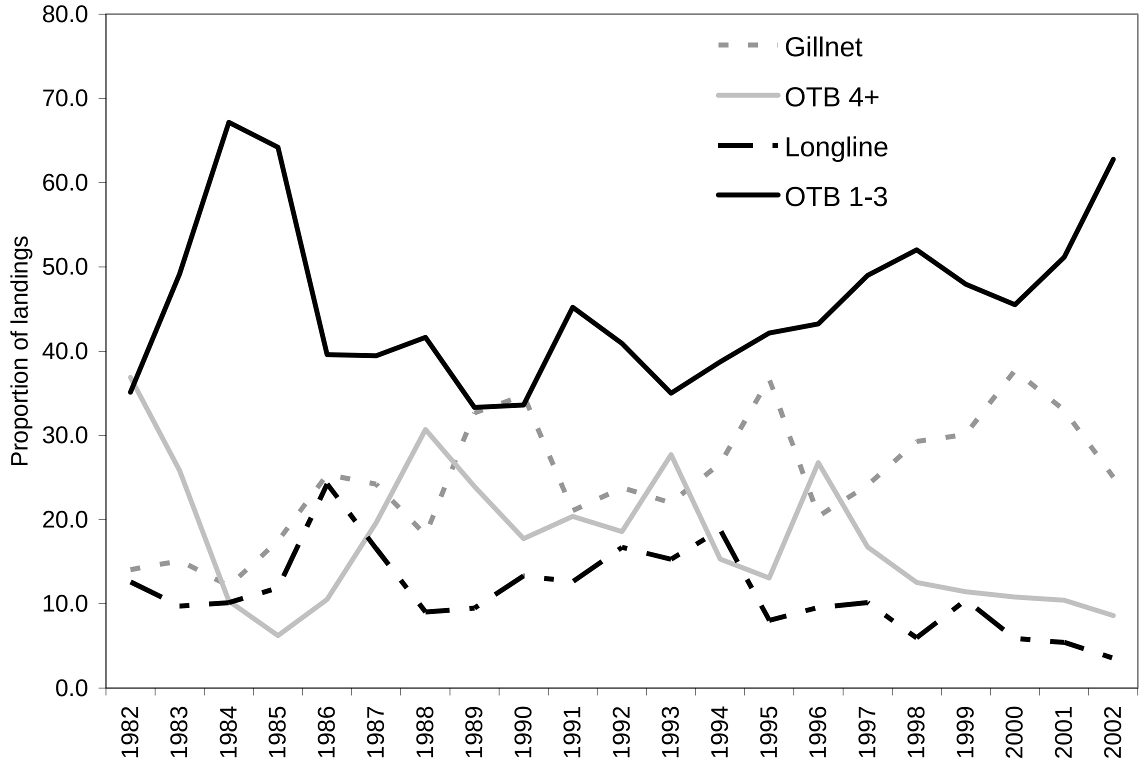

Fig. 5. Proportional landings of pollock by gear type, (western component) 1982 -2002.

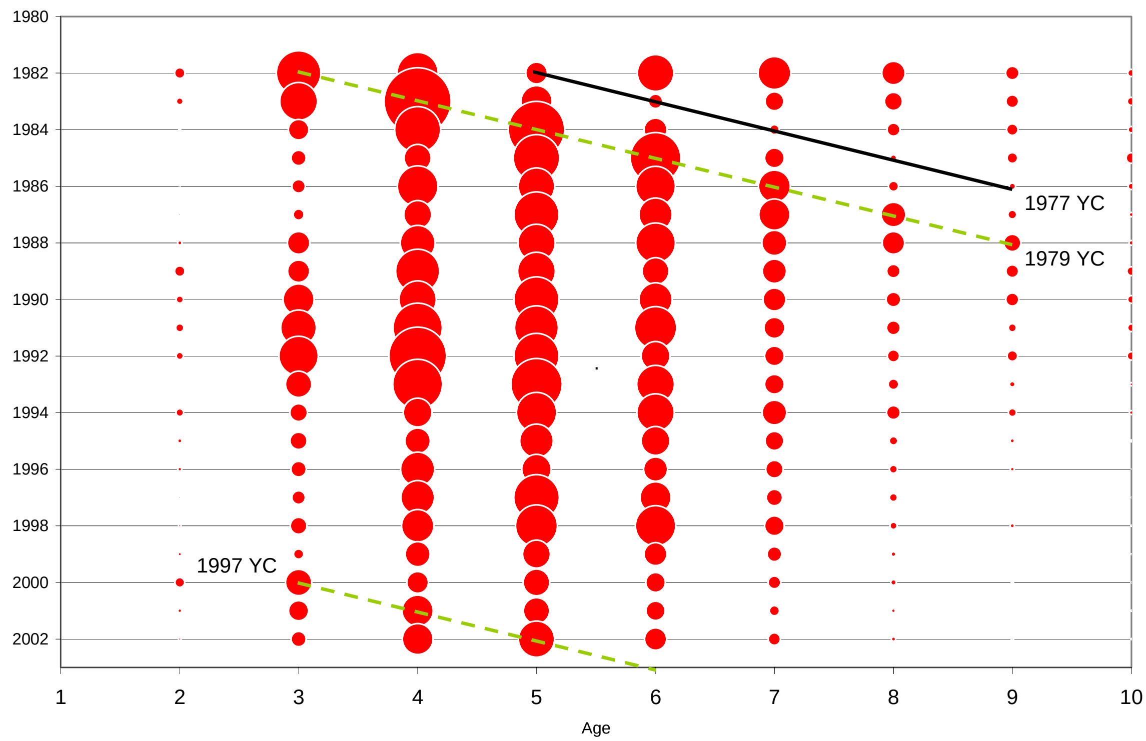

Fig. 6. Catch at age for pollock in the western component. The area of the circle is proportional to the catch at that age and year. Two examples of strong cohorts are highlighted with a dashed line, and a weak cohort is indicated by the solid line.

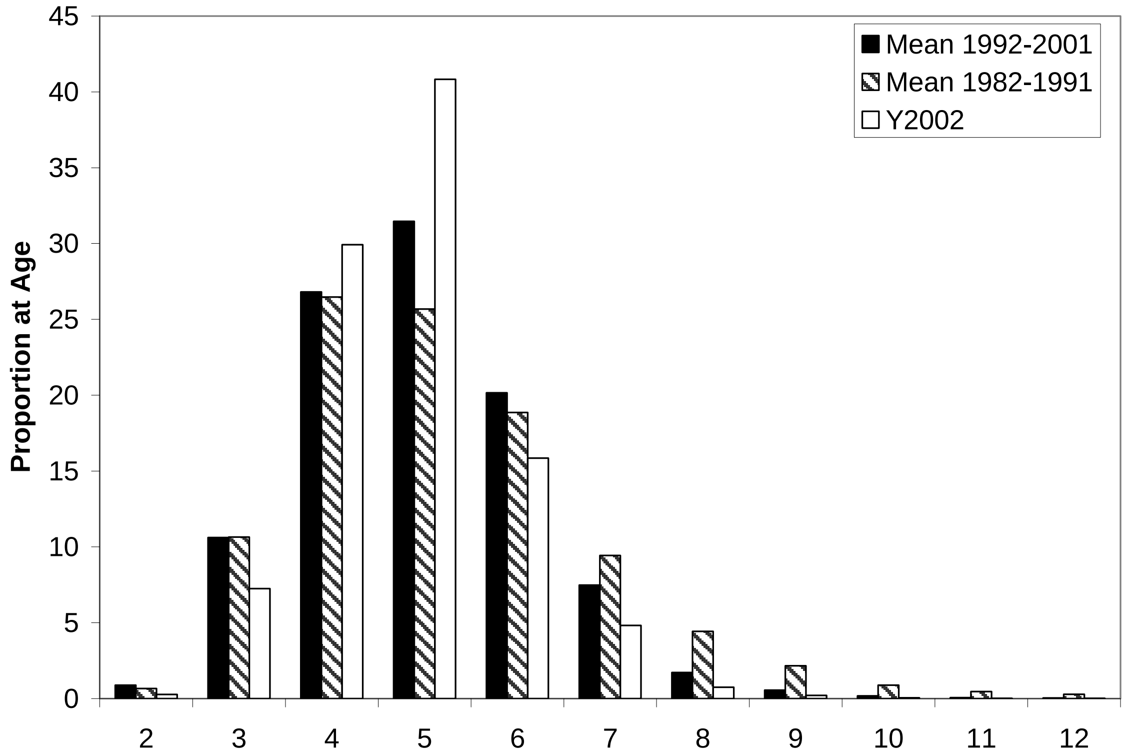

Fig. 7. Age composition of western component pollock catch in 2002 compared with the 10 year averages from 1982-1991 and 1992-2001.

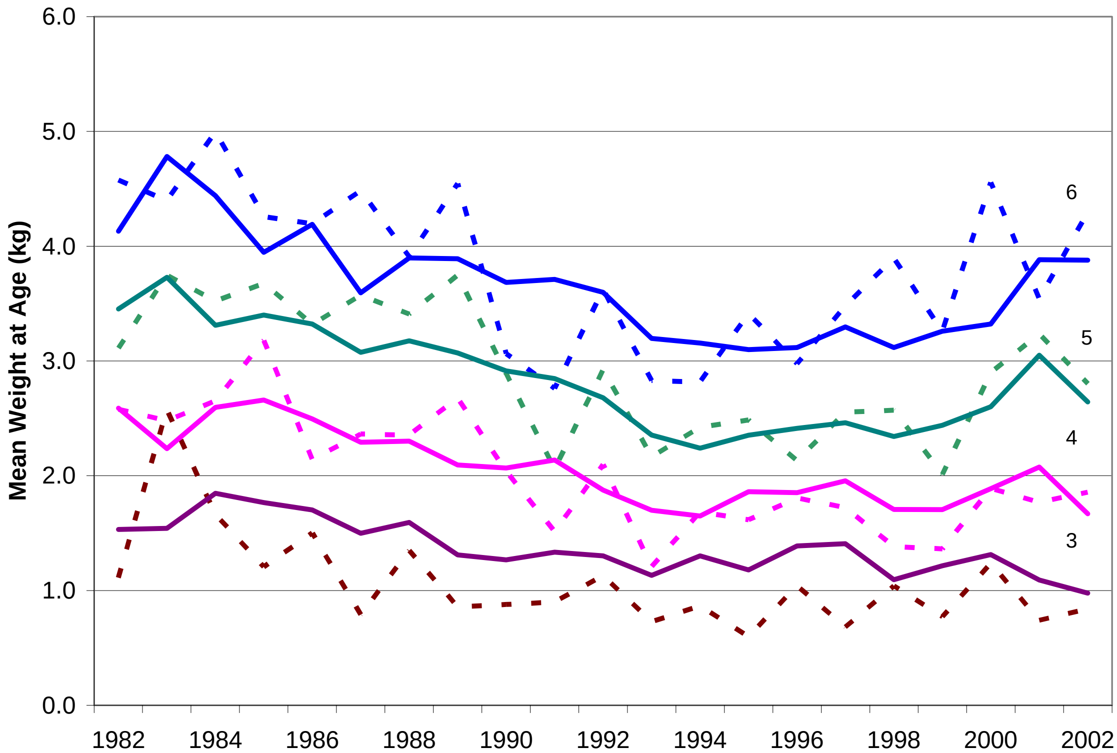

Fig. 8. Trends in mean weight at age (kg) for pollock of ages 3-6 in the western component. The solid lines represent the data from the commercial fishery, and the dashed lines represent weights at age from RV surveys conducted in strata corresponding approximately to the western component.

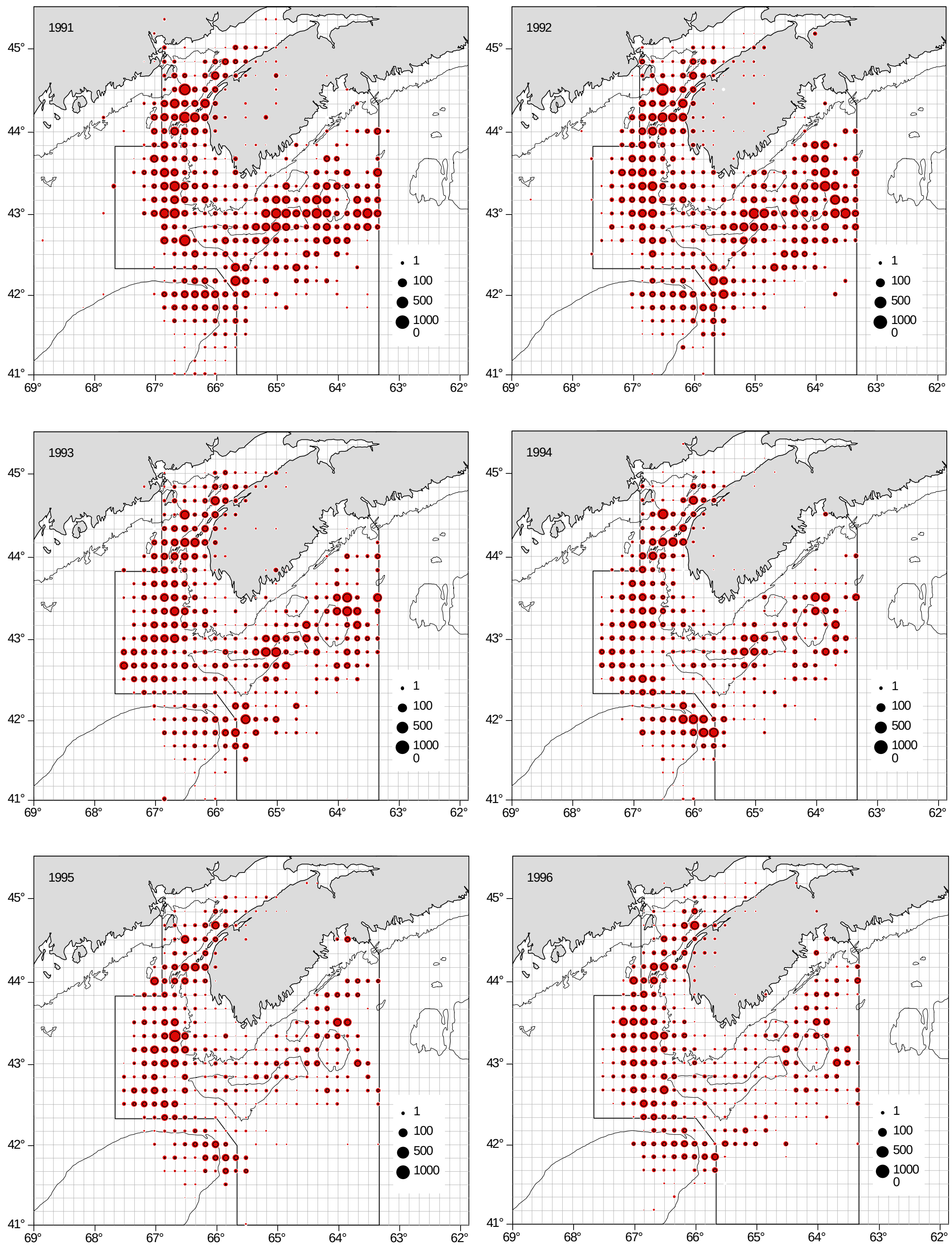

Fig. 9. Distribution of pollock catches by small mobile gear, summarized by ten minute grid cells from 1991-1996.

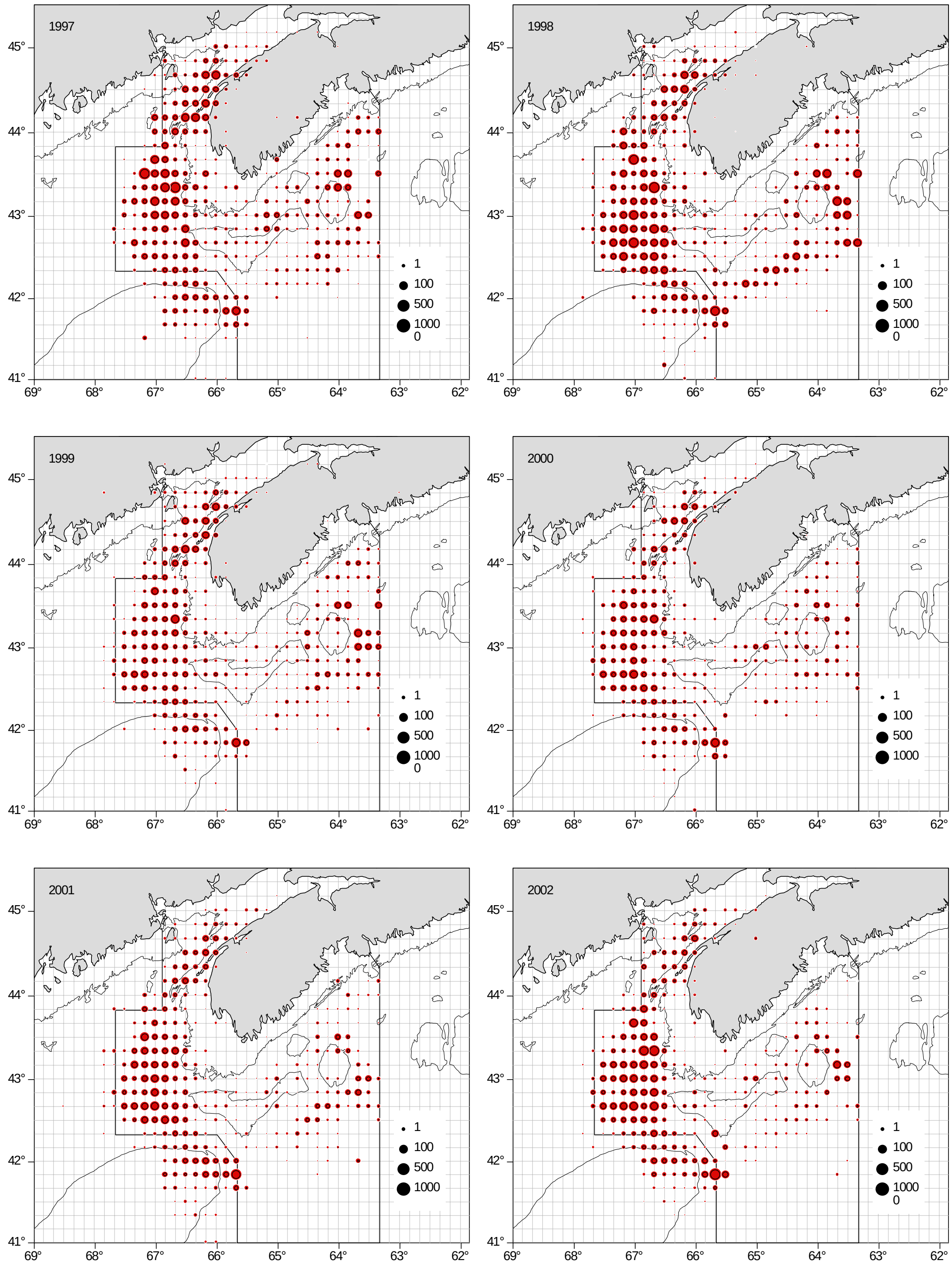

Fig. 9 (cont). Distribution of pollock catches by small mobile gear, summarized by ten minute grid cells from 1997-2002.

Fig. 10. Standardized mobile gear (OTB 1-3) catch rate series (t/hr) for pollock for discrete areas within the western component, 1982-2002.

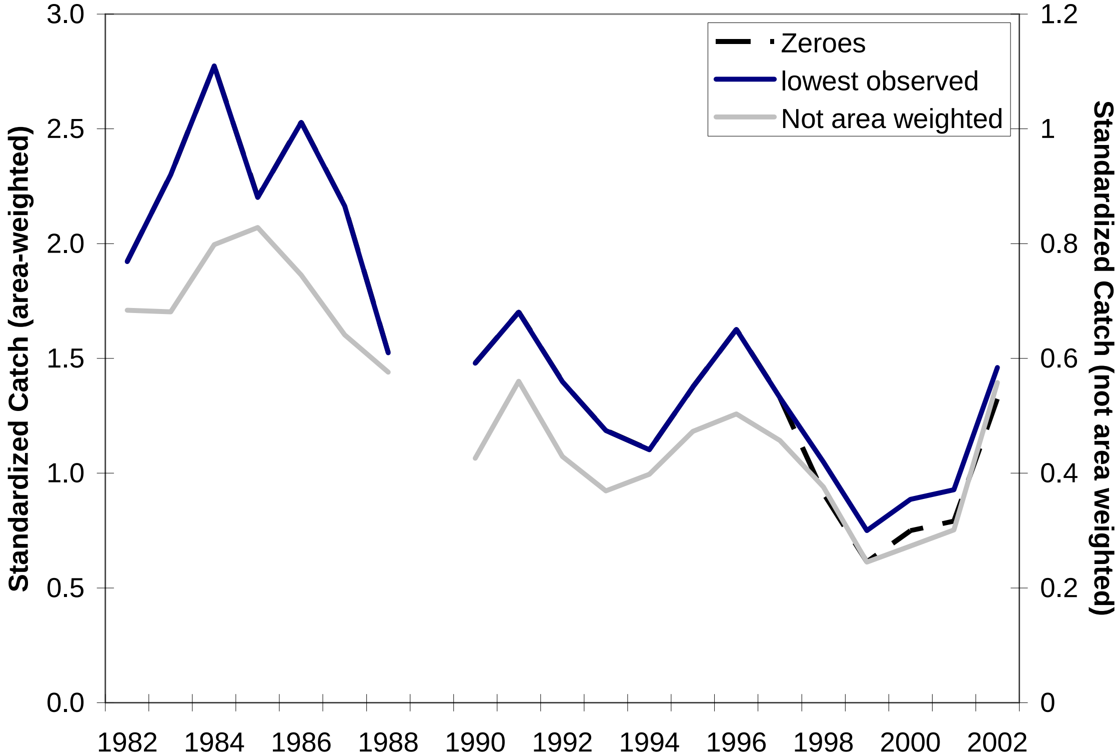

Fig. 11. Standardized catch rate series (kg) calculated using an area-weighted approach (with two methods for filling years with few observations), compared with the unweighted standardized series.

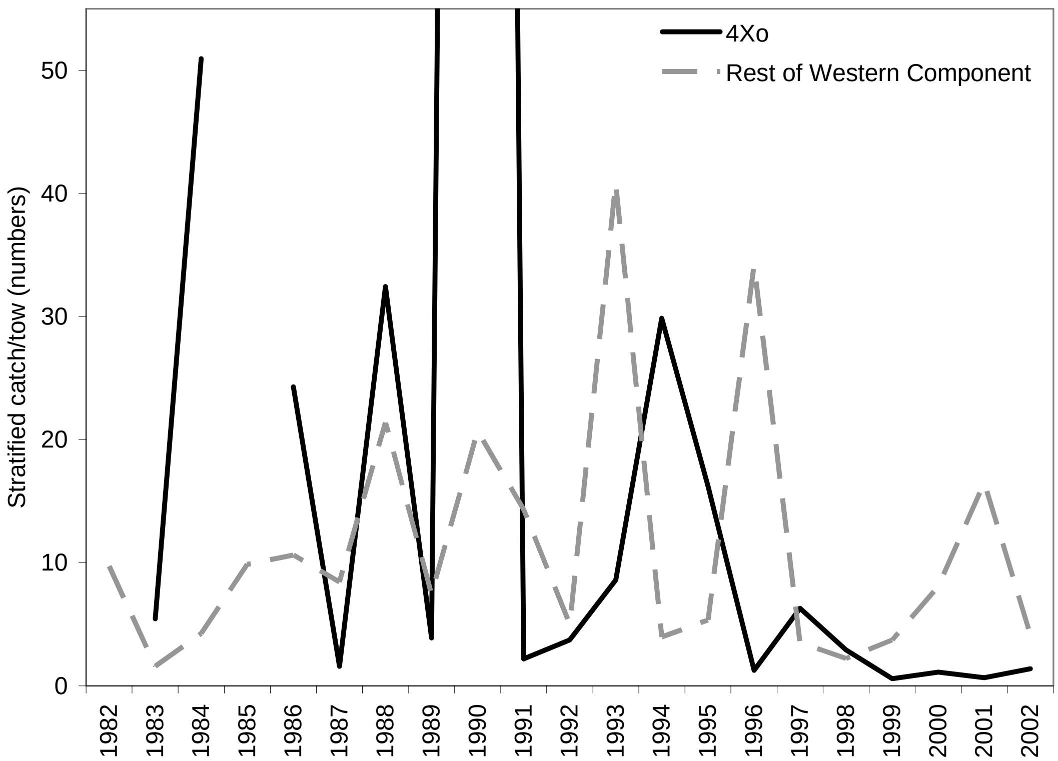

Fig. 12. Research vessel survey catch/tow (number) in strata corresponding with Unit Area 4Xo compared with the strata corresponding to 4Xpqrs in the rest of the western component.

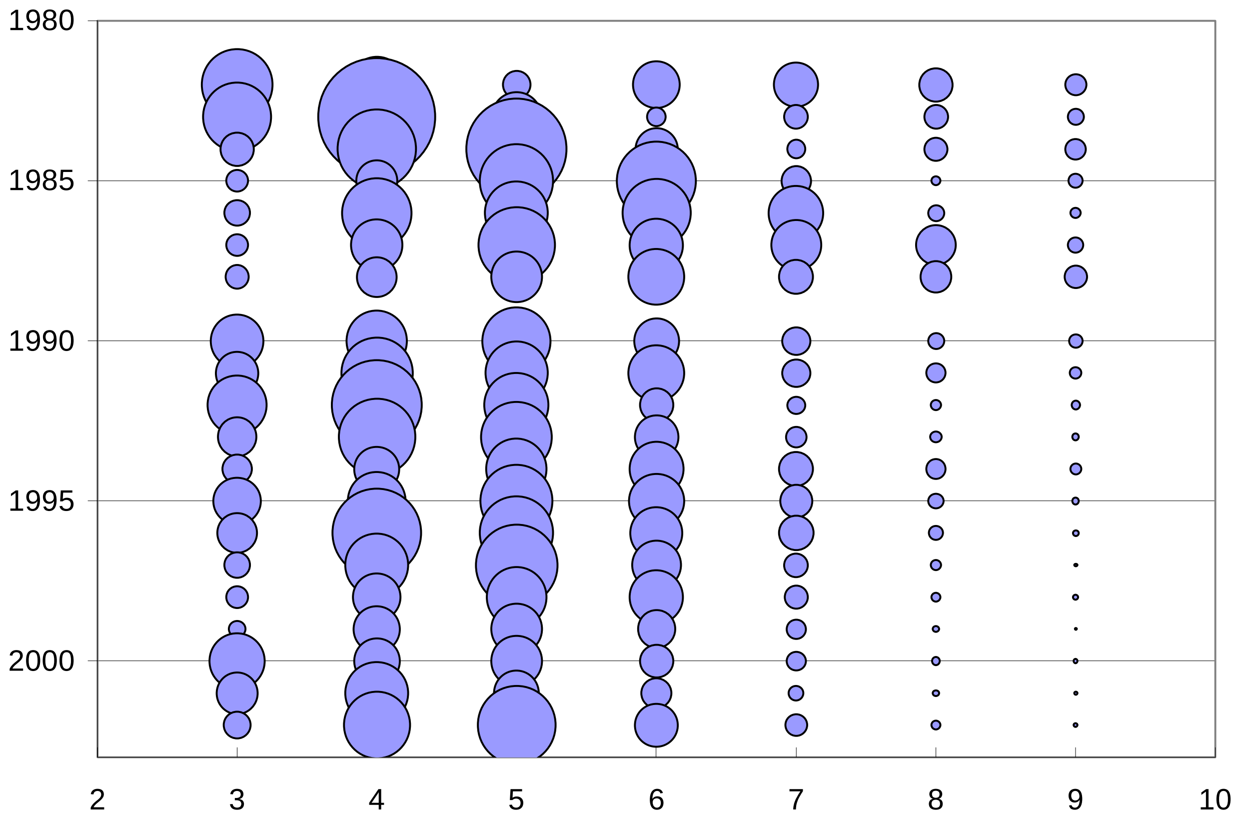

Fig. 13. Age-disaggregated catch rates for small mobile gear operating in the western component, 1982 – 2002.

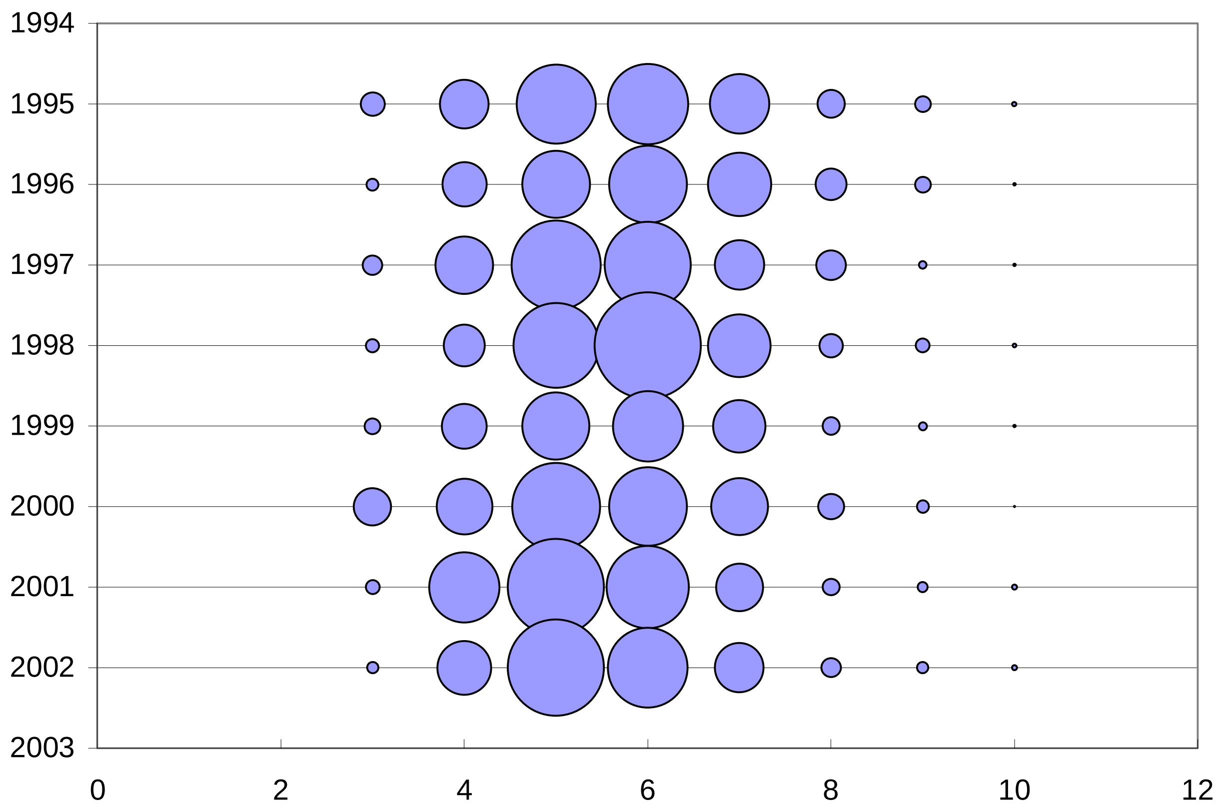

Fig. 14. Age-disaggregated catch rates for the gillnet fishery operating in the western component, 1995 – 2002.

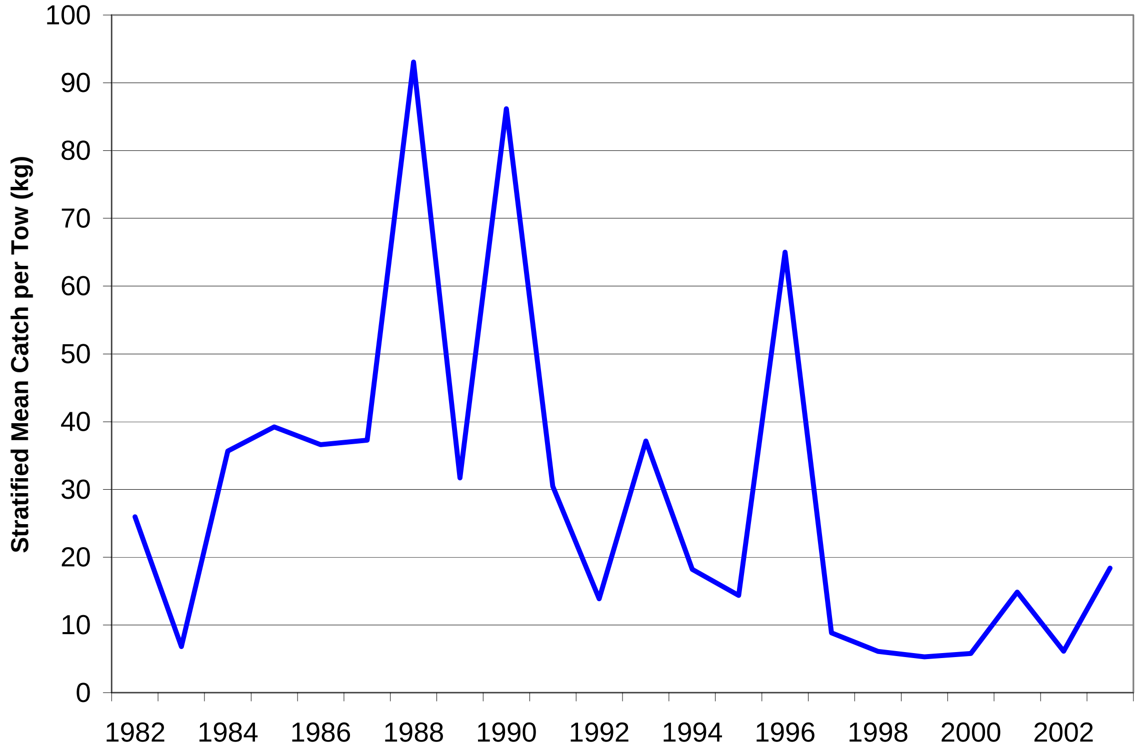

Fig. 15. Stratified mean catch per tow (kg) of pollock from the DFO summer research vessel survey in 4X strata corresponding to the western component, 1982-2002.

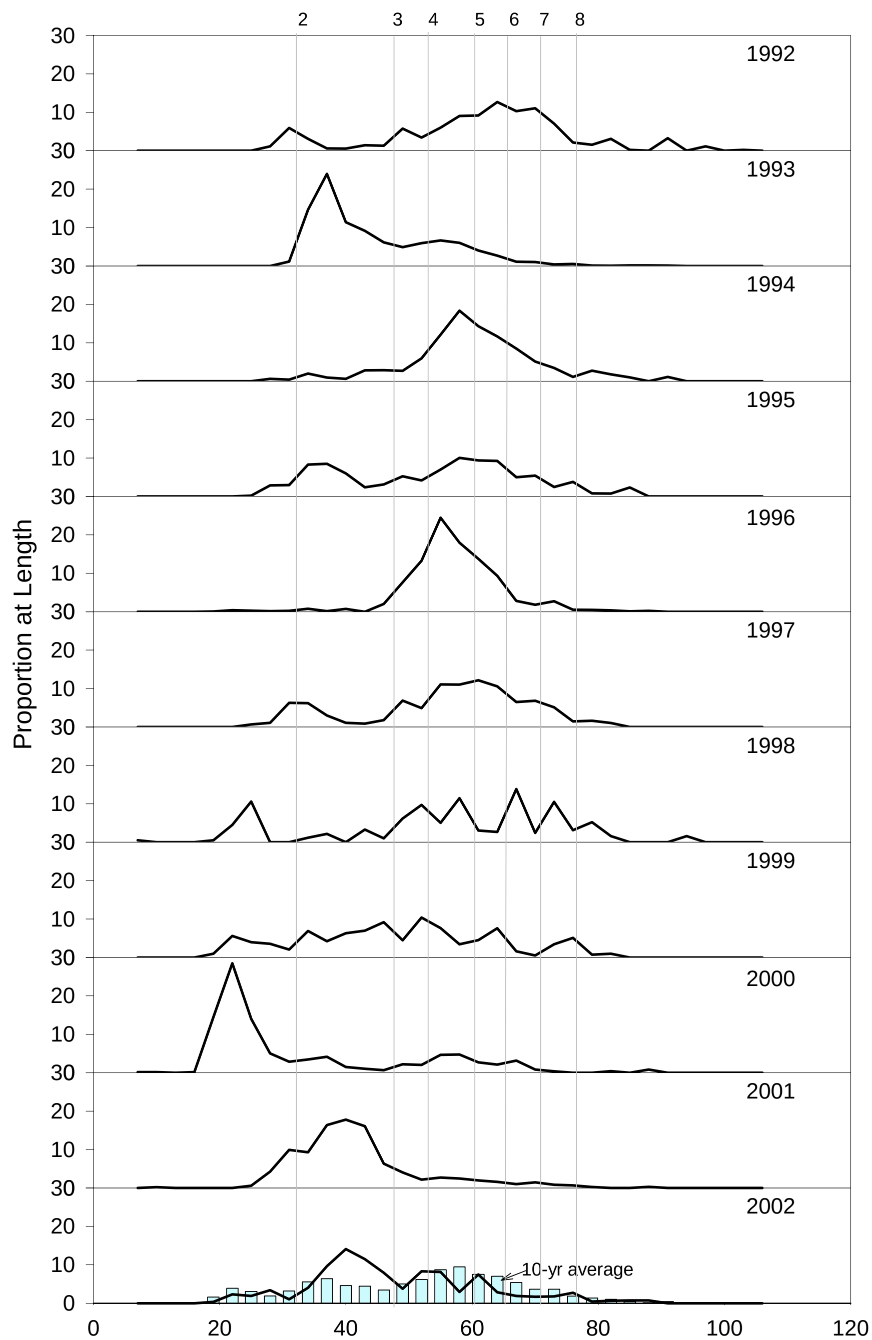

Fig. 16. Length-frequency distribution of pollock collected in the DFO summer surveys in the western component. The vertical lines correspond to the mean length at age observed over the 10-yr period (age 2 from surveys, balance of ages from commercial catch at age).

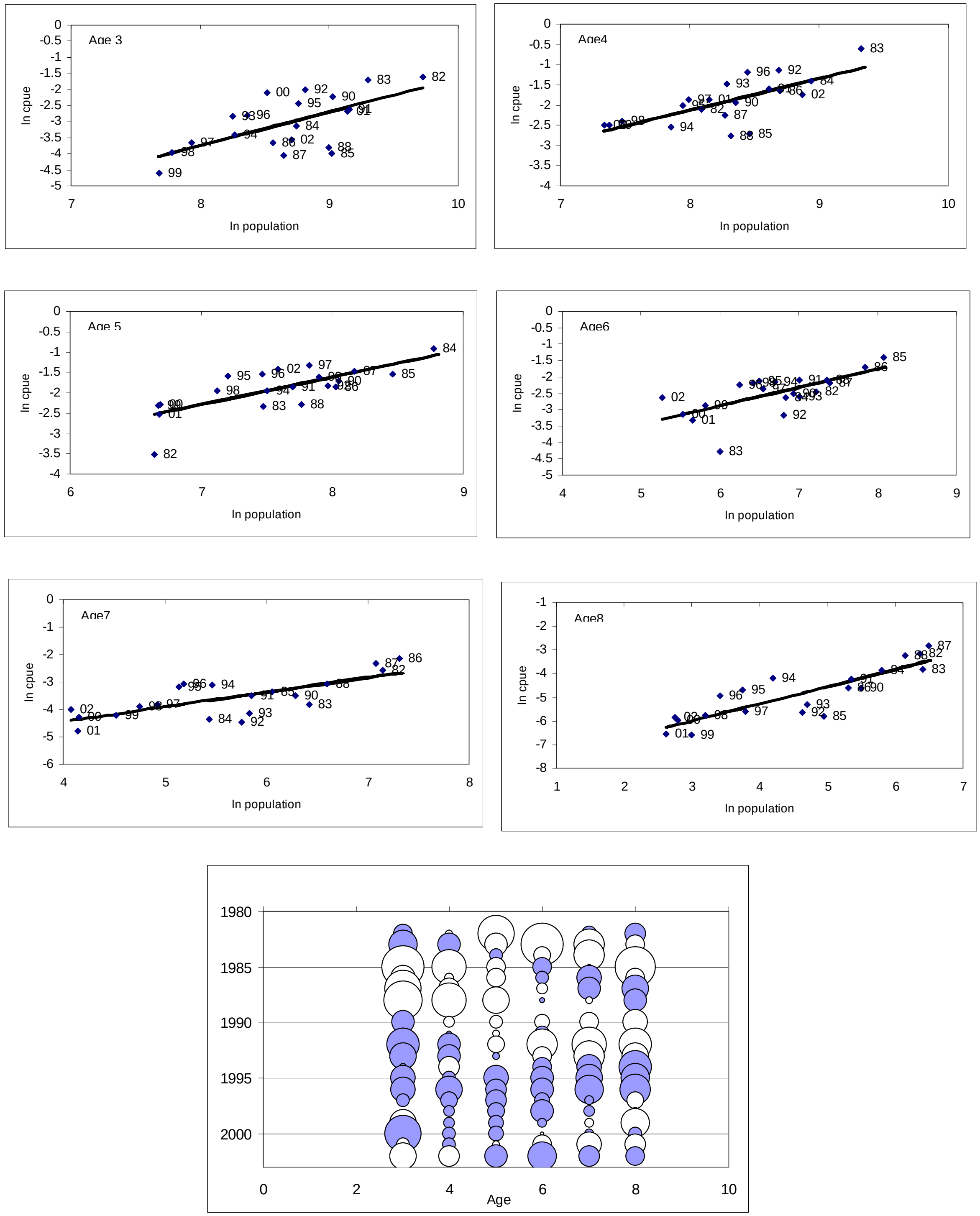

Fig. 17. Age-specific relationships between the small mobile gear indices (y axis) and population (x axis) on a ln scale, and the resulting residuals at age (bottom figure). Consensus formulation, western component pollock. Closed circles denote positive residuals and open circles denote negative residuals.

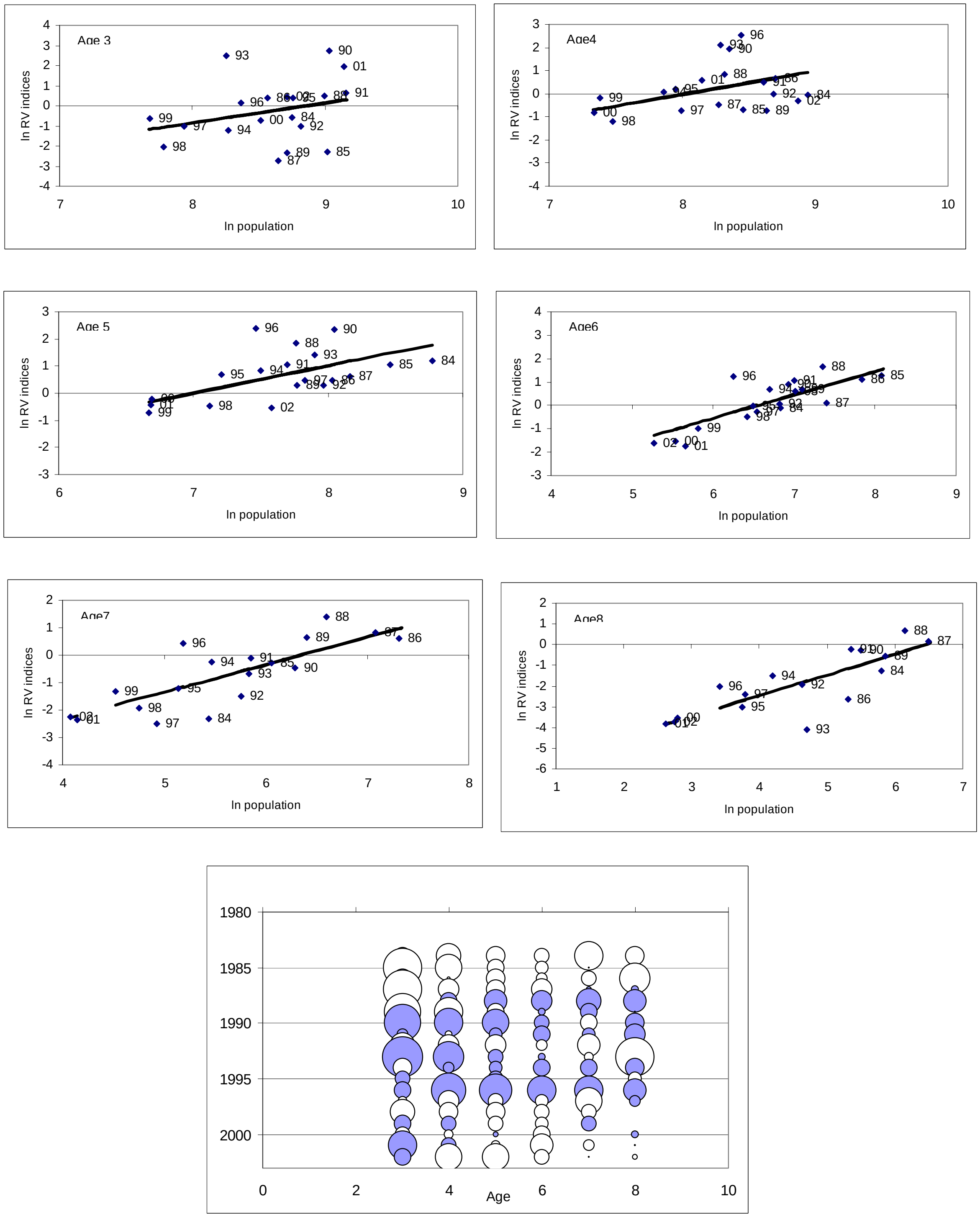

Fig. 18. Age-specific relationships between the RV indices (y axis) and population (x axis), and the resulting residuals at age (bottom right figure). Consensus formulation, western component pollock. Closed circles denote positive residuals and open circles denote negative residuals.

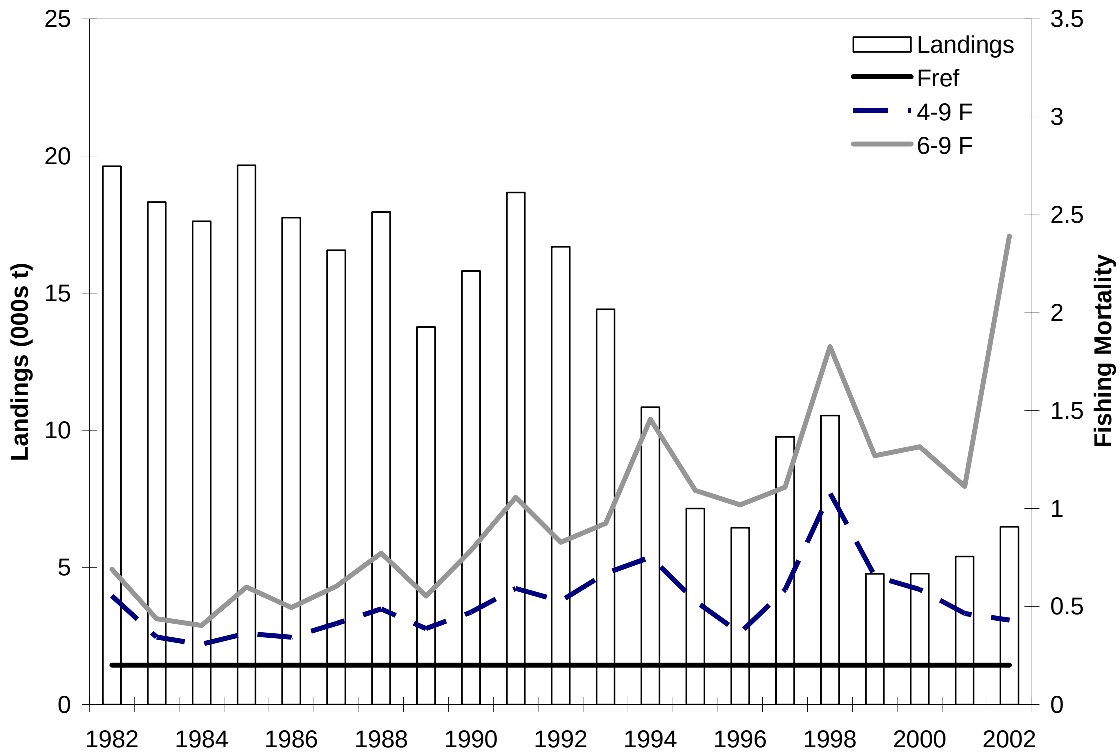

Fig. 19. Trends in fishing mortality for the western component of pollock as indicated by the consensus formulation.

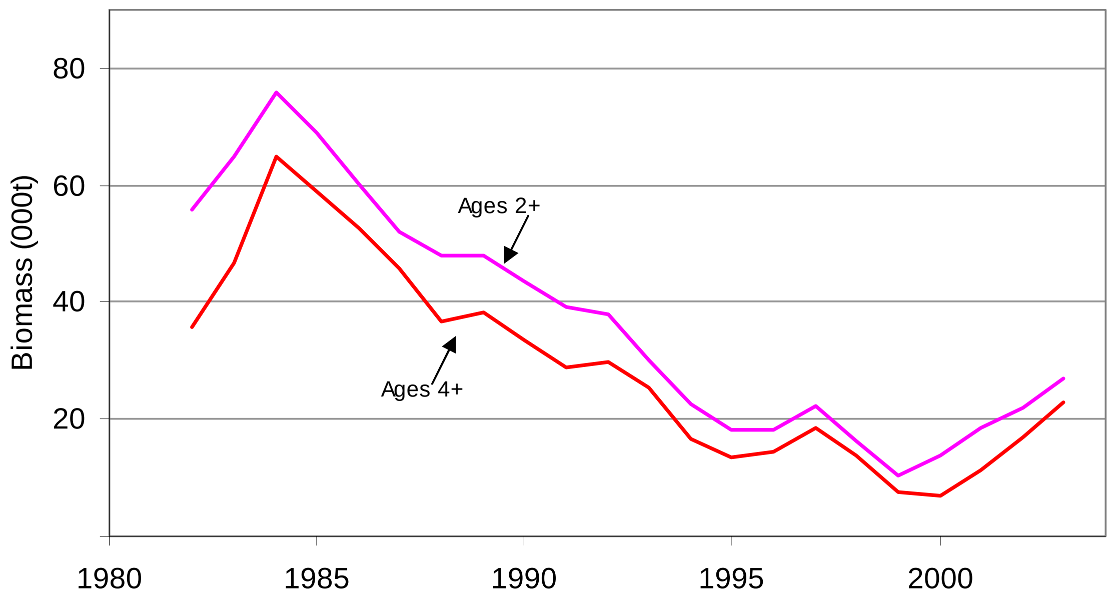

Fig. 20. Trends in biomass (000t), western component pollock for ages 2+ and 4+, as indicated by the consensus formulation.

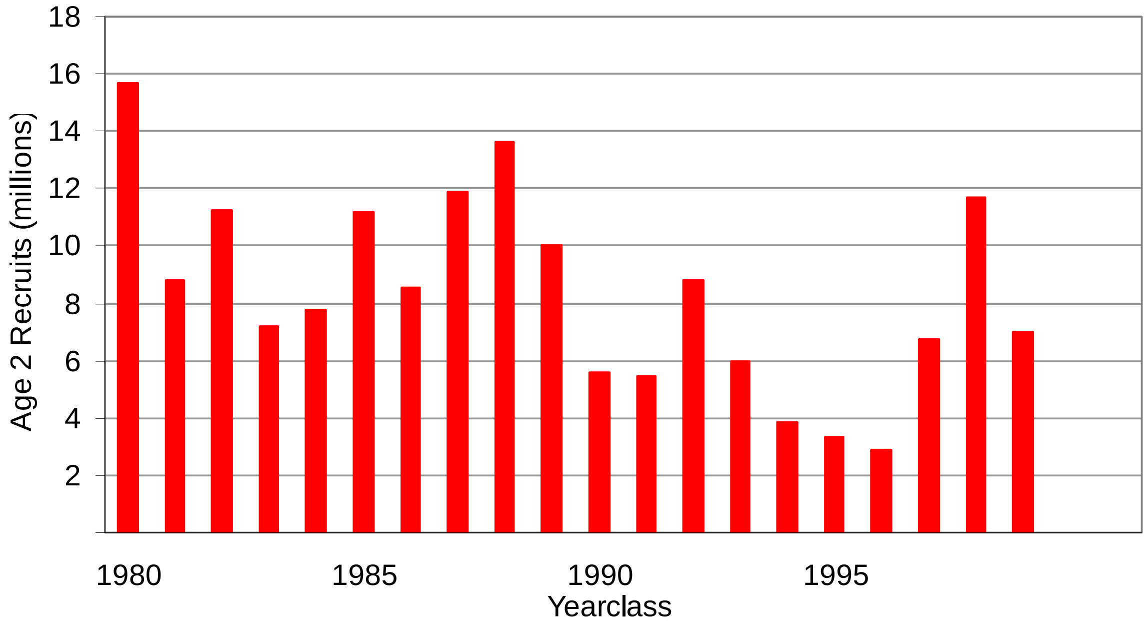

Fig. 21. Trends in age 2 recruits (number in millions) for the western component of pollock, as indicated by the consensus formulation.

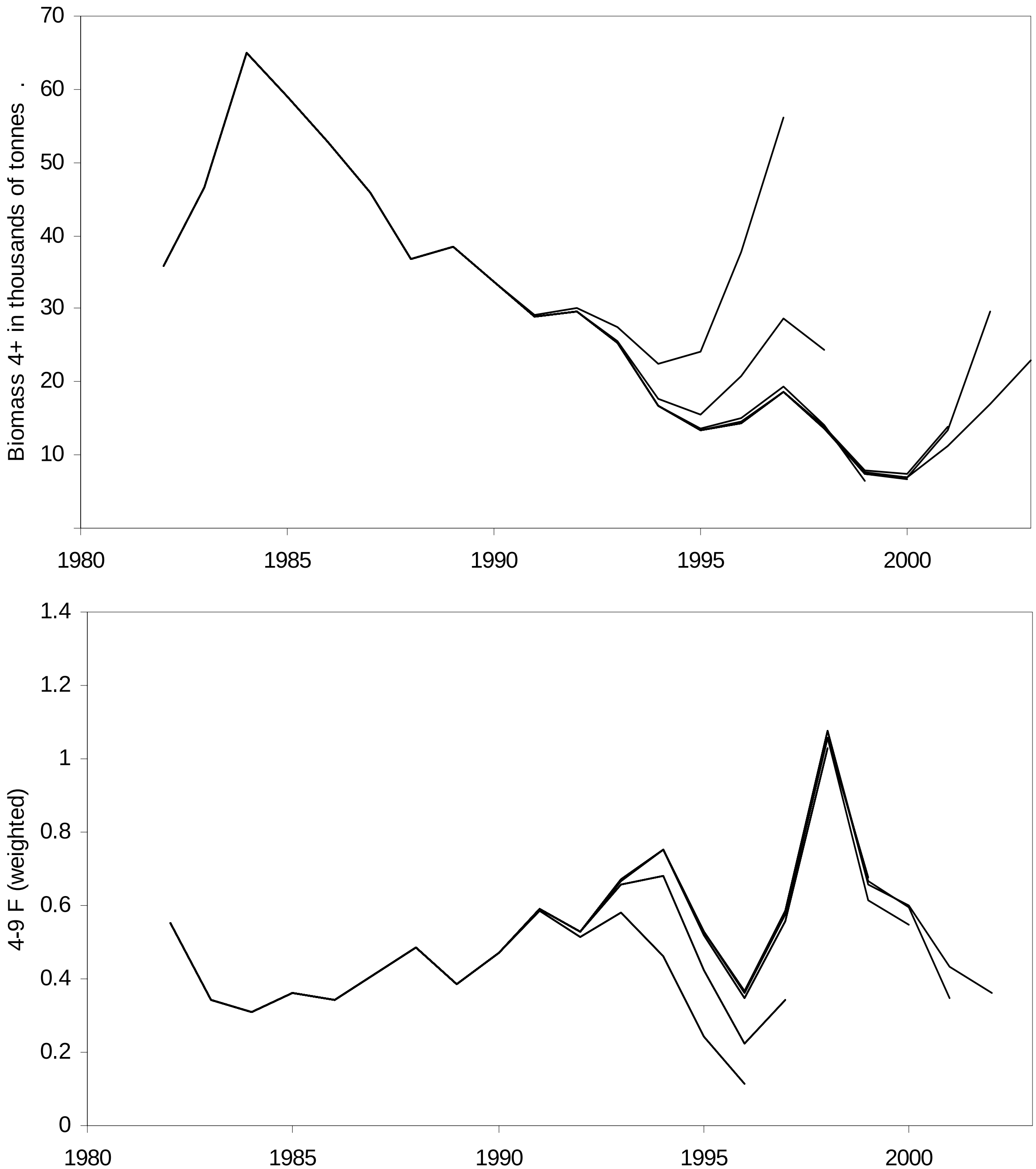

Fig. 22. Retrospective analysis of trends in fishing mortality (bottom panel) and biomass (top panel). The current assessment model was re-run with up to seven years of input values sequentially deleted to generate these plots. Western component pollock, consensus formulation.

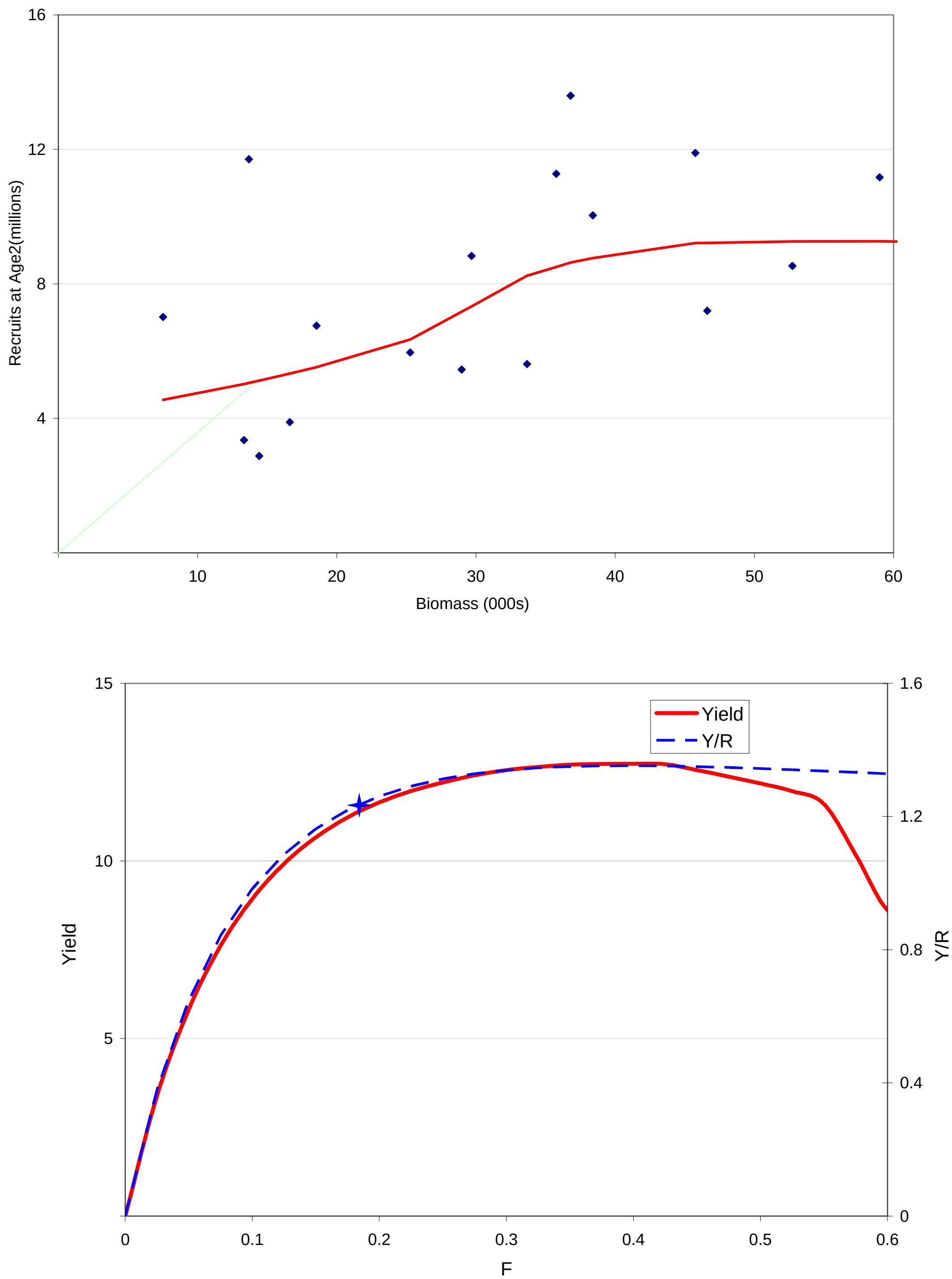

Fig. 23. Relationship between spawning stock biomass and age two recruits (top panel) for the western component of pollock. The line signifies the smoothed trend. The relationships between yield, yield per recruit and fishing mortality is shown on the bottom panel. The star signifies the $F_{0.1}$ reference point.

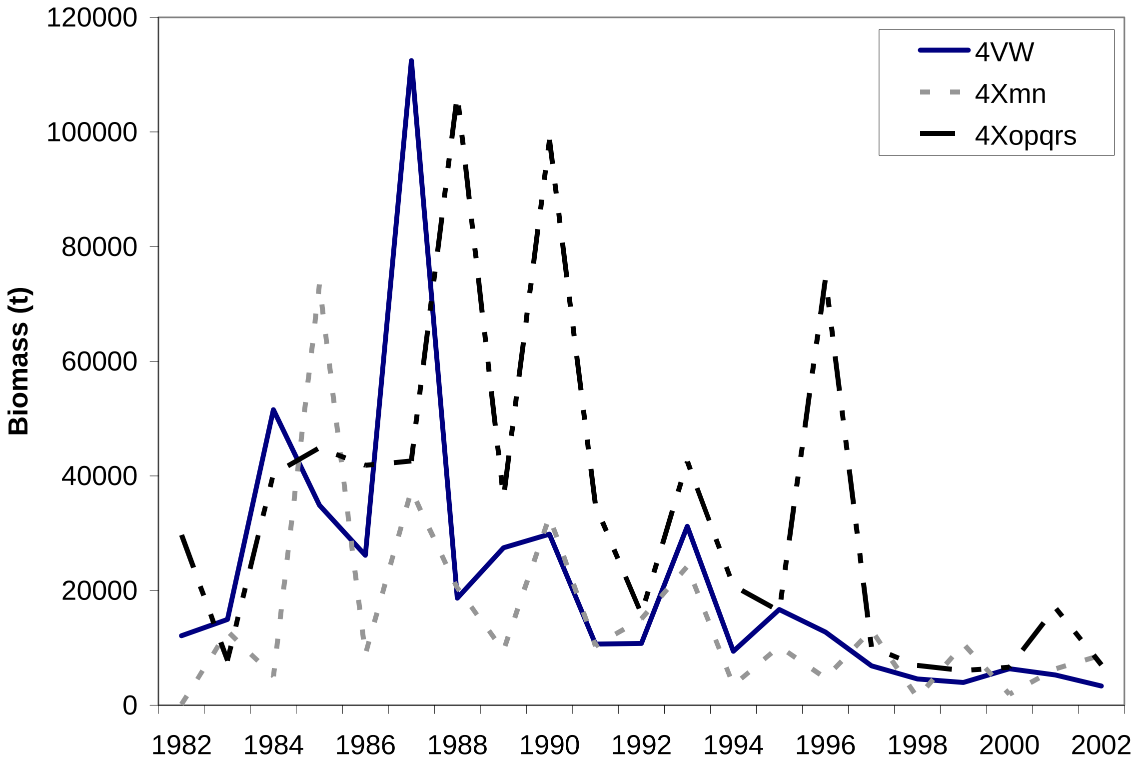

Fig. 24. Survey biomass in the eastern and western components of pollock, 1982-2002. A portion of the eastern component (4Xmn) is shown separately.

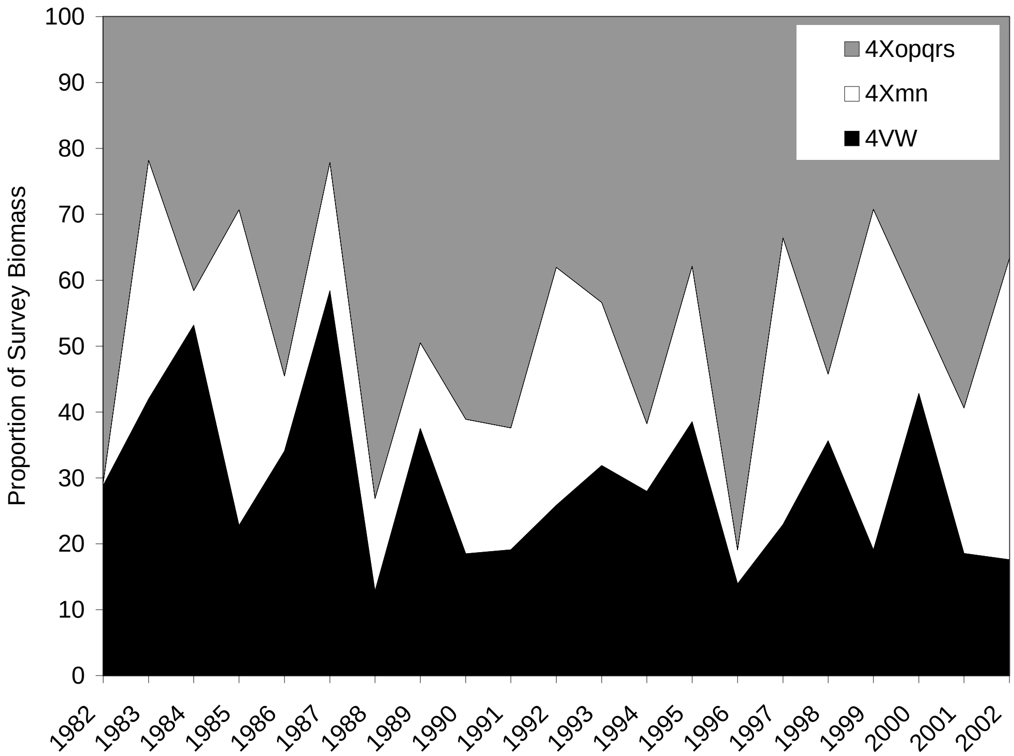

Fig.25. Proportion of survey biomass in the western component compared with the 4VW and 4Xmn components.

Appendix One

Consensus VPA – Setup, Statistics, Parameter Estimates
and Population Results
Western Component Pollock

VPA setup

Plus Group : No plus group

Population

	2	3	4	5	6	7	8	9	10	11	12	13
1995.00												(1)
1996.00												(1)
1997.00												(1)
1998.00												(1)
1999.00												(1)
2000.00												(1)
2001.00												(1)
2002.00	(5000)											(1)
2003.00	(5000)		5000	4000	2000	1000	500	100		(1)	(1)	(1)

F ratios

	2	3	4	5	6	7	8	9	10	11	12	13
1982.00								1.00	1.00	1.00	**wtd**	
1983.00								1.00	1.00	1.00	**wtd**	
1984.00								1.00	1.00	1.00	**wtd**	
1985.00								1.00	1.00	1.00	**wtd**	
1986.00								1.00	1.00	1.00	**wtd**	
1987.00								1.00	1.00	1.00	**wtd**	
1988.00								1.00	1.00	1.00	**wtd**	
1989.00								1.00	1.00	1.00	**wtd**	
1990.00								1.00	1.00	1.00	**wtd**	
1991.00								1.00	1.00	1.00	**wtd**	
1992.00								1.00	1.00	1.00	**wtd**	
1993.00								1.00	1.00	1.00	**wtd**	
2002.00						1.00	1.00	**wtd**				

Natural Mortality

	2	3	4	5	6	7	8	9	10	11	12	13
1982.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1983.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1984.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1985.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1986.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1987.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1988.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1989.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1990.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1991.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1992.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1993.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1994.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1995.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1996.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1997.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1998.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1999.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
2000.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
2001.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
2002.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)

APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

ORTHOGONALITY OFFSET......... 0.001076
MEAN SQUARE RESIDUALS 0.618133

Parameter	Est.	Std. Err.	Rel. Err.	Bias	Rel. Bias
N[2003 4]	5.41E3	3.07E3	0.567	8.88E2	0.164
N[2003 5]	6.13E3	2.85E3	0.465	6.73E2	0.110
N[2003 6]	1.38E3	8.20E2	0.596	1.75E2	0.127
N[2003 7]	7.35E1	8.52E1	1.159	3.97E1	0.541
N[2003 8]	2.21E1	2.58E1	1.167	1.23E1	0.554

N[2003 9]	8.04E0	7.74E0	0.963	2.91E0	0.362
q ID#[1]	1.44Eý4	2.65Eý5	0.185	1.80Eý6	0.013
q ID#[2]	3.27Eý4	5.98Eý5	0.183	4.10Eý6	0.013
q ID#[3]	9.22Eý4	1.68Eý4	0.182	1.19Eý5	0.013
q ID#[4]	1.43Eý3	2.64Eý4	0.184	2.09Eý5	0.015
q ID#[5]	1.75Eý3	3.33Eý4	0.190	2.97Eý5	0.017
q ID#[6]	1.57Eý3	3.16Eý4	0.201	2.93Eý5	0.019
q ID#[7]	5.49Eý6	1.67Eý5	3.036	2.48Eý5	4.513
q ID#[7]	1.05E0	3.50Eý1	0.334	1.07Eý2	0.010
q ID#[8]	2.25Eý4	6.52Eý4	2.891	9.23Eý4	4.092
q ID#[8]	7.83Eý1	3.49Eý1	0.445	1.00Eý2	0.013
q ID#[9]	9.14Eý4	2.07Eý3	2.262	2.28Eý3	2.494
q ID#[9]	6.73Eý1	2.97Eý1	0.442	8.02Eý3	0.012
q ID#[10]	1.98Eý3	3.26Eý3	1.646	2.59Eý3	1.309
q ID#[10]	5.57Eý1	2.45Eý1	0.440	6.37Eý3	0.011
q ID#[11]	1.38Eý3	1.43Eý3	1.039	7.15Eý4	0.518
q ID#[11]	5.36Eý1	1.82Eý1	0.339	3.44Eý3	0.006
q ID#[12]	2.85Eý4	1.87Eý4	0.656	5.82Eý5	0.204
q ID#[12]	7.24Eý1	1.38Eý1	0.190	2.08Eý3	0.003

VPA using analytical bias adjusted parameters (linear scale)

Population Numbers

	2	3	4	5	6	7	8	9	10	11	12	13
1982.00	15671	19385	4409	1077	2193	1947	926	393	86	98	32	0
1983.00	8785	12748	14459	2408	546	859	829	369	188	29	50	15
1984.00	11272	7157	9414	8662	1281	300	447	440	188	105	9	26
1985.00	7197	9226	5559	6217	4848	668	175	244	266	121	71	6
1986.00	7759	5888	7390	4028	3574	2175	273	112	115	133	46	33
1987.00	11168	6351	4685	4869	2345	1810	1045	149	60	62	74	25
1988.00	8531	9139	5107	3275	2544	1136	785	421	61	34	38	36
1989.00	11894	6968	7110	3312	1694	967	478	275	134	31	15	13
1990.00	13598	9654	5356	4442	1701	871	380	259	110	52	20	6
1991.00	10039	11091	7208	3400	2196	619	333	156	90	46	22	8
1992.00	5611	8167	8160	4183	1429	553	197	132	78	30	16	9
1993.00	5450	4554	5587	4336	1983	583	181	54	25	12	12	3
1994.00	8828	4459	3241	2824	1688	625	199	67	20	11	3	5
1995.00	5956	7183	3425	2067	1166	395	90	22	5	4	2	1
1996.00	3883	4860	5665	2347	881	375	73	20	3	1	2	1
1997.00	3352	3166	3802	3807	1300	309	85	13	3	3	1	1
1998.00	2878	2739	2457	2309	1647	374	62	23	7	3	1	1
1999.00	6752	2350	2035	1262	665	230	36	10	5	4	1	1
2000.00	11707	5517	1845	1224	484	169	37	11	4	3	1	1
2001.00	7013	9512	4019	1165	498	127	23	7	4	3	2	1
2002.00	5000	5729	7498	2588	465	141	27	7	2	1	1	1
2003.00	5000	4087	4526	5461	1201	34	10	5	1	1	1	1

Fishing Mortality

	2	3	4	5	6	7	8	9	10	11	12	13
1982.00	0.006	0.093	0.405	0.480	0.737	0.654	0.720	0.540	0.901	0.476	0.583	0.000
1983.00	0.005	0.103	0.312	0.431	0.397	0.453	0.433	0.473	0.379	0.935	0.466	0.000
1984.00	0.000	0.053	0.215	0.380	0.451	0.340	0.406	0.304	0.244	0.196	0.273	0.000
1985.00	0.001	0.022	0.122	0.354	0.602	0.696	0.248	0.555	0.489	0.760	0.567	0.000
1986.00	0.000	0.029	0.217	0.341	0.480	0.533	0.406	0.420	0.407	0.386	0.404	0.000
1987.00	0.000	0.018	0.158	0.449	0.525	0.636	0.710	0.691	0.371	0.306	0.532	0.000
1988.00	0.002	0.051	0.233	0.460	0.767	0.666	0.850	0.941	0.473	0.599	0.863	0.000
1989.00	0.009	0.063	0.270	0.467	0.465	0.735	0.411	0.717	0.749	0.238	0.693	0.000
1990.00	0.004	0.092	0.254	0.505	0.810	0.761	0.688	0.856	0.667	0.658	0.782	0.000
1991.00	0.006	0.107	0.344	0.667	1.178	0.947	0.728	0.498	0.894	0.889	0.682	0.000
1992.00	0.009	0.180	0.432	0.547	0.697	0.919	1.098	1.465	1.690	0.705	1.442	0.000
1993.00	0.001	0.140	0.482	0.744	0.955	0.873	0.795	0.793	0.577	1.041	0.766	0.000
1994.00	0.006	0.064	0.250	0.685	1.253	1.734	1.999	2.378	1.423	1.400	1.021	0.000
1995.00	0.004	0.037	0.178	0.653	0.933	1.482	1.308	1.746	1.025	0.328	0.639	0.000
1996.00	0.004	0.045	0.197	0.391	0.848	1.282	1.568	1.645	0.000	0.000	0.639	0.000
1997.00	0.002	0.054	0.299	0.638	1.045	1.403	1.119	0.430	0.000	0.550	0.000	0.000
1998.00	0.003	0.097	0.466	1.045	1.769	2.135	1.672	1.412	0.398	0.550	0.000	0.000
1999.00	0.002	0.042	0.308	0.759	1.167	1.632	0.992	0.610	0.276	0.899	0.000	0.000
2000.00	0.008	0.117	0.260	0.699	1.141	1.806	1.435	0.899	0.298	0.000	0.000	0.000
2001.00	0.002	0.038	0.240	0.719	1.064	1.354	0.966	0.932	0.899	0.550	0.639	0.000
2002.00	0.002	0.036	0.117	0.568	2.421	2.458	1.451	2.297	0.639	0.000	0.000	0.000