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Assessment of pollock in 4VWX5Zc using a Framework Approach

Évaluation-cadre de la goberge dans 4VWX5Zc

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ABSTRACT

A comprehensive review of assessment methodology (referred to here as a Framework Assessment) was completed in 2004, and included inputs up to and including 2002. This assessment updates the results with 2003 indices and catch, and provides advice for the two stock components comprising the pollock resource in the Canadian Maritimes. The fishery is currently focused almost exclusively on the western component. For the western component, fishing mortality has steadily increased from the early 80s until 1994, when severe quota restrictions commencing in 1992 halted the increase. Quotas were relaxed again in 1998, causing a rapid increase in F. Subsequent reduced quotas and harvests have contributed to the decline in fishing mortality, which remains above the target level, particularly for the older ages. Population biomass was at its highest level in 1984, then steadily declined until 1999. Biomass has been rebuilding since, but remains at a low level compared with 1984. The 1998 and 1999 year-classes have helped the population recover somewhat, but the preliminary estimate of the 2000 year-class indicates that it is comparatively weak. The Framework Assessment examined yield per recruit analyses and stock-recruitment patterns to derive a fishing mortality reference point of F_{ref} =0.2. When stock biomass is less than 30,000 t, exploitation may be further constrained to achieve rebuilding. While the population has a high likelihood of achieving a 10% increase in biomass over the 2005/06 fishing year with removals as high as about 4500 t, the range of harvest strategies in the fishing year that are risk averse (25% risk of exceeding F_{ref}) to risk neutral (50% risk of exceeding F_{ref}) are about 2200 to 2900 t.

For the eastern component, indices from the summer research vessel surveys, while extremely variable, indicate that total mortality is high and increasing, even with relatively small landings from the fishery. Large scale directed pollock fisheries should not be considered until the eastern component recovers.

RÉSUMÉ

Un examen détaillé de la méthode d'évaluation (cadre d'évaluation) des stocks de goberge, comprenant les données obtenues jusqu'en 2002 inclusivement, a été réalisé en 2004. Cette évaluation met à jour les résultats en y intégrant les indices et les données de capture de 2003 et offre des avis sur les deux composantes du stock de goberge des provinces maritimes. La pêche vise actuellement presque exclusivement la composante ouest du stock, dont la mortalité par pêche a constamment augmenté du début des années 1980 jusqu'en 1994, lorsque d'importantes restrictions sur les quotas qui ont débuté en 2002 ont stoppé la hausse. Les quotas ont été rehaussés en 1998, ce qui a entraîné une augmentation rapide de F. Les réductions ultérieures des quotas et des captures ont contribué à la baisse de la mortalité par pêche, qui reste supérieure au niveau cible, particulièrement pour les poissons plus vieux. La biomasse de la population a atteint son maximum en 1984, puis a baissé constamment jusqu'en 1999. Depuis, la biomasse augmente mais elle reste basse par rapport au niveau de 1984. Les classes d'âge de 1998 et de 1999 ont aidé la population à se rétablir dans une certaine mesure, mais l'estimation préliminaire de la classe d'âge de 2000 montre qu'elle est relativement faible. L'évaluation a étudié les analyses de production par recrue et les relations stock-recrutement pour calculer un point de référence (F_{ref}) de 0,2 pour la mortalité par pêche. Lorsque la biomasse du stock est inférieure à 30 000 tonnes, on peut restreindre davantage l'exploitation pour permettre au stock de se reconstituer. Bien que pour un prélèvement d'environ 4 500 tonnes, la probabilité que la biomasse de la population augmente de 10 % durant l'année 2005-2006 serait élevée, des prélèvements de 2 200 et de 2 900 tonnes environ seraient respectivement prudent (25 % de risque de dépasser F_{ref}) et de risque neutre (50 % de risque de dépasser F_{ref}).

Quant à la composante est du stock de goberge, les indices obtenus lors des relevés estivaux par navire de recherche sont extrêmement variables mais indiquent que la mortalité totale est élevée et augmente, même si les captures sont relativement basses. Il ne faut pas envisager des pêches dirigées de la goberge à grande échelle avant que la composante est du stock se rétablisse.

INTRODUCTION

A comprehensive review of assessment methodology (referred to here as a Framework Assessment) defined western and eastern components for the pollock resource (Neilson et al. 2004, Fig. 1). An age-structured population model was developed for the western component that incorporated indices of abundance from both the DFO summer RV survey and standardized CPUE from the commercial fishery (Neilson et al. 2004), and included information available through 2002. The stock assessment provided here applies the model described in Neilson et al. (2004) to updated catch and indices. As the fishery is almost exclusively based on the western component, the results described in this document generally pertain to this component, unless otherwise indicated. The population model results include indices and catch through 2003, but 2004 indices are also shown graphically to illustrate the most recent information. The 2004 RV survey indices were obtained using the *CGSS Teleost*, and given the lack of availability of conversion factors with the *CGSS Alfred Needler*, the 2004 data were not included in the population model.

THE FISHERY

Recent landings for all of 4VWX5Zc have been less than the 10,000 TAC (Table 1, Fig. 2). Landings in the fishery from Jan 1 though August 31, 2004 are 6947 t. The spatial distribution of the fishery has changed considerably. The eastern component now comprises only 3% of total landings (Fig. 3). Within the western component, landings now come mostly from three unit areas that include the mouth of the Bay of Fundy and Georges Bank, whereas as recently as 1997, landings were more evenly distributed among unit areas (Table 3, Fig. 4). Considering the distribution of landings by month within the western component, the months with the largest fraction of landings in the recent fishery are June and July. From time to time, a significant winter fishery occurred during December and January (see, for example, year 1988 in Table 4), but this fishery is no longer apparent.

The sector composition of the fishery has also changed. The contribution of larger trawlers to total landings (Tonnage Class (TC) 4+), has been steadily declining since 1982 and accounted for less than 1% of total removals in 2003. In contrast, the contributions of TC 1-3 trawlers and fixed gear vessels (gillnet) have been increasing over the same period and now account for 73 and 24% of the total landings, respectively (Table 5, Fig. 5).

Unit area 4Xu is prorated in Tables 3 – 5 (Neilson et al. 2004).

SAMPLING AND CATCH/WEIGHT AT AGE

The age composition of the recent catch is younger than that observed in the period 1982-1991 and there are currently relatively few fish older than age 8 in the catch at age (Table 6, Figs 6, 7). Tables 7 – 10 provide gear-specific details of the catch at age. For mobile gear, ages 4-6 comprise most of the catch, but for gillnets, ages 5 and 6 are dominant. Both strong and weak year-classes are apparent in the catch at age (Fig. 6), and the 1999 year-class appears noteworthy in the 2004 catch. There has been a trend of increasing weights at age for ages 6 and 7 (Fig. 8, Table 11), but for younger ages, the trend is not discernable.

INDICES OF ABUNDANCE

The time series of mobile gear (TC 2-3) CPUE is shown in Fig. 9. After a rapid increase from 2001 to 2002, catch rates remained relatively high in 2003, then declined considerable in 2004. Age-specific indices of abundance from the mobile gear sector of the fishery indicate a reduction in the abundance of older (7+) fish since 1996 (Neilson et al. 2004). In recent years, the 1997, 1998 and 1999 year-classes were relatively strong (Fig. 10, Table 12). The fishing industry reported that catch rates in 2004 improved considerably in some areas compared with recent years, especially on Georges Bank, and this observation may be consistent with the strong 1999 year-class. However, the reports of increased catch rates on Georges Bank are inconsistent with the overall trend in mobile gear CPUE from 2003 to 2004 as shown in Fig. 9.

The trend in stratified mean catch per tow from the summer RV surveys declined from the mid 1980s until 1999 (Fig. 11, Table 13). Strong year effects are apparent. Age disaggregated indices show that the 1999 year-class was notable in the 2003 and 2004 surveys (Fig. 12). The 1997 and 1998 year-classes may have experienced higher survival in 2004, as the age 6 and 7 indices are higher than those seen for other recent year-classes. This conclusion, however, is qualified by the use of a different RV in 2004 and the absence of conversion factors between that vessel and the earlier vessel.

ESTIMATION OF CURRENT POPULATION STATE

Following the approach outlined in Neilson et al. (2004), the current population status was determined using 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 $\kappa = \ln \kappa'$.

As noted by Neilson et al. (2004), this generic framework was intended to provide guidance for upcoming assessments of this stock. Further, it was noted that certain year-classes may be problematic in the future and estimation may not always be possible. For the 2004 assessment, we found that the model was unable to estimate the 1996 year-class at age 8. Accordingly, we set the initial numbers for that cohort at age 8 to a value similar to that observed from 1999-2003 (30,000, Table 16). This procedure did not significantly impact the interpretation of more recent year-classes, when compared with the results presented in Neilson et al. (2004).

Population Model Results

Diagnostic plots using age-specific relationships between indices and population are shown in Figs. 13 and 14 for the commercial CPUE and RV indices, respectively. Although there is some indication of time-trended residuals, the model fits were generally considered adequate.

Estimates of population numbers at age are provided in Table 16 and Fig. 15. A period of much-diminished numbers at age in older ages during the 1990s continues to be apparent in the current population numbers at age. However, the 1998 year-class (age 6 in 2004) is contributing to first indication of improvement in age structure. The strong 1999 year-class is expected to continue that trend next year.

Trends in fishing mortality are shown with respect to total landings in Table 14 and Fig. 16. Estimates of fishing mortality have steadily increased from the early 1980s until 1994, in spite of decreased landings. Fishing mortality declined in 1995 and 1996 but increased again to a maximum in 1998 when landings also increased. Subsequent reduced quotas and harvests have contributed to a decline in fishing mortality for ages 4-9, but fishing mortality remains high, particularly for older fish (ages 6-9), and above the F_{ref} of 0.2. We also updated the retrospective analyses presented in Neilson et al. (2004), and confirmed that the population model is providing consistent estimates of fishing mortality in recent years.

Estimates of biomass (ages 2+ and 4+) declined from about 60,000 t in 1984 to about 10,000 t in 1999 (Table 15, Fig. 17). Biomass has been rebuilding since then, doubling to about 20,000 t by 2004, but remains low compared to 1984.

Recruitment (age 2) to the population is shown in Fig. 18. After a period of low recruitment (1995-1996 year-classes), the 1998 and 1999 year-classes were comparatively strong. The 1999 year-class is stronger than indicated in Neilson et al. (2004), whose initial estimate was based on the first available data for that year-class. The preliminary estimate of the 2000 year-class indicates that it is considerably weaker than the 1999 year-class.

The statistical properties of the population model are reported in Table 17.

CHARACTERIZATION OF PRODUCTIVITY TO DETERMINE HARVEST STRATEGY REFERENCE POINTS

During the assessment framework review for pollock (Stephenson 2004), a moderate fishing mortality rate reference point and a biomass reference point below which a reduced fishing mortality rate could be considered were established. For evaluation of productivity, adult biomass for ages 4 and older was considered a suitable proxy of spawning biomass.

A dynamic pool model, which coupled the yield per recruit analysis with the stock-recruitment pattern, was used to evaluate productivity and to derive a fishing mortality rate reference point as the F corresponding to 90% of maximum yield (Neilson et al 2004). This result was compared to $F_{0.1}$ and to the F corresponding to 40% maximum biomass per recruit. The F corresponding to 90% of maximum yield was 0.19. The resulting $F_{0.1}$ was 0.19. The F corresponding to 40% biomass per recruit was 0.2. The value of F_{ref} = 0.2 was considered a practical limit fishing mortality threshold.

A reduced fishing mortality, lower than F_{ref}, could be considered when the biomass is thought to be low enough that recruitment is impaired. One practical approach is to establish the biomass reference point, B_{ref} corresponding to the biomass level below which the chance of good recruitment is reduced. Stock recruit data are typically represented with recruitment on the abscissa and biomass on the ordinate and convex forms are considered the norm. The convex forms may either attain a maximum or may be asymptotic. The biomass at which the maximum recruitment is achieved or where recruitment begins to asymptote may be taken as B_{ref}. It should be recognized that B_{ref} may not exist if recruitment is constant or progressively decreasing over the entire observed biomass range. Also, B_{ref} may not be identifiable if recruitment progressively increases over the observed biomass range. For pollock, the chance of good recruitment has been higher when the adult biomass is greater than a B_{ref} = 30,000 t threshold. Reduced production and recruitment has been observed below this biomass. 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.

A harvest strategy with two biomass zones as described above could be sufficient if there was confidence that the recruits per spawner does not decrease at low biomass, a phenomenon referred to as reproductive depensation. While convincing evidence for reproductive depensation is equivocal (Myers et al 1995, Liermann and Hilborn 1997), Shelton and Healey (1999) concluded that depensation would generally be difficult to detect even if it did occur. Recovery from such a depleted state could be very protracted or perhaps not even possible. In recognition of this, the Canadian policy on Precautionary Approach advocates the identification of conditions that represent serious or irreversible harm. Accordingly, a lower biomass reference point, B_{harm} is required.

The harvest strategy established during the framework review based on reference points, F_{ref} = 0.2 and B_{ref} = 30,000 t was augmented with a B_{harm} reference point during this assessment review. In the absence of convincing evidence for a depensatory response in the recruitment or production function, there does not appear to be a completely non-arbitrary method of determining the biomass limit reference point, B_{harm}, at which serious harm can be considered to have taken place. Therefore it is inevitable that there will be some subjectivity in the determination of this limit reference points. Various practical, but arbitrary, proxies have been put forth as candidates for B_{harm}.

The DFO Precautionary Approach workshops examined approaches for determining B_{harm} that fall into three basic categories, reference points derived from a) stock recruitment relationships, b) historical biomass trajectory and c) interpretation of percentiles for recruits per spawner and percentiles for recruitment (Serebryakov 1991). There was general consensus at recent workshops that approaches based on c) while intuitively attractive, performed poorly in application and the results were not trustworthy. A consensus regarding the relative merits of approaches a) and b) has not developed.

Criticisms of approach b) concern the absence of a suitable biomass history from a period of full exploitation and the potential impacts of trends in demographic parameters. These are discussed further below. If these criticisms can be allayed, establishing a B limit reference point on the basis of an empirically observed low biomass from which a stock has recovered, $B_{recovery}$, is attractive because of its simplicity and its basis on observation. For stocks with a biomass history under full exploitation, proposing a lower B limit than the lowest observed biomass has risks that cannot be quantified. In the presence of a $B_{recovery}$ candidate for B_{harm}, proponents of a higher value must address the obvious statement “But the stock has previously recovered from…”.

Criticisms of approach a) concerns unconvincing fits of data to parametric forms and sensitivity of reference points to particular parametric forms. It is generally recognized that it is inappropriate to assume that a stock recruitment relationship does not exist. Convincing cases have been made that recruitment is often diminished at lower biomass. Nevertheless, data for few if any stocks can be fit satisfactorily to a parametric stock recruitment relationship. The unfortunate aspect of this situation is that the B limit reference points derived from stock recruitment relationships are very sensitive to the parametric form chosen and to the assumptions used in fitting that form, e.g. log transform, error in biomass, etc. Pseudo non-parametric fits (hockey stick) are also subject to these concerns. Non-parametric fits are subject to some of these concerns, but may prove acceptable. Even if non-parametric fits are considered acceptable, they appear to contain more information about MSY type reference points than about B limit reference points (depensation is difficult to demonstrate). The absence of demonstrable recruitment depensation has given rise to the proposal of a somewhat arbitrary definition for B_{harm}, the biomass at which 50% of maximum recruitment occurs, B50%Rmax, based on some theoretical considerations. Unfortunately, the limited empirical experience with B50%Rmax reference points suggests that the resulting biomass value appears to be more closely related to "the onset of recruitment impairment" that to "serious harm". Therefore, general application of B50%Rmax as a basis for a B_{harm} must be questioned. Other than the theoretical arguments for using 50%, a case for an alternative % has not been made. Adoption of another % would then appear even more arbitrary.

On balance therefore, the arguments to adopt a $B_{recovery}$ approach, when possible, appear to be the most compelling. Caveats on acceptance of a B_{harm} limit reference point based on $B_{recovery}$ can be summarized as:

- if the stock does not have a history of full exploitation with depletion and recovery cycles, $B_{recovery}$ may be too high.
- if demographic parameters vary with trend, historical production dynamics and associated reference points may not be suitable for the current situation

Production is a function of recruitment, somatic growth, maturation, natural mortality and exploitation processes. The demographic parameters involve the first four processes. These can be conveniently summarized by recruits per spawning biomass and spawning biomass per recruit when F=0. For stocks with a history of full exploitation, if contemporary values for recruits per spawning biomass and spawning biomass per recruit are similar to those from a period when the stock rebuilt from a depleted state, $B_{recovery}$ is a credible candidate for the B limit reference point. Recruits per spawning biomass for pollock do not show any persistent trends over time and the two most recent values were the highest in the time series (Figure 19). Considering the absence of marked trends for M, growth and maturity, spawning biomass per recruit would show little variation. Therefore, the second criticism is not a concern regarding the use of $B_{recovery}$ for pollock.

In the case of pollock, the first criticism is a concern. While there is a longer history for the pollock fishery, the assessment reconstruction is available only from 1982 to the present. The stock has been considered fully exploited and presently in a depleted state with biomass at a historical low in 2000. There is evidence of recovery since 2000 as a result of recent improved recruitment, but it is premature to conclude that the stock experienced a secure recovery from the low 2000 biomass. The short time series of available stock and recruitment data is an even greater impediment to meaningful investigation of biomass limit reference points based on the stock recruitment relationship.

In summary, there is evidence for the beginnings of a recovery since the low 2000 biomass, however this cannot be taken as conclusive evidence supporting use of the 2000 biomass level as a biomass limit reference point associated with serious harm. A biomass of about 10,000 t may be considered a tentative B_{harm}, pending confirmation over the next few years of a secure recovery.

The fishing mortality reference point and the two biomass reference points may be used to evaluate the consequences of management choices (Figure 20). 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%). When biomass is less than B_{ref} = 30,000 t, the risk of biomass decline (□B < 0) should be neutral to risk averse (less than 50%). The further biomass is below 30,000 t, the decisions should be more risk averse. When biomass is less than B_{harm}=10,000 t, normal fishing operations may be curtailed to secure recovery. These risk evaluations are conditioned on the model assumptions.

PROJECTIONS OF CATCH AND POPULATION BIOMASS

Neilson et al. 2004(b) noted that 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. For the catch projections that follow, we used catch weights at age and partial recruitments averaged over the period 1998 to 2003 (Table 18). For the projections of population biomass, landings from Jan 1,2004 to August 31,2004 wew 6947t and an additional 3300t was assumed to be caught bt March 31,2005. Estimates of mean weights at age were obtained from the summer RV survey series for ages 2-4 (again averaged over 1998 to 2003), and commercial fishery mean weights at age were used for used for ages 5+ (Table 18).

Alternative TAC tactics are evaluated through risk analysis. The risk of F exceeding F_{ref} should generally be neutral to risk averse (less than 50%) and the risk of biomass decline(ΔB < 0) should be neutral to risk averse (less than 50%) when biomass is less than B_{ref} = 30,000 t. The further biomass is below 30,000 t, the decisions should be more risk averse. These risk evaluations are conditioned on the model assumptions.

The results of the population projection risk analyses are shown in Fig. 21. While the population has a high likelihood of achieving a 10% increase in biomass by the end of the 2005/06 fishing year with removals as high as about 4500 t, the range of harvest strategies in the fishing year that are risk averse (25% risk of exceeding F_{ref}) to risk neutral (50% risk of exceeding F_{ref}) are about 2200 to 2900 t.

Several factors indicate a conservative harvesting strategy is appropriate. Population rebuilding is still at an early stage and there are relatively few age 7+ fish (Fig. 15). Although not included in the model, available 2004 indices from the mobile gear fishery have decreased compared to 2003 (Fig. 9). The population biomass is currently lower than that associated with improved recruitment (30,000 t).

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. While a VPA is not possible with the limited fishery and sampling information available, RV data are available. However, survey estimates of total mortality are noisy, even when smoothed. Estimates of total mortality have been following an increasing trend since the early 1990s (Fig. 22), coincident with declining fishery landings (Fig. 23). The observations of high and increasing total mortality while landings are low imply that fishery removals should be kept to a minimum in the eastern component.

LITERATURE CITED

Liermann, M., and Hilborn, R. 1997. Depensation in fish stocks: a hierarchic Bayesian meta-analysis. Can. J. Fish. Aquat. Sci. 54:1976–1984.

Neilson, John D., Perley, Peter, Carruthers, Erin H., Stobo, Wayne, and Donald Clark. 2003. Stock structure of pollock in NAFO Divs. 4VWX5Zc. CSAS Research Document 2003/045, 53 p.

Neilson, John D., Perley, Peter, and Stratis Gavaris. 2004. Pollock stock status in the Canadian Maritimes: a framework assessment. CSAS Research Document 2004/040, 48 p.

Myers, R.A., Barrowman, N.J., Hutchings, J.A., and Rosenberg, A.A. 1995. Population dynamics of exploited fish stocks at low population levels. Science (Washington, D.C.), 269: 1106–1108.

Serebryakov, V.P. 1991. Predicting year-class strength under uncertainties related to the survival in the early life history of some North Atlantic commercial fish. NAFO Sci. Coun. Stud. 16:49-56.

Shelton, P.A. and Healey, B.P. 1999. Should depensation be dismissed as a possible explanation for the lack of recovery of the northern cod (*Gadus morhua*) stock? Can. J. Fish. Aquat. Sci. 56:1521-1524.

Stephenson, R.L., Chairperson. 2004. Proceedings of the pollock framework assessment: 1 May 2003; 16-18 June 2003; and 6-8 April 2004. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2004/030.

Table 1. Landings of pollock by country in 4VWX5Zc. The landings for 2004 represent a partial year (Jan 1 to Aug. 31).

	Canada	Japan	France2	Fed. Rep Germany	German Dem. Rep.	Cuba	USSR (Russia)	USA	Spain	Other	Total
1982	38029	3	44			84	297	840			39297
1983	32749	6	22			261	226	1324			34588
1984	33465	1	46			123	97	1691		1	35424
1985	43300	17	77			66	336				43796
1986	43249	51	77			387	564			4	44332
1987	45330	82	28			343	314				46097
1988	41831	1				225	1054				43111
1989	41112	1				99	1782				42994
1990	36178					261	1040				37479
1991	37931	38				459	1177				39605
1992	32002	72	9			1015	1006				34104
1993	20253					644	176				21073
1994	15240					10					15250
1995	9781					58					9839
1996	9145					129	6				9280
1997	11927					64					11991
1998	14371					9	1				14381
1999	7738					6					7744
2000	5672										5672
2001	6318										6318
2002	7090										7090
2003	8090										8090
2004	6947										6947

Table 2. Pollock landings (t) for the western component (4Xopqrs, 5Yb in Canadian waters and 5Zc). The landings for 2004 represent a partial year (Jan 1 to Aug. 31).

	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
2003	7839		7839
2004	6716		6716

Table 3. Pollock landings (t) by area in the western component, (4Xopqrs, 5Yb in Canadian waters and 5Zc). The landings for 2004 represent a partial year (Jan 1 to Aug. 31).

	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
2003	114	1823	2578	403	665	316	594	1347	7839
2004	34	2094	2148	146	398	111	89	1694	6715

Table 4. Pollock landings (t) by month in the western component, (4Xopqrs, 5Yb in Canadian waters and 5Zc). The landings for 2004 represent a partial year (Jan 1 to Aug. 31).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1982	766	667	258	196	1555	2789	3413	2510	2317	2085	1140	620	18317
1983	1147	805	477	495	1814	4650	3272	1659	1207	568	172	77	16344
1984	167	170	362	753	1413	3922	3818	1619	1325	1090	346	91	15076
1985	114	681	841	1892	981	4503	5243	1885	1556	1048	357	222	19323
1986	1023	682	758	452	2221	3015	3678	2649	2069	664	169	23	17404
1987	1428	648	643	34	2212	3686	2797	1905	1431	490	114	836	16224
1988	1043	563	140	375	912	4213	4534	1241	1159	409	151	2561	17301
1989	645	1473	329	459	712	3740	1682	1230	1140	561	1317	320	13607
1990	244	233	44	132	1039	3199	3465	2944	2002	1182	465	923	15874
1991	1091	884	433	1235	1884	3435	3189	2136	1750	1335	729	681	18783
1992	432	625	222	783	1744	2916	3073	2414	1813	1572	817	232	16644
1993	1089	654	633	385	1202	2725	2741	1684	1172	550	900	629	14363
1994	36	244	228	517	801	1931	2950	1350	1061	903	473	489	10981
1995	106	217	206	472	319	2013	1406	255	1472	255	300	180	7200
1996	277	199	222	223	470	786	1226	914	544	606	387	604	6457
1997	56	458	508	681	597	1482	1917	1392	1209	661	560	282	9802
1998	285	624	807	711	953	1872	2193	1109	986	789	165	51	10544
1999	64	59	174	236	348	781	1112	825	666	215	180	111	4771
2000	135	272	301	98	318	738	850	684	553	506	184	140	4778
2001	231	46	417	224	418	775	1180	566	610	534	261	146	5410
2002	139	268	328	415	947	1346	1266	599	505	345	221	121	6501
2003	39	235	941	643	893	1171	1205	901	877	450	374	116	7845
2004	47	514	871	527	676	1806	1544	737					6722

Table 5. Pollock landings(t) by gear in the western component, (4Xopqrs, 5Yb in Canadian waters and 5Zc). The landings for 2004 represent a partial year (Jan 1 to Aug. 31).

	Gillnet	OTB 4+	Longline	Misc	OTB 1-3	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
2003	1902	11	217	9	5699	7839
2004	1660	90	89	1	4876	6716

Table 6. Total catch at age (000s) for pollock in the western component (4Xopqrs 5Yb in Canadian waters and 5Zc). The catch at age for 2004 include Jan 1 – August 31.

	2	3	4	5	6	7	8	9	10	11	12
1982	95	1618	1352	371	1031	838	425	145	45	33	13
1983	45	1283	3966	854	179	314	291	138	59	17	19
1984	4	370	1832	2751	465	85	148	114	41	19	2
1985	5	195	621	1806	2142	328	38	100	99	62	30
1986	1	162	1410	1136	1329	876	88	37	37	41	15
1987	5	104	628	1622	883	786	490	68	17	15	28
1988	19	425	990	1126	1281	519	424	242	22	14	20
1989	93	386	1533	1129	576	463	147	129	65	6	7
1990	47	776	1102	1621	873	429	174	138	49	23	10
1991	58	1013	1900	1506	1395	347	157	56	49	25	10
1992	46	1250	2678	1651	675	314	124	96	61	14	12
1993	4	551	1989	2125	1143	318	92	27	10	7	6
1994	51	259	675	1327	1151	494	166	59	14	8	2
1995	24	263	537	949	676	294	63	17	4	1	1
1996	14	202	949	710	473	256	55	15	0	0	1
1997	6	151	900	1654	780	217	54	4	0	1	0
1998	7	228	829	1368	1262	307	47	16	2	1	0
1999	13	89	496	621	426	173	22	4	1	2	0
2000	86	581	404	592	319	139	27	6	1	0	0
2001	15	335	814	571	314	91	14	5	2	1	1
2002	7	191	787	1073	416	127	20	6	1	0	0
2003	2	111	1302	1331	513	120	18	5	1	1	0
2004	2	131	421	1670	577	108	13	4	1	1	

Table 7. OTB 1-3 catch at age (000s) for pollock in the western component, (4Xopqrs, 5Yb in Canadian waters and 5Zc). The catch at age for 2004 include Jan 1 – August 31.

	2	3	4	5	6	7	8	9	10	11	12
1982	39	719	438	104	297	264	144	57	20	15	6
1983	18	751	2209	386	55	88	88	39	17	6	6
1984	4	183	1019	1652	295	53	87	66	24	11	1
1985	3	115	413	1310	1505	215	18	47	47	28	11
1986	1	75	557	452	527	340	29	11	14	16	5
1987	4	50	297	643	317	279	171	25	5	5	8
1988	1	106	302	492	596	222	187	95	10	3	6
1989	17	256	798	414	177	110	27	21	9	1	0
1990	28	403	531	668	294	111	36	26	9	4	1
1991	14	361	1008	783	620	150	72	26	19	9	4
1992	22	683	1605	814	215	59	18	14	8	1	2
1993	0	256	1002	858	320	70	21	7	3	1	2
1994	29	137	331	592	465	178	60	19	5	3	1
1995	21	206	306	463	269	96	21	4	2	1	0
1996	4	107	546	375	187	82	13	2	0	0	0
1997	5	93	556	958	338	79	14	1	0	0	0
1998	5	173	573	839	651	118	18	5	0	0	0
1999	9	61	343	365	197	54	6	1	0	0	0
2000	65	391	250	310	127	40	7	2	1	0	0
2001	15	291	538	286	134	31	6	2	1	0	0
2002	7	172	636	739	219	56	9	2	1	0	0
2003	2	108	1210	1087	304	50	6	2	1	1	0
2004	2	130	387	1405	364	44	4	2	1	1	0

Table 8. OTB 4+ catch at age (000s) for pollock in the western component, (4Xopqrs, 5Yb in Canadian waters and 5Zc). The catch at age for 2004 include Jan 1 – August 31.

	2	3	4	5	6	7	8	9	10	11	12
1982	48	781	787	191	433	279	113	34	11	8	3
1983	27	504	1351	260	71	116	90	37	15	3	5
1984	0	167	583	564	65	11	18	13	4	4	0
1985	1	61	79	117	129	22	4	6	7	3	1
1986	0	28	173	134	187	109	7	2	4	4	1
1987	1	46	175	367	198	141	89	16	4	5	8
1988	18	314	593	405	377	143	96	39	3	4	5
1989	75	124	546	333	108	87	27	20	10	2	1
1990	18	351	423	403	153	42	14	10	3	2	1
1991	41	569	509	300	225	47	20	6	7	3	1
1992	16	437	718	310	87	32	10	7	4	1	0
1993	4	222	643	645	259	60	12	4	2	2	2
1994	9	42	125	254	184	60	18	5	1	1	0
1995	0	31	103	154	82	28	6	1	1	0	0
1996	9	76	313	192	115	59	10	3	0	0	0
1997	1	33	181	318	113	33	4	0	0	0	0
1998	1	32	157	214	144	23	4	1	0	0	0
1999	2	17	71	82	42	13	2	0	0	0	0
2000	19	138	57	52	20	8	2	0	0	0	0
2001	0	36	138	56	18	5	1	0	0	0	0
2002	0	15	75	100	36	8	1	0	0	0	0
2003	0	0	2	3	1	0	0	0	0	0	0
2004	0	1	11	31	4	0	0	0	0	0	0

Table 9. Gillnet gear catch at age (000s) for pollock in the western component (4Xopqrs, 5Yb in Canadian waters and 5Zc). The catch at age for 2004 include Jan 1 – August 31.

	2	3	4	5	6	7	8	9	10	11	12
1982	0	4	52	46	181	163	80	25	5	3	1
1983	0	23	372	164	37	61	49	18	6	1	1
1984	0	6	92	234	56	15	34	27	10	3	1
1985	0	14	118	317	347	43	4	6	8	3	1
1986	0	6	246	294	369	226	19	4	2	5	1
1987	0	5	99	364	215	208	132	13	5	2	5
1988	0	4	64	133	163	82	89	79	7	6	8
1989	0	4	161	295	211	188	71	63	33	2	5
1990	0	9	102	404	313	192	79	63	19	9	3
1991	0	23	183	214	338	98	43	16	16	8	3
1992	0	14	102	296	261	148	59	40	26	6	6
1993	0	17	134	318	333	127	47	14	5	4	2
1994	1	3	20	141	306	191	66	25	6	3	1
1995	2	24	100	263	272	148	31	10	1	0	0
1996	0	3	42	97	128	84	20	5	0	0	0
1997	0	12	105	252	233	77	27	2	0	1	0
1998	0	6	60	258	404	139	19	7	1	0	0
1999	0	7	58	130	141	80	9	2	0	0	0
2000	0	34	76	190	149	81	16	4	0	0	0
2001	0	4	105	198	144	48	6	2	0	0	0
2002	0	3	65	209	143	54	8	3	1	0	0
2003	0	1	58	201	196	65	11	3	0	0	0
2004	0	1	17	209	202	63	9	2	1	1	0

Table 10. Longline and miscellaneous gear catch at age (000 s) for pollock in the western component, (4Xopqrs, 5Yb in Canadian waters and 5Zc). The catch at age for 2004 include Jan 1 – August 31.

	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1982	8	115	75	31	121	132	88	30	9	8	3
1983	0	4	34	43	16	49	63	44	21	8	7
1984	0	14	138	301	49	6	9	8	2	1	0
1985	0	4	11	62	160	47	12	41	37	28	16
1986	0	52	433	256	246	201	33	19	16	16	8
1987	0	3	58	249	153	159	98	14	3	3	7
1988	0	1	31	96	145	72	52	29	3	1	2
1989	0	3	28	86	80	78	22	25	13	2	1
1990	0	13	46	145	113	85	45	40	18	9	5
1991	3	59	201	209	213	51	23	8	7	5	3
1992	7	115	254	231	112	73	37	35	23	6	3
1993	0	56	210	304	231	61	13	2	0	0	0
1994	12	77	200	340	196	65	22	9	3	1	0
1995	0	3	27	69	54	22	5	1	1	0	0
1996	1	16	48	46	43	31	11	5	0	0	0
1997	0	13	57	127	96	27	8	1	0	0	0
1998	1	17	38	58	63	26	6	3	1	0	0
1999	1	4	24	44	45	25	5	1	1	1	0
2000	2	17	21	40	23	9	2	1	0	0	0
2001	0	4	32	31	18	6	1	1	0	0	0
2002	0	1	10	25	18	9	2	1	0	0	0
2003	0	1	30	41	13	5	1	0	0	0	0
2004	0	0	7	25	7	1	0	0	0	0	0

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

	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12
1982	0.000	0.943	1.427	2.529	3.462	4.211	4.772	5.681	6.239	7.687	8.622	10.621
1983	0.000	0.881	1.349	1.983	3.373	4.367	5.105	5.651	6.624	7.220	8.381	8.886
1984	0.000	0.914	1.635	2.331	3.005	4.078	5.401	6.062	6.208	6.661	7.230	9.725
1985	0.000	0.974	1.615	2.462	3.169	3.695	4.296	6.022	7.315	7.185	7.968	9.343
1986	0.000	0.738	1.554	2.306	3.095	3.929	4.530	5.791	6.651	7.161	7.322	8.698
1987	0.000	0.943	1.475	2.266	3.046	3.564	4.315	4.907	5.300	6.794	7.482	7.909
1988	0.000	1.195	1.549	2.240	3.096	3.807	4.191	4.979	5.886	7.073	8.169	8.454
1989	0.000	0.880	1.313	2.095	3.068	3.885	4.491	4.869	6.012	6.334	8.911	7.133
1990	0.000	0.571	1.263	2.055	2.894	3.657	4.766	5.818	6.371	6.966	7.625	9.770
1991	0.000	0.906	1.344	2.153	2.866	3.736	4.730	5.711	6.460	6.815	8.060	9.030
1992	0.000	1.033	1.271	1.831	2.615	3.509	4.614	5.466	6.141	6.864	8.164	9.189
1993	0.000	0.761	1.110	1.666	2.312	3.143	3.754	4.723	5.492	6.704	7.704	8.131
1994	0.000	0.805	1.250	1.586	2.163	3.058	3.765	4.219	4.854	6.268	6.082	7.846
1995	0.000	0.671	1.132	1.806	2.296	3.038	3.941	4.796	5.389	7.348	8.573	8.781
1996	0.000	0.896	1.336	1.795	2.353	3.057	3.665	5.205	6.296	8.502	9.561	11.422
1997	0.000	0.915	1.388	1.938	2.446	3.288	3.976	5.101	7.763	10.058	6.737	11.915
1998	0.000	0.867	1.103	1.720	2.361	3.144	4.219	5.159	5.640	8.615	8.833	12.063
1999	0.000	0.806	1.193	1.682	2.419	3.245	4.288	5.659	7.057	9.939	9.943	
2000	0.000	0.757	1.247	1.796	2.478	3.166	4.168	5.412	5.745	9.003	9.821	
2001	0.105	0.453	1.039	1.987	2.929	3.734	4.775	6.532	8.118	8.539	9.026	10.788
2002	0.062	0.280	0.931	1.592	2.528	3.714	4.829	6.328	6.936	8.663	10.872	11.081
2003	0.000	0.675	0.990	1.535	2.376	3.528	4.780	6.289	7.427	9.267	10.079	8.875

Table 12. Small mobile age-disaggregated catch rates in the western component, calculated using the area-weighted approach.

	Age 3	Age4	Age 5	Age 6	Age 7	Age 8
1982	0.185	0.112	0.027	0.076	0.068	0.037
1983	0.183	0.537	0.094	0.013	0.021	0.021
1984	0.044	0.242	0.392	0.070	0.013	0.021
1985	0.019	0.067	0.213	0.244	0.035	0.003
1986	0.025	0.185	0.150	0.175	0.113	0.010
1987	0.017	0.104	0.225	0.111	0.098	0.060
1988	0.022	0.063	0.103	0.125	0.046	0.039
1989	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.106	0.139	0.175	0.077	0.029	0.010
1991	0.070	0.196	0.152	0.121	0.029	0.014
1992	0.126	0.295	0.149	0.039	0.011	0.003
1993	0.054	0.213	0.182	0.068	0.015	0.005
1994	0.030	0.072	0.131	0.104	0.041	0.014
1995	0.079	0.121	0.184	0.107	0.038	0.008
1996	0.058	0.296	0.203	0.101	0.044	0.007
1997	0.024	0.142	0.243	0.086	0.020	0.003
1998	0.014	0.068	0.107	0.084	0.015	0.002
1999	0.008	0.067	0.081	0.045	0.012	0.001
2000	0.094	0.063	0.079	0.033	0.011	0.002
2001	0.054	0.123	0.063	0.029	0.007	0.001
2002	0.023	0.144	0.198	0.060	0.015	0.002
2003	0.017	0.211	0.194	0.055	0.009	0.001
2004	0.020	0.059	0.216	0.056	0.007	0.001

Table 13. Summer DFO research vessel survey age-disaggregated numbers per tow in the western component.

	Age 3	Age 4	Age 5	Age 6	Age 7	Age 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
2003	0.904	6.055	2.146	0.491	0.021	0.024
2004	2.462	1.438	3.659	1.347	0.313	0.000

Table 14. ADAPT results (consensus formulation) – Bias adjusted fishing mortality at age estimates, Western component pollock.

	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	4-9 F	6-9 F	Landings
1982	0.006	0.089	0.383	0.453	0.695	0.615	0.675	0.498	0.863	0.431	0.538	0.000	0.521	0.649	18347
1983	0.005	0.110	0.327	0.446	0.413	0.470	0.449	0.484	0.387	0.996	0.477	0.000	0.358	0.453	16448
1984	0.000	0.057	0.226	0.396	0.467	0.352	0.424	0.317	0.257	0.207	0.285	0.000	0.321	0.419	15291
1985	0.001	0.023	0.127	0.364	0.616	0.716	0.262	0.571	0.502	0.769	0.580	0.000	0.375	0.615	19511
1986	0.000	0.030	0.229	0.358	0.500	0.555	0.423	0.439	0.429	0.401	0.421	0.000	0.359	0.515	17520
1987	0.000	0.018	0.158	0.446	0.523	0.630	0.705	0.682	0.370	0.309	0.528	0.000	0.411	0.599	16460
1988	0.002	0.052	0.237	0.466	0.776	0.677	0.860	0.954	0.490	0.596	0.875	0.000	0.495	0.782	17899
1989	0.009	0.062	0.269	0.465	0.463	0.731	0.410	0.708	0.745	0.238	0.686	0.000	0.386	0.552	13724
1990	0.004	0.091	0.254	0.506	0.812	0.762	0.682	0.860	0.651	0.651	0.779	0.000	0.471	0.787	15595
1991	0.006	0.104	0.336	0.652	1.155	0.934	0.716	0.488	0.894	0.843	0.668	0.000	0.578	1.038	18602
1992	0.009	0.179	0.432	0.548	0.699	0.916	1.115	1.481	1.717	0.705	1.462	0.000	0.528	0.831	16639
1993	0.001	0.139	0.477	0.736	0.948	0.869	0.773	0.793	0.577	1.041	0.766	0.000	0.662	0.917	14410
1994	0.006	0.065	0.251	0.686	1.253	1.740	2.025	2.238	1.423	1.400	1.021	0.000	0.753	1.456	10836
1995	0.004	0.041	0.186	0.667	0.945	1.500	1.332	1.746	1.216	0.328	0.639	0.000	0.542	1.107	7144
1996	0.004	0.047	0.202	0.398	0.858	1.287	1.582	1.645	0.000	0.000	0.639	0.000	0.371	1.029	6441
1997	0.002	0.053	0.299	0.641	1.048	1.407	1.131	0.430	0.000	0.550	0.000	0.000	0.588	1.112	9759
1998	0.002	0.092	0.452	1.022	1.736	2.092	1.672	1.412	0.398	0.550	0.000	0.000	1.051	1.794	10534
1999	0.002	0.036	0.293	0.735	1.125	1.538	0.998	0.610	0.276	0.899	0.000	0.000	0.626	1.216	4760
2000	0.009	0.137	0.228	0.679	1.130	1.721	1.205	0.848	0.298	0.000	0.000	0.000	0.551	1.274	4768
2001	0.001	0.043	0.286	0.578	0.985	1.301	0.849	0.759	0.786	0.550	0.639	0.000	0.454	1.036	5400
2002	0.001	0.018	0.132	0.742	1.170	1.683	1.266	1.193	0.328	0.000	0.000	0.000	0.377	1.273	6485
2003	0.000	0.021	0.159	0.325	0.872	1.510	1.181	1.485	0.639	0.639	0.000	0.000	0.276	0.989	7839

Table 15. ADAPT results (consensus formulation) – Bias-adjusted biomass trends at age estimates. Western component pollock.

	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	2+	3+	4+
1982	4726	16919	7886	3332	8570	8928	4920	2409	586	840	327	10	59453	54727	37808
1983	2761	16748	25936	7670	2256	4251	4576	2417	1351	235	480	163	65440	48692	49335
1984	4162	7006	26010	25190	5057	1527	2610	2728	1321	808	80	279	72257	65251	65610
1985	2350	7632	13217	18831	16946	2927	1033	1674	1834	917	612	54	65012	57380	58047
1986	3311	5361	12177	12994	13041	9198	1395	722	842	988	398	342	56717	51356	52096
1987	2076	4108	8916	12599	7878	7557	4982	832	405	454	568	257	47731	43622	44447
1988	4918	6391	7021	8951	8801	4450	3708	2298	381	254	297	361	42254	35863	36521
1989	4417	5268	13570	8934	5899	4025	2164	1517	824	248	117	127	42448	37180	37425
1990	3519	6427	7146	12435	5726	3770	1962	1449	724	365	188	63	40003	33577	33828
1991	3770	6685	8440	8293	7251	2584	1746	974	594	358	186	76	36924	30239	30500
1992	1910	6503	11492	8522	4642	2361	1017	793	532	225	145	94	36087	29584	29823
1993	2465	2622	6704	9788	5813	2162	869	294	160	85	100	32	28498	25876	26007
1994	2763	3149	3698	4713	4633	2213	814	337	117	73	26	47	19747	16598	16671
1995	1275	3495	4125	4183	3079	1415	393	105	37	29	17	10	16861	13366	13393
1996	7814	2998	5940	4622	2367	1275	337	110	21	13	23	10	17684	14686	14718
1997	718	3131	5117	8020	3625	1081	373	80	25	20	13	10	21472	18340	18364
1998	1268	1736	2424	4677	4561	1394	282	122	55	24	11	10	15274	13539	13560
1999	1339	1677	2553	2377	1892	871	185	58	34	34	11	10	9680	8004	8025
2000	2640	3444	2634	2407	1413	668	201	65	34	28	12	10	10895	7451	7473
2001	3782	4263	5210	3344	1653	525	139	68	28	23	24	10	15254	10991	11025
2002	1205	5963	7444	4550	2154	704	165	63	33	14	12	10	21090	15127	15149
2003	880	2708	9284	9426	2401	699	132	48	19	22	12	10	24737	22030	22052
2004	880	2899	3559	11124	7400	850	165	25	10	9	10	10	26042	23153	19603

Table 16. ADAPT results – population numbers, bias adjusted (bootstrap). Pollock in the western component.

	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13
1982	16669	20863	4658	1115	2244	1992	945	405	85	103	34	1
1983	9117	13562	15622	2600	580	917	881	394	201	29	55	16
1984	11568	7424	9946	9227	1363	315	469	461	199	112	9	28
1985	7286	9467	5744	6495	5086	699	181	251	275	126	75	5
1986	7821	5961	7575	4143	3696	2248	280	114	116	136	48	34
1987	11229	6402	4734	4933	2372	1835	1057	150	60	62	75	26
1988	8600	9189	5148	3310	2585	1151	800	428	62	34	37	36
1989	12058	7024	7140	3324	1701	974	479	277	135	31	15	13
1990	13890	9788	5402	4467	1709	876	384	260	112	52	20	6
1991	10303	11329	7314	3432	2205	621	335	159	90	48	22	8
1992	5773	8383	8362	4281	1464	569	200	134	80	30	17	9
1993	5552	4685	5737	4445	2027	596	186	54	25	12	12	3
1994	8918	4542	3339	2915	1742	643	205	70	20	11	3	5
1995	5999	7255	3485	2127	1201	408	92	22	6	4	2	1
1996	3943	4890	5702	2370	893	382	74	20	3	1	2	1
1997	3512	3215	3821	3814	1303	310	86	13	3	3	1	1
1998	3380	2870	2496	2319	1645	374	62	23	7	3	1	1
1999	6049	2761	2144	1301	684	237	38	10	5	4	1	1
2000	10015	4941	2180	1310	511	182	42	11	4	3	1	1
2001	12060	8122	3522	1422	543	135	27	10	4	3	2	1
2002	4676	9861	6347	2152	653	166	30	9	4	1	1	1
2003	5000	3822	7901	4487	804	166	24	7	2	2	1	1
2004	5000	4092	3029	5295	2478	202	30	4	1	1	1	1

Table 17. Statistical properties of estimates of population abundance (numbers in 000's) at time 2004.25 and survey calibration constants (unitless, survey: population) for pollock in the western component obtained from a bootstrap with 500 replications.

Age	Estimate	Standard Error	Relative Error	Bias	Relative Bias
Population Abundance (000 s)					
4	3587	2661	0.742	558	0.156
5	5855	3388	0.579	560	0.096
6	2696	1521	0.564	218	0.081
7	282	276	0.977	81	0.286
8	30				
9	6	9	1.593	2	0.373

Age	Estimate	Standard Error	Relative Error	Bias	Relative Bias
Survey Calibration Constants					
4	0.00014	0.00002	0.16494	0.00000	-0.00115
5	0.00034	0.00006	0.17699	0.00001	0.01933
6	0.00089	0.00016	0.18276	0.00002	0.02485
7	0.00134	0.00023	0.16868	0.00001	0.00932
8	0.00156	0.00027	0.17493	0.00002	0.01417
9	0.00154	0.00028	0.18262	0.00001	0.00922

Age	Estimate	Standard Error	Relative Error	Bias	Relative Bias
CPUE Calibration Constants					
4	0.000005	0.002693	542.67431	0.000446	89.93129
5	0.000072	0.048559	675.42141	0.006043	84.04764
6	0.000513	0.022077	43.04840	0.005020	9.78879
7	0.000808	0.006998	8.66573	0.002000	2.47637
8	0.000850	0.001628	1.91545	0.000502	0.59037
9	0.000172	0.000117	0.67781	0.000031	0.17749

Age	Estimate	Standard Error	Relative Error	Bias	Relative Bias
CPUE Power Coefficients					
4	1.046062	0.358014	0.3422498	-0.00778	-0.007438
5	0.915079	0.34996	0.3824367	-0.004367	-0.004772
6	0.741071	0.289613	0.390803	0.014093	0.019017
7	0.680026	0.237534	0.3493022	-0.002901	-0.004266
8	0.607340	0.170672	0.2810162	-0.000537	-0.000884
9	0.808592	0.123981	0.1533292	-0.002835	-0.003506

Table 18. Input parameters for pollock projections in the western component for the 2005/06 fishery.

Year	Age Group											
	2	3	4	5	6	7	8	9	10	11	12	13
Population Numbers (000s)												
2004	5000	4092	3029	5295	2478	202	30	4	1	1	1	1
Partial Recruitment to the Fishery												
2004	0.002	0.036	0.164	0.419	0.734	1	0.772	0.641	0.293	0.282	0.082	0
2005.25	0.002	0.036	0.164	0.419	0.734	1	0.772	0.641	0.293	0.282	0.082	0
Weight at beginning of year for population (kg)												
2004	0.268	0.625	1.200	2.042	2.939	3.904	5.076	6.219	7.840	9.426	9.750	10.000
2005.25	0.268	0.625	1.200	2.042	2.939	3.904	5.076	6.219	7.840	9.426	9.750	10.000
2006.25	0.268	0.625	1.200	2.042	2.939	3.904	5.076	6.219	7.840	9.426	9.750	10.000
Weight at age for catch (kg)												
2004	0.640	1.084	1.718	2.515	3.422	4.510	5.897	6.820	9.004	9.762	10.468	11.000
2005.25	0.640	1.084	1.718	2.515	3.422	4.510	5.897	6.820	9.004	9.762	10.468	11.000
Maturity												
2004	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2005.25	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2006.25	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

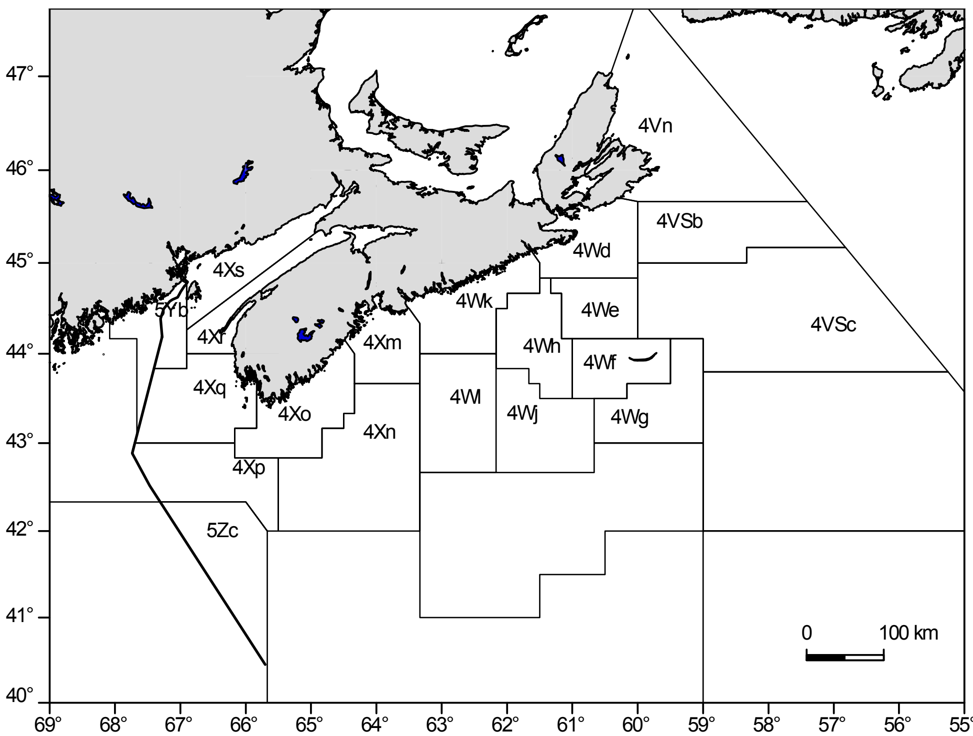

Fig. 1. DFO Statistical Unit Areas in the Scotian Shelf and Bay of Fundy and NAFO SubDivision 5Zc. Those areas forming the western component of pollock on the Scotian Shelf, Bay of Fundy and Georges Bank are outlined as solid lines, and those comprising the eastern component are shown dashed lines.

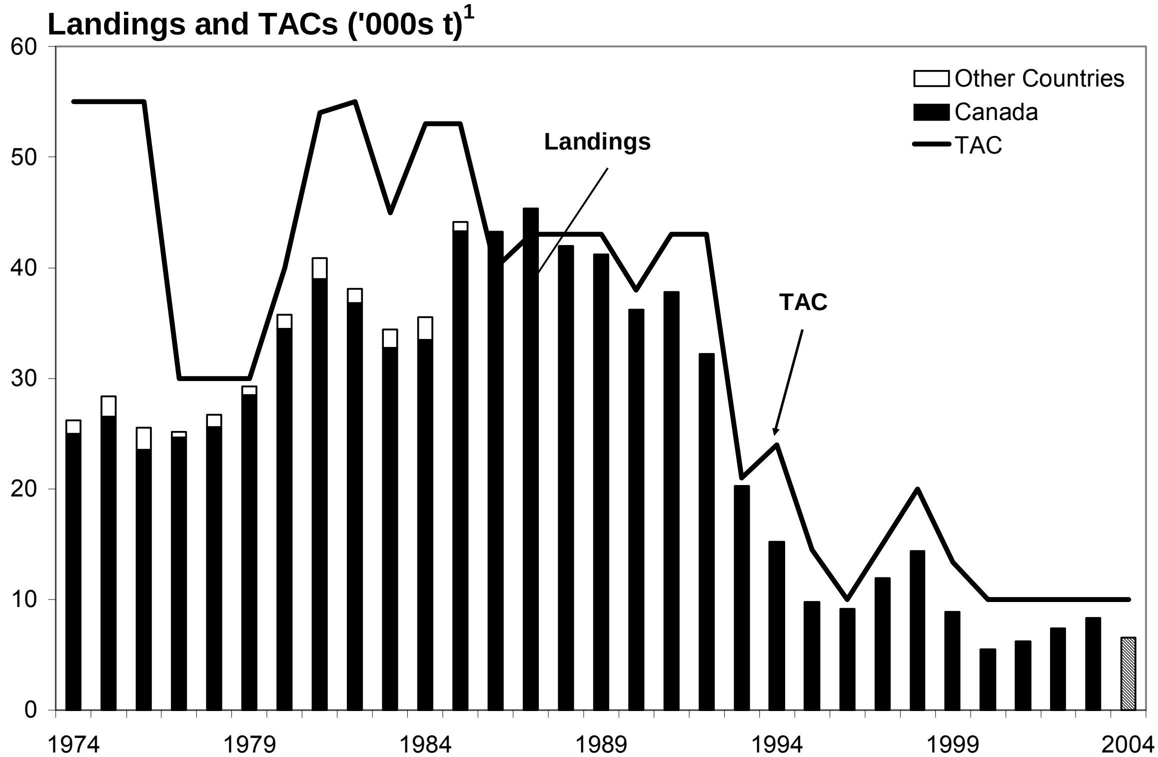

Fig. 2. Landings of 4VWX5Zc pollock, shown with respect to the Total Allowable Catch (TAC). The striped bar in 2004 signifies incomplete landings. Prior to 1999, the quota year was Jan. 1 to Dec. 31. In 1999, the quota year was Jan. 1, 1999 to Mar. 31, 2000. Subsequently, it is Apr 1 to Mar. 31. All landings are shown for quota years.

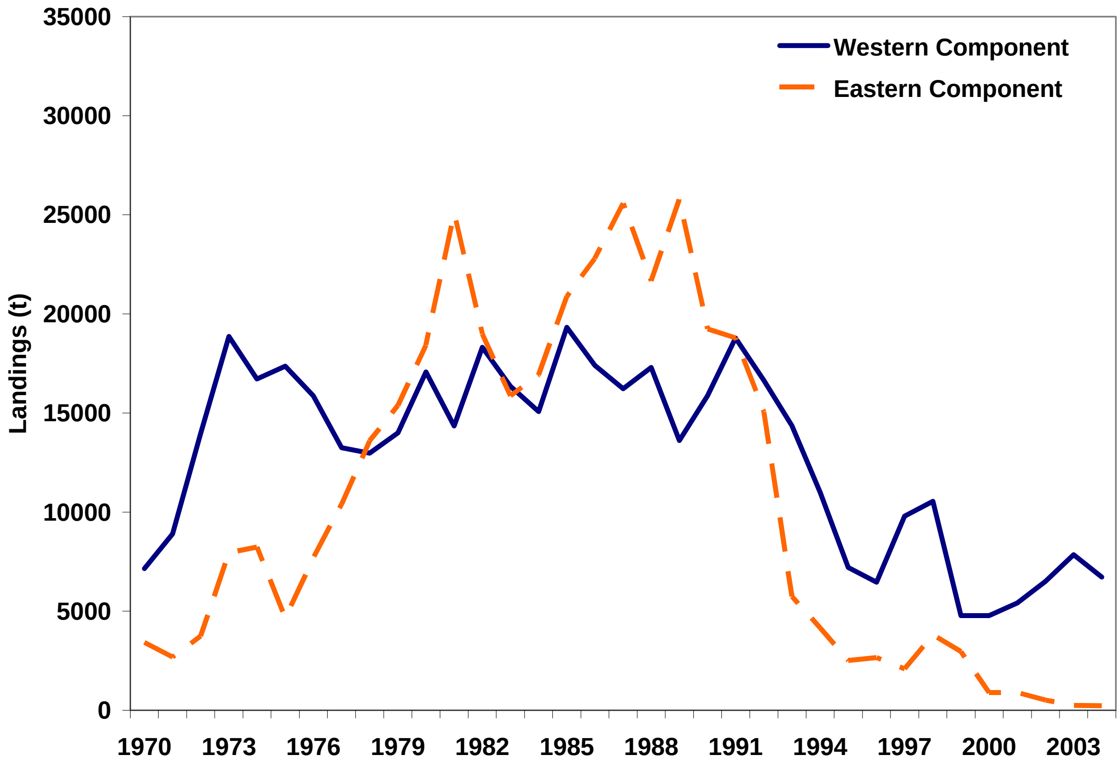

Fig. 3. Landings of pollock from the eastern and western components, 1970-2004.

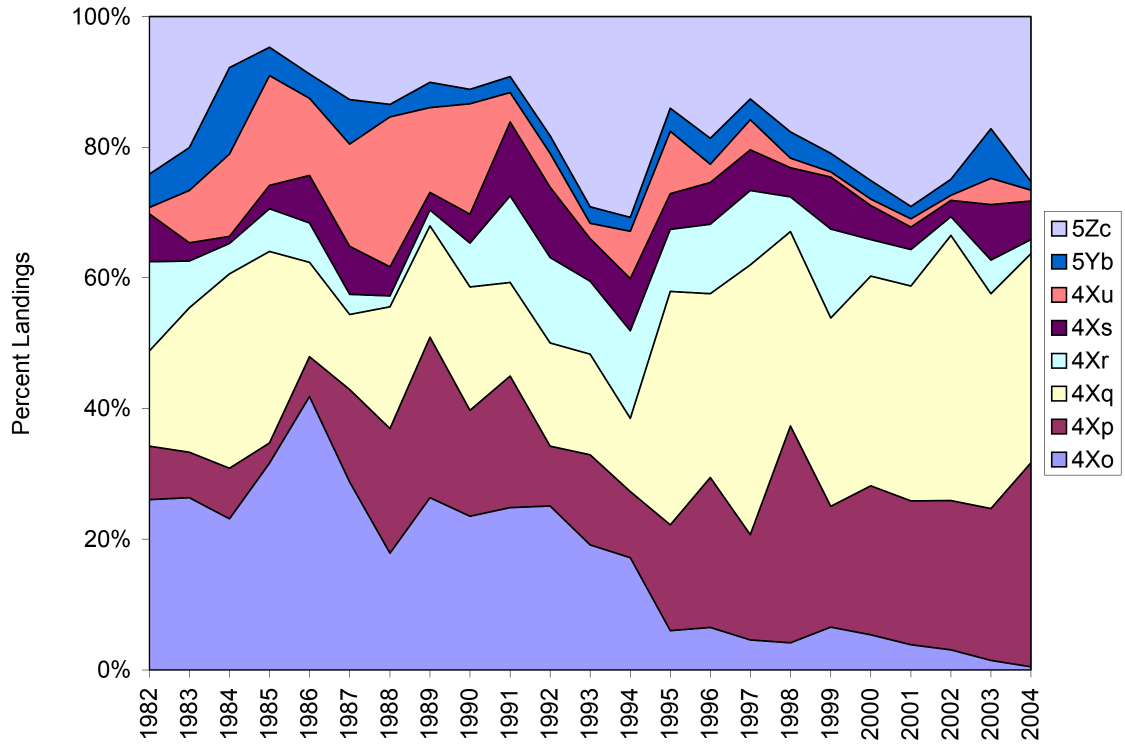

Fig. 4. Proportional landings of pollock by statistical Unit Area, 1982-2004 (western component).

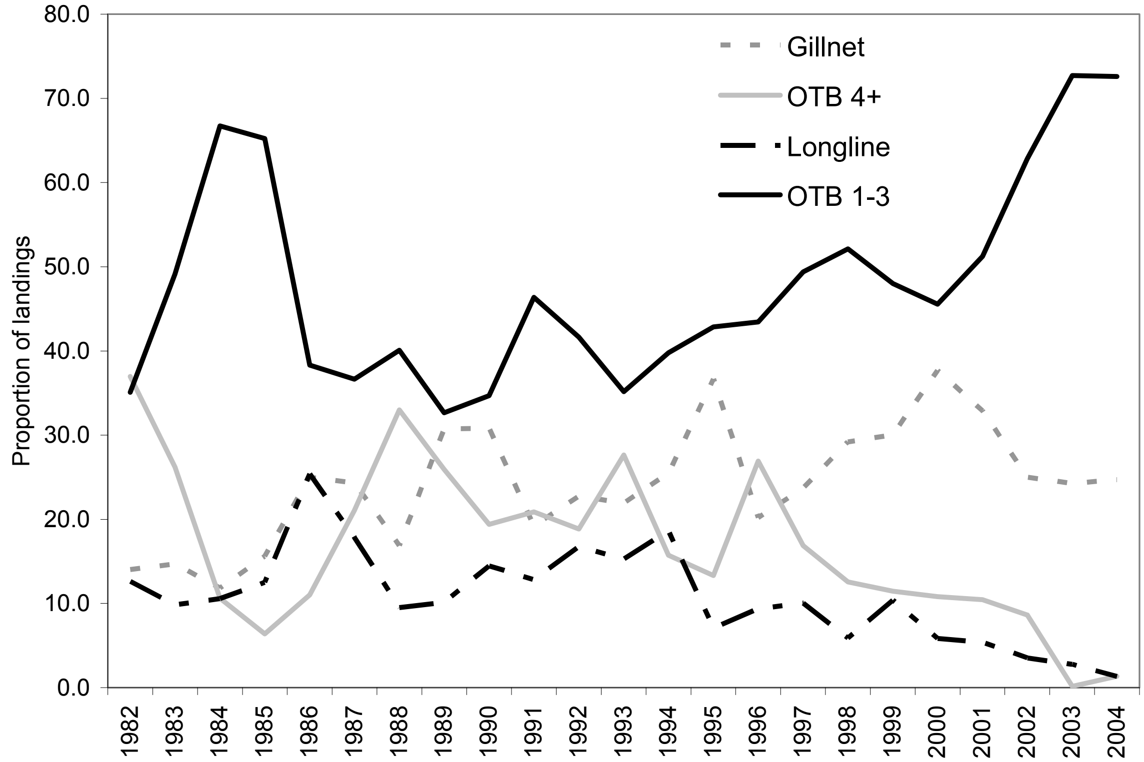

Fig. 5. Proportional landings of pollock by gear type, (western component) 1982-2004.

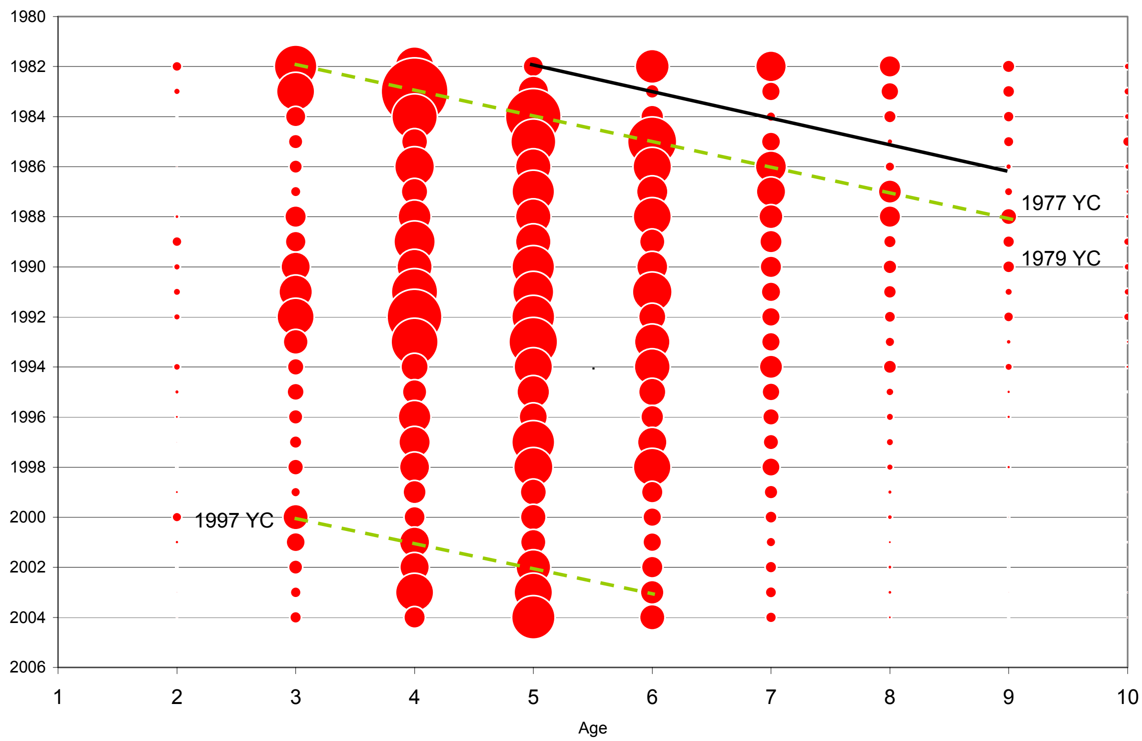

Fig. 6. Catch at age for pollock in the western component. The area of the circle is proportional to the catch at that age and year. Two examples of strong cohorts are highlighted with a dashed line, and a weak cohort is indicated by the solid line.

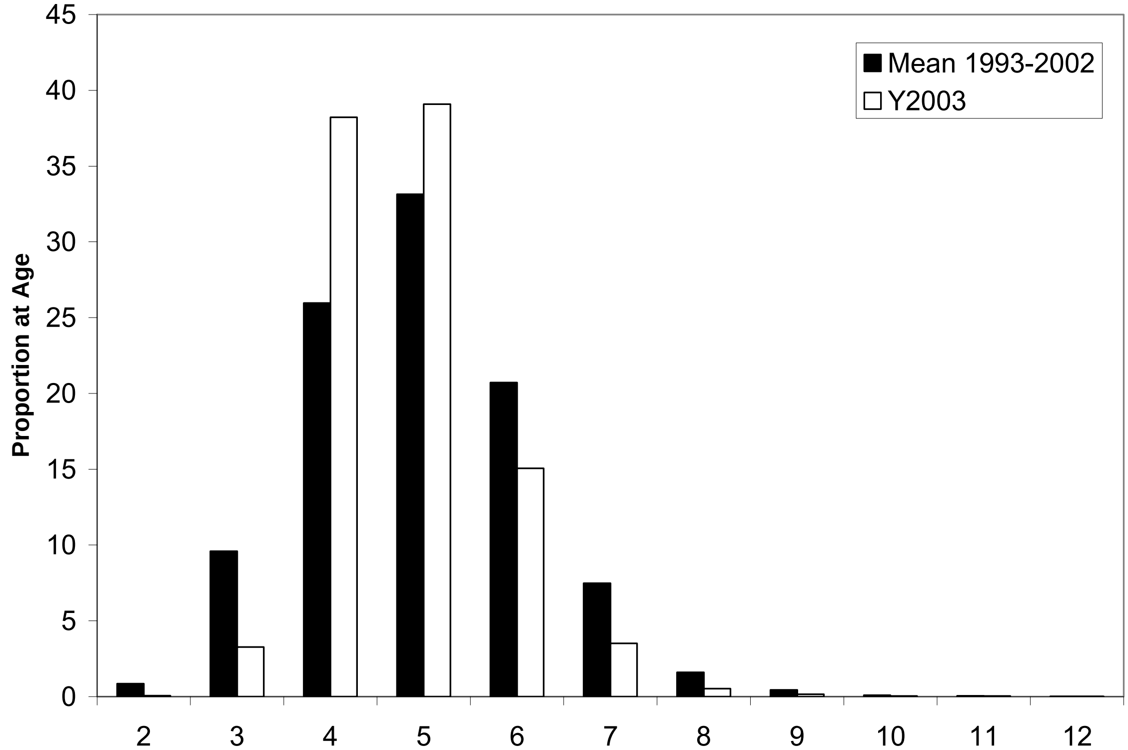

Fig. 7. Age composition of western component pollock catch in 2003 compared with the 10 year average from 1993-2002.

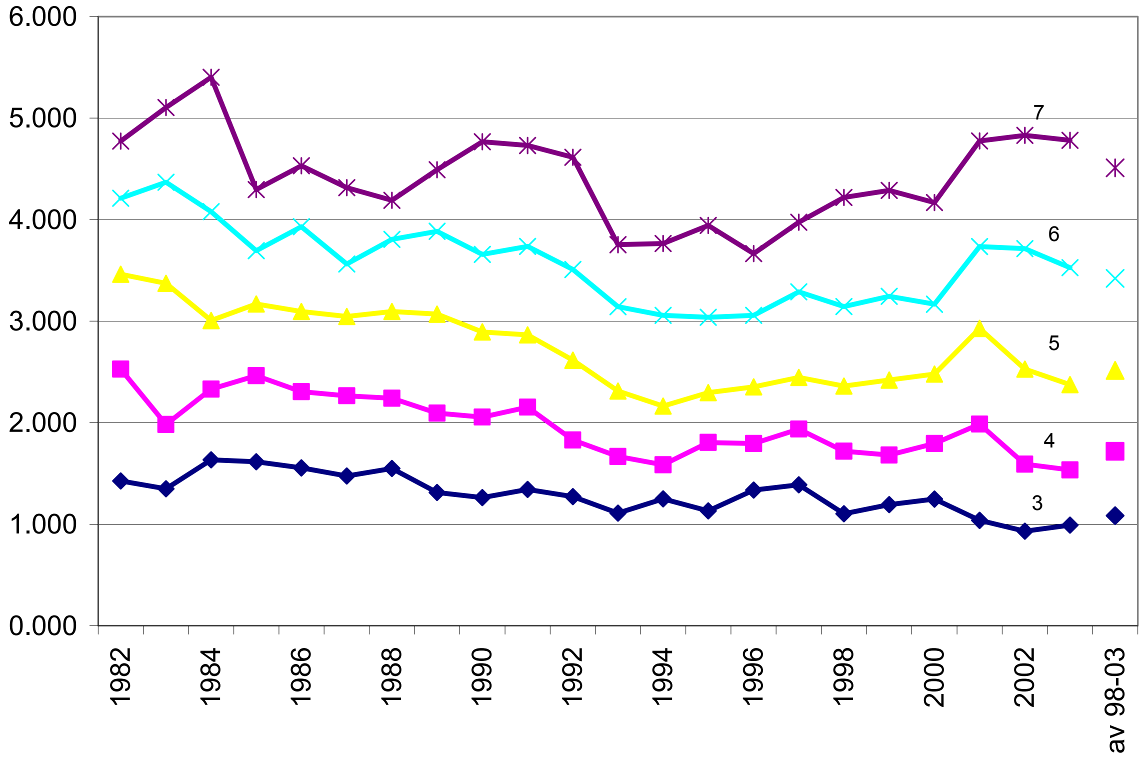

Fig. 8. Trends in mean weight at age (kg) for pollock of ages 3-7 in the western component from the commercial fishery. The average values from 1998-2003 signify the weights at age used in the projections of total catch.

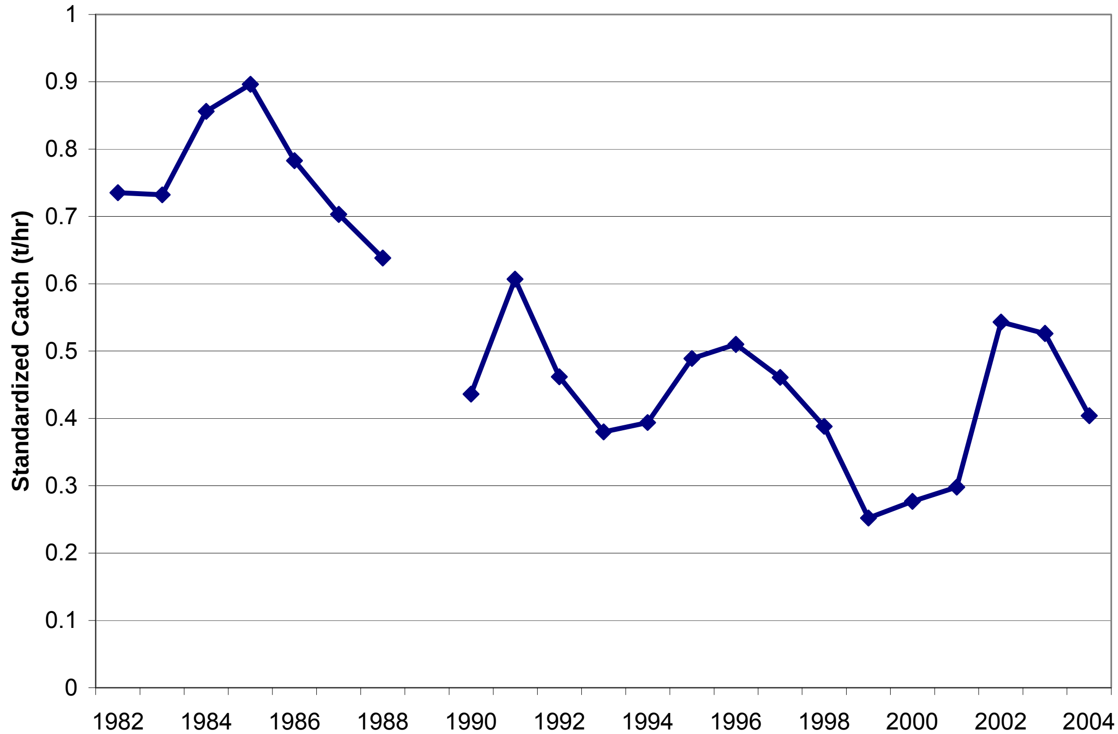

Fig. 9. Standardized mobile gear (OTB 1-3) catch rate series (t/hr) for pollock for the western component, 1982-2004.

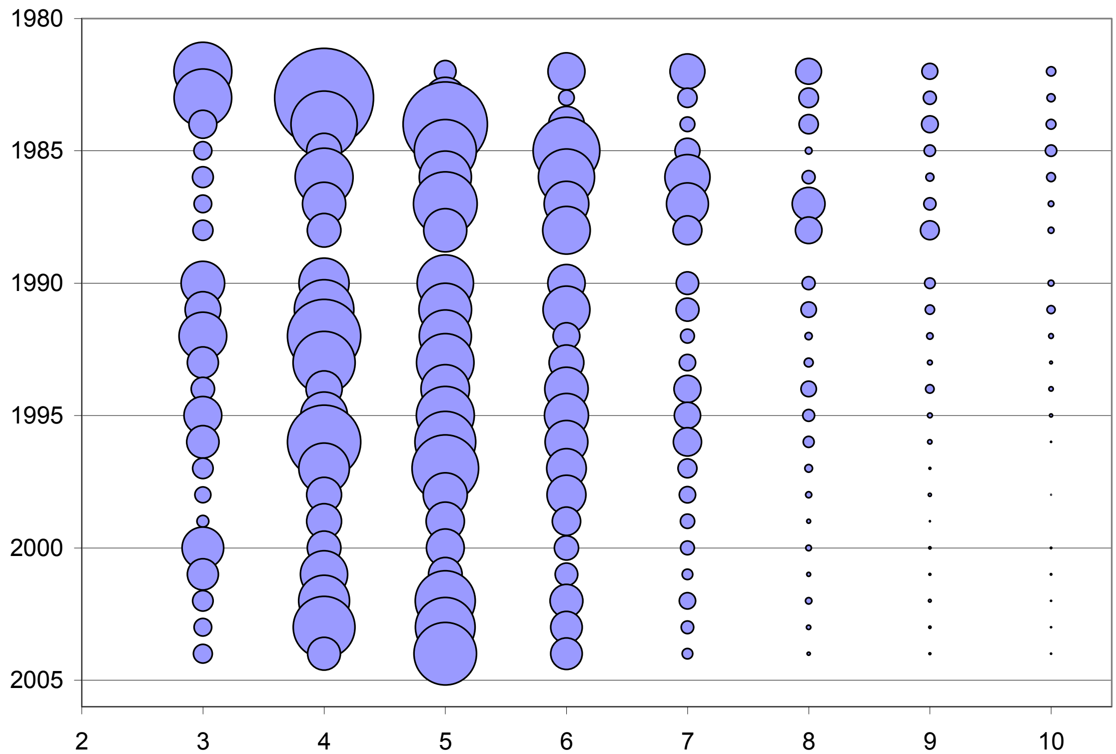

Fig. 10. Age-disaggregated catch rates for small mobile gear operating in the western component, 1982 – 2004.

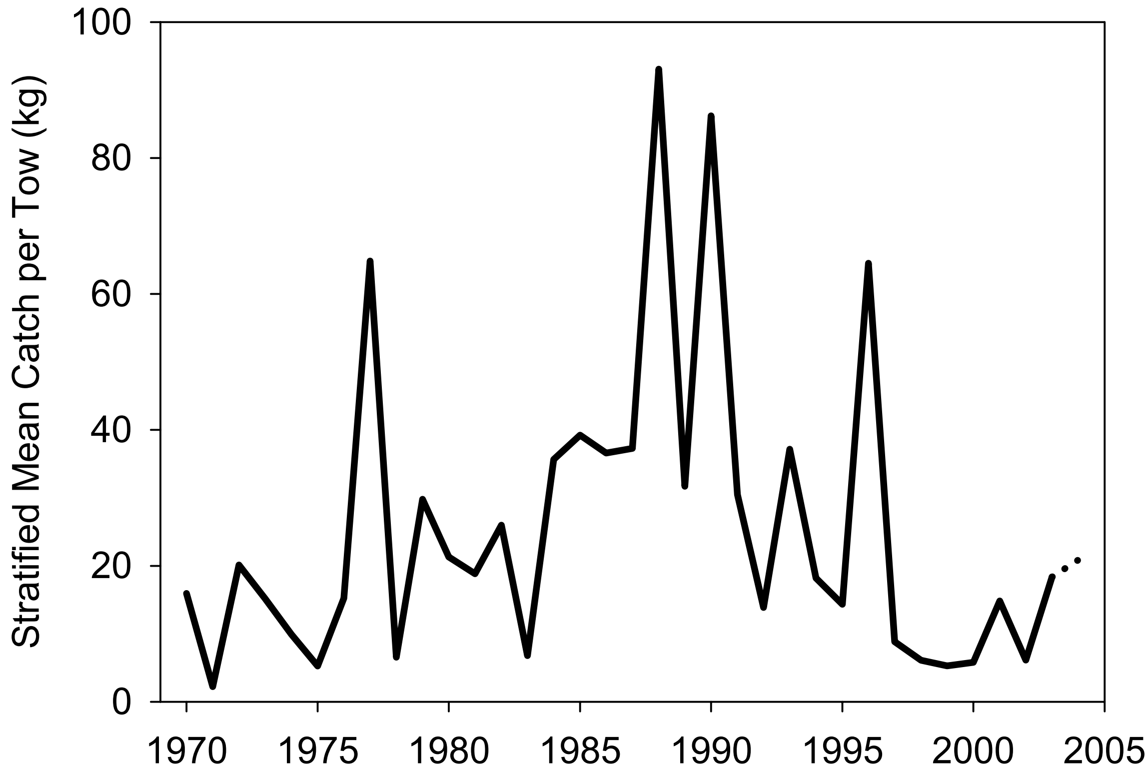

Fig. 11. Stratified mean catch per tow (kg) of pollock from the DFO summer research vessel survey in 4X strata corresponding to the western component, 1982-2004. The dotted line signifies a change in research vessel in 2004.

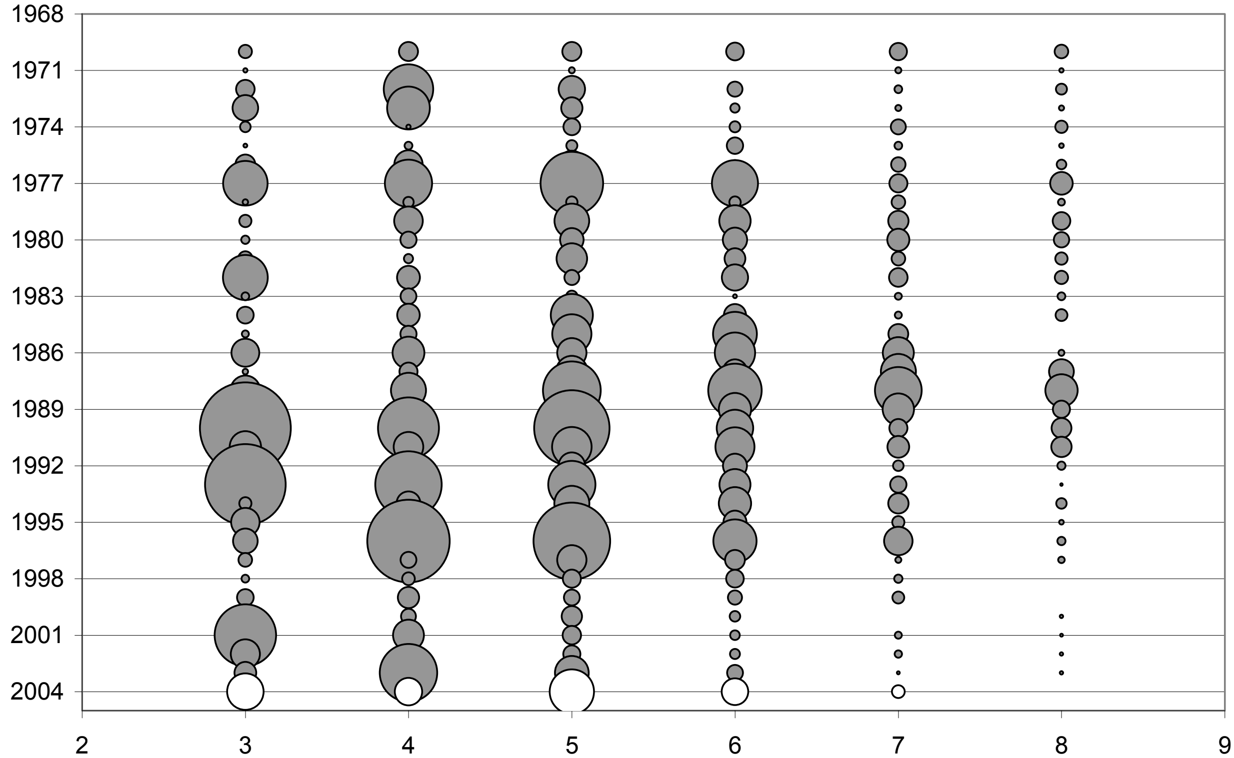

Fig. 12. Stratified mean number per tow at age of pollock from the DFO summer research vessel survey in 4X strata corresponding to the western component, 1982-2004. The open circles signify a change in research vessel in 2004.

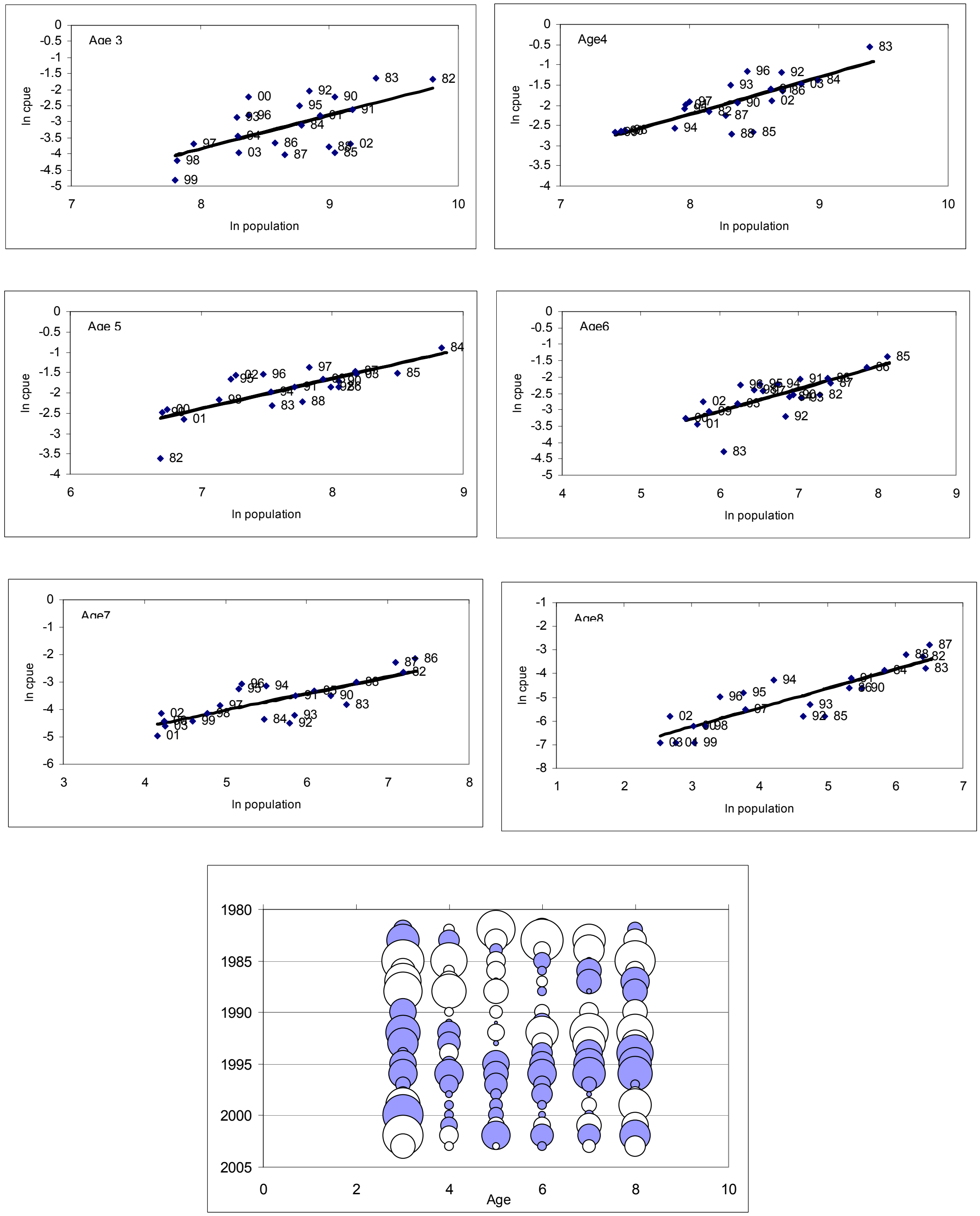

Fig. 13. Age-specific relationships between the small mobile gear indices (y axis) and population (x axis) on a ln scale, and the resulting residuals at age (bottom figure). Consensus formulation, western component pollock. Closed circles denote positive residuals and open circles denote negative residuals.

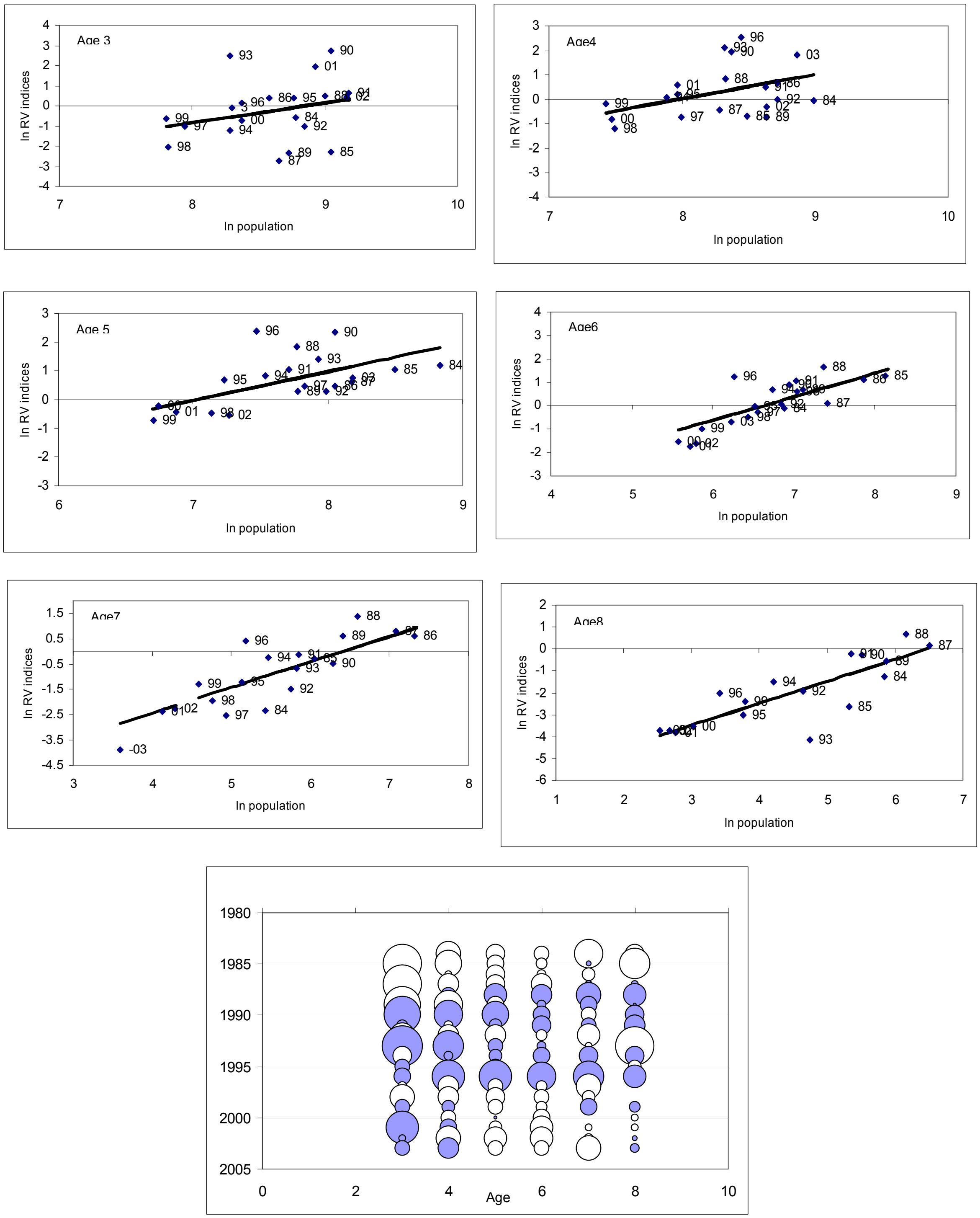

Fig. 14. Age-specific relationships between the RV indices (y axis) and population (x axis), and the resulting residuals at age (bottom right figure). Consensus formulation, western component pollock. Closed circles denote positive residuals and open circles denote negative residuals.

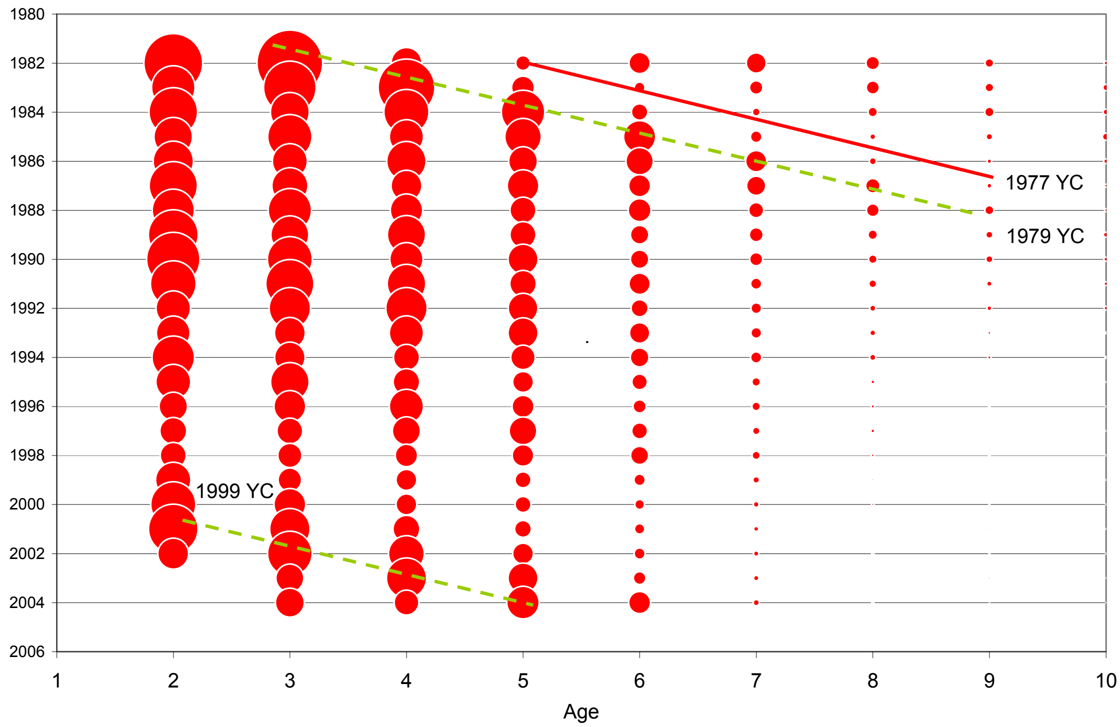

Fig. 15. Population numbers at age, western component pollock. Examples of strong and weak-classes are highlighted.

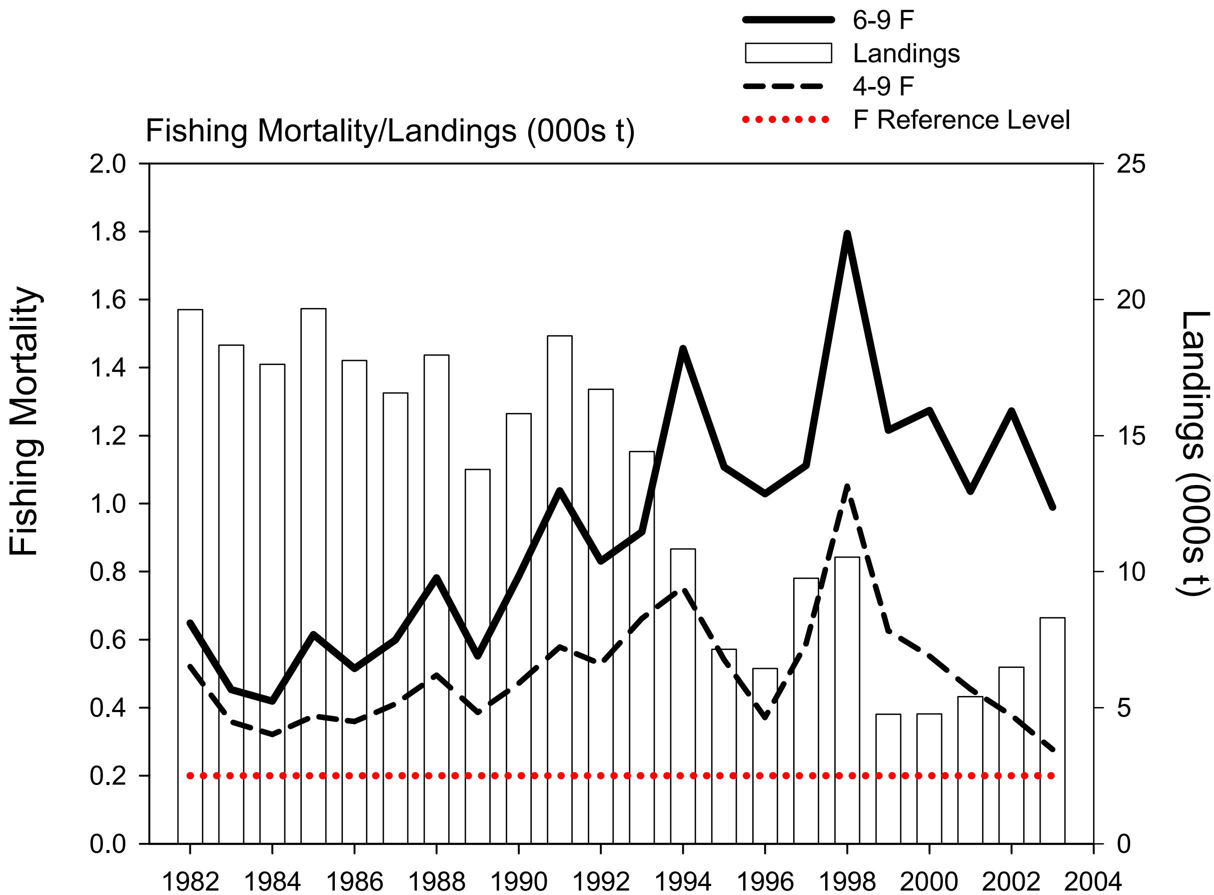

Fig. 16. Trends in fishing mortality for the western component of pollock as indicated by the consensus formulation.

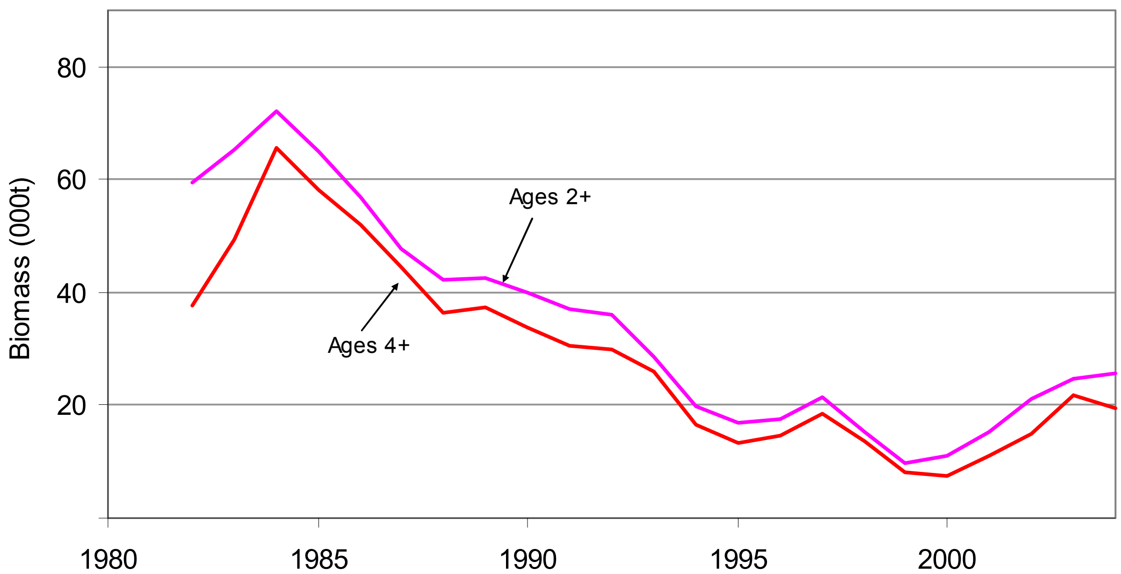

Fig. 17. Trends in biomass (000t), western component pollock for ages 2+ and 4+, as indicated by the consensus formulation.

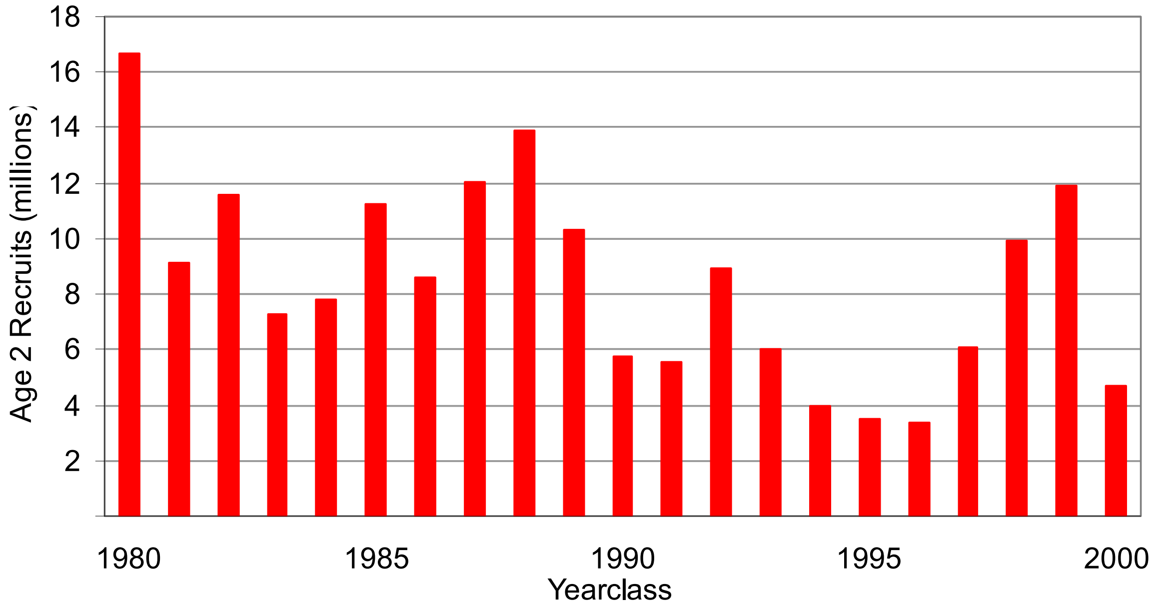

Fig. 18. Trends in age 2 recruits (number in millions) for the western component of pollock, as indicated by the consensus formulation.

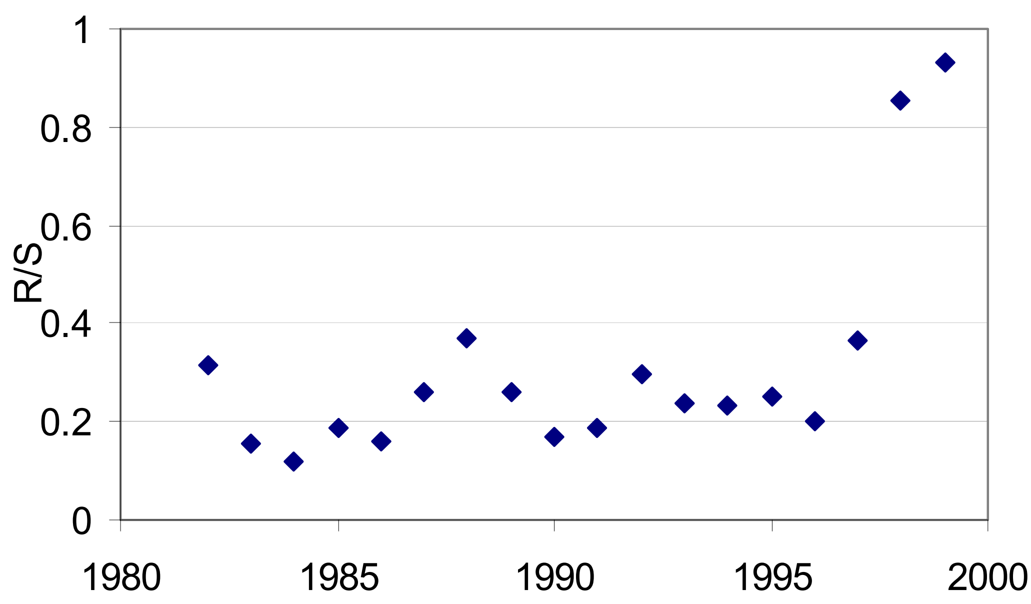

Fig. 19. Time trend in recruits per spawner for the western component of pollock.

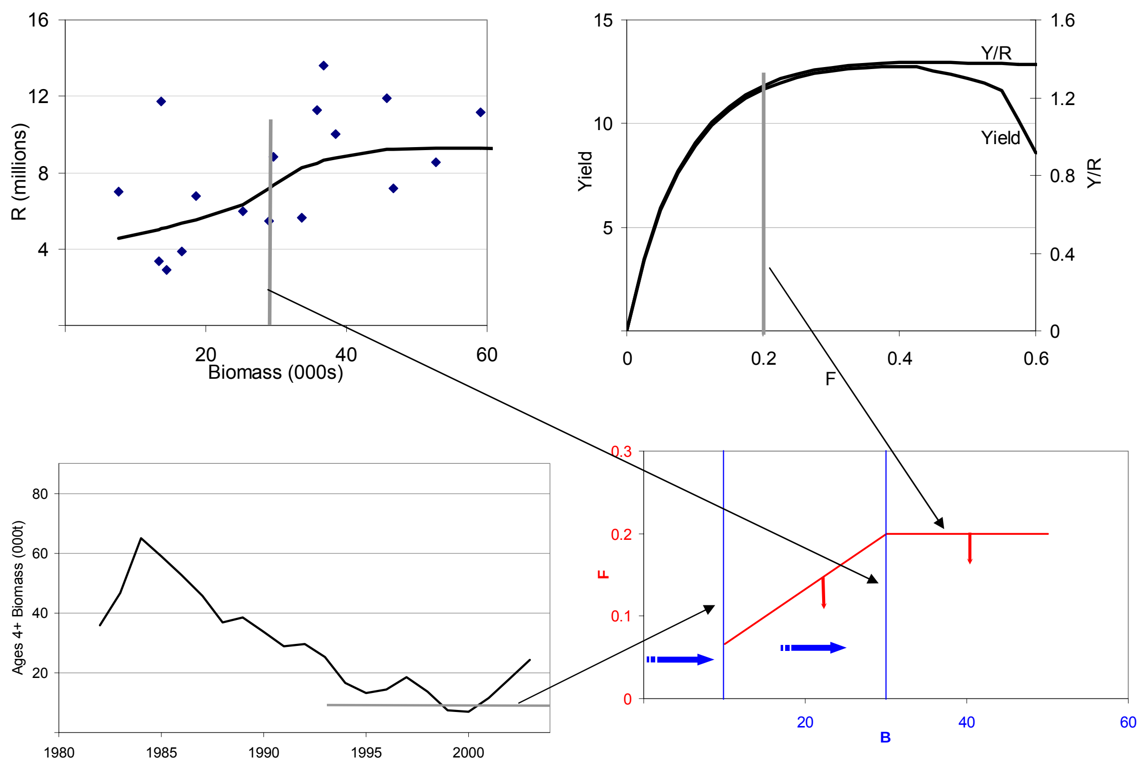

Fig. 20. Development of harvest strategy reference points for the western component of pollock.

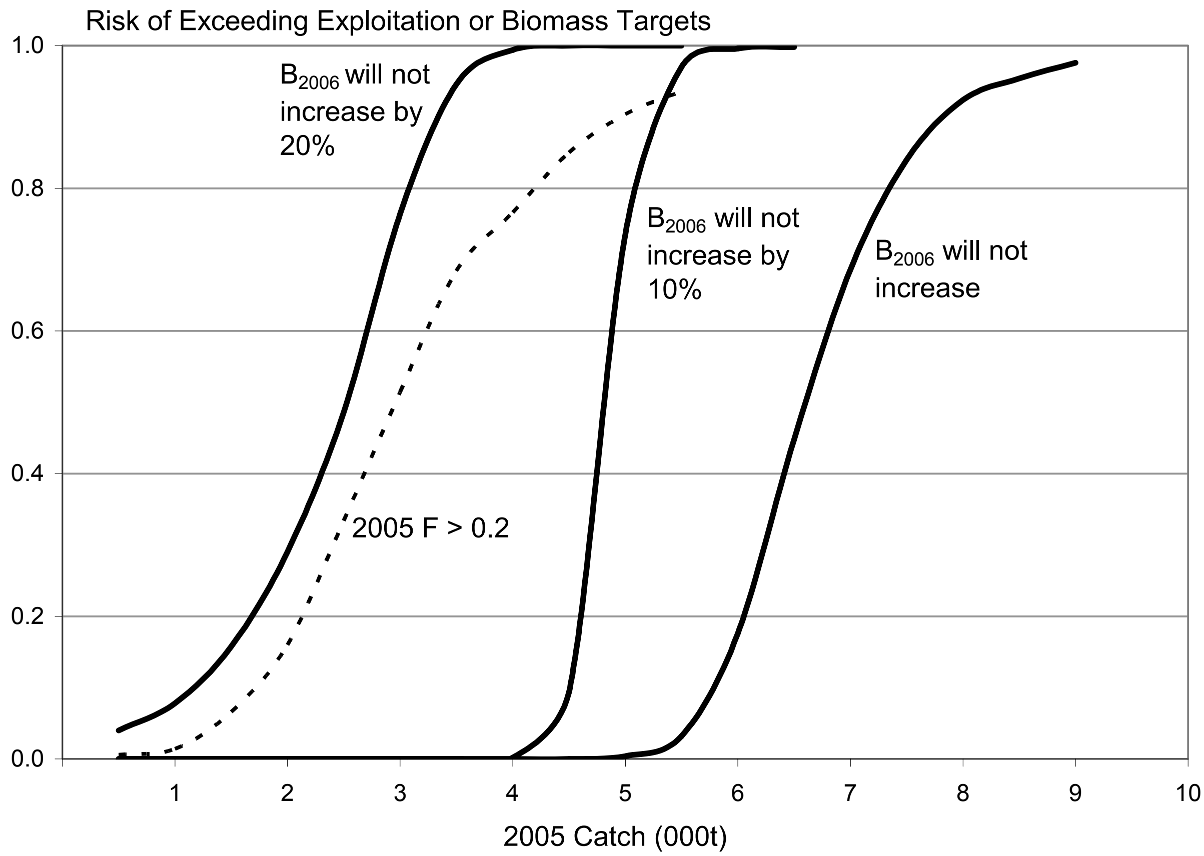

Fig. 21. Risk of exceeding exploitation or biomass rebuilding targets, western component pollock.

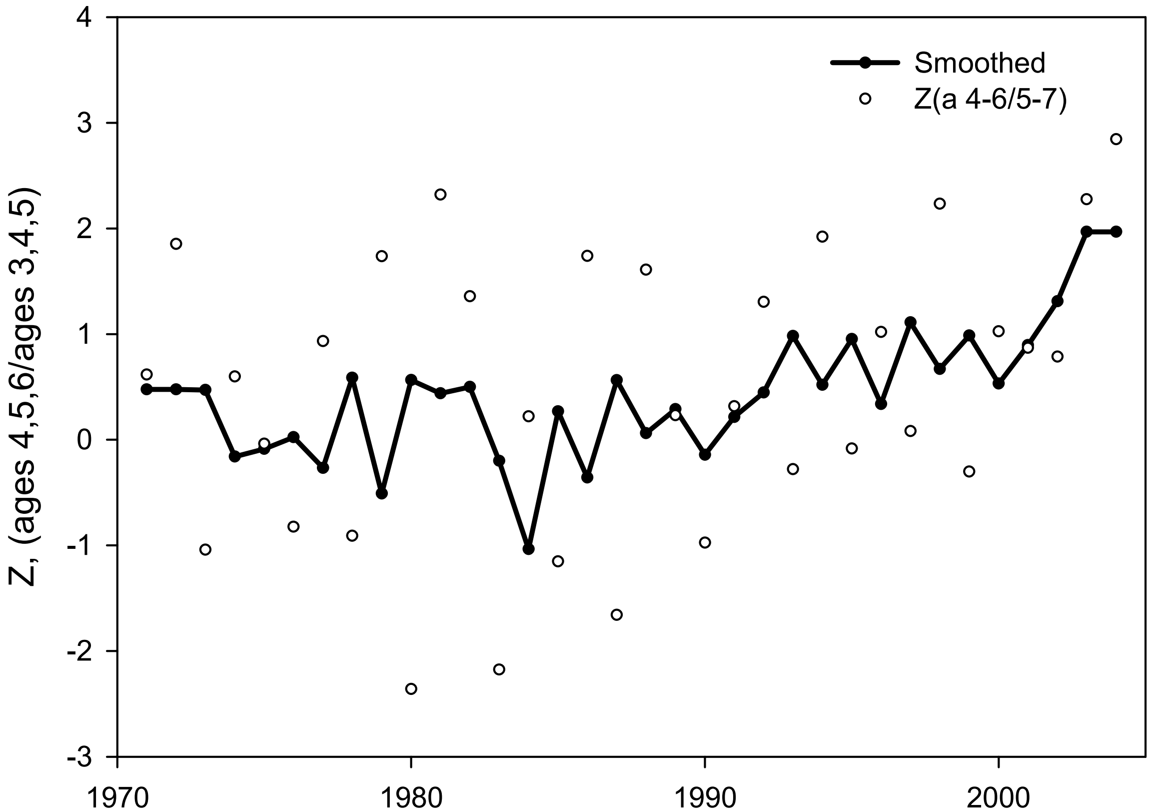

Fig. 22. Smoothed (running average of three year) estimates of total mortality from RV surveys, eastern component pollock. Annual estimates of total mortality (unsmoothed) are shown as open circles.

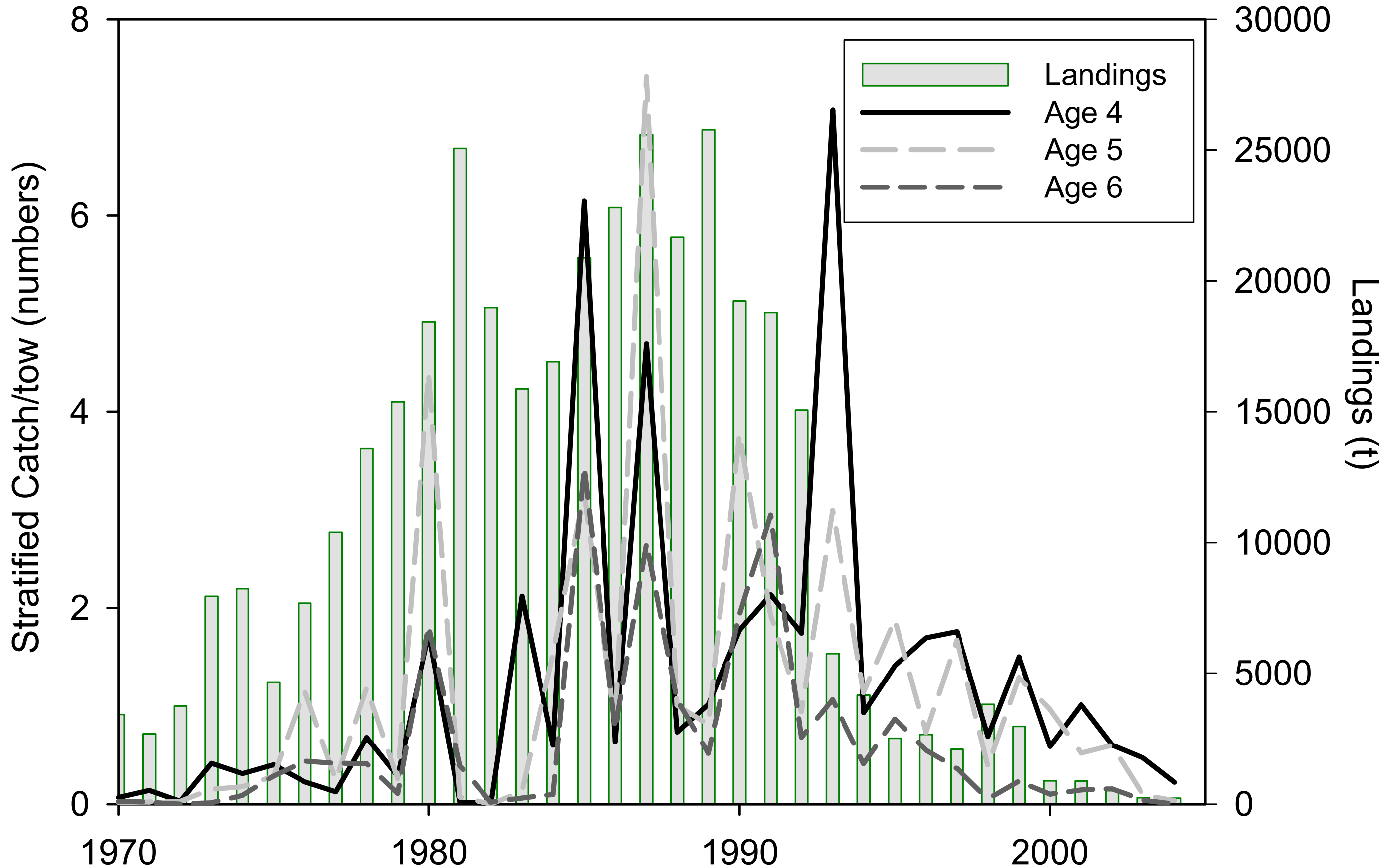

Fig. 23. Trends in landings of pollock from the eastern component, compared with survey indices at age (eastern component).