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Recovery potential assessment of American Plaice (*Hippoglossoides platessoides*) in Newfoundland and Labrador

Évaluation du potentiel de rétablissement de la plie canadienne (*Hippoglossoides platessoides*) de Terre-Neuve-et-Labrador

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ABSTRACT

Recent trends and status, as well as projected population size at different exploitation levels, were evaluated for the 3 populations in the Newfoundland and Labrador designatable unit (DU) of American Plaice. Projections were also evaluated for the DU as a whole.

For SA2 + Div. 3K, there has been some increase in the number of adults since 2005 but the average of the last 3 years remains at only 16% of the 1980-85 average. For Div. 3LNO, the number of adults has increased since the late 1980's but the number in 2010 is estimated to be only 25% of the 1980-85 average. In Subdiv. 3Ps there has been some increase in population size and the average number of adults in 2007-09 is 30% of the 1983-85 average.

American Plaice in each of the 3 areas occupied most of the available habitat and 80% or more of the survey area was occupied in most years in all areas.

Projections of population size show that there is scope for management to facilitate recovery as all three populations (and for the DU combined) increase under scenarios of no fishing mortality (F). Current fishing mortality (average of last 3 years) is estimated to be 0.172 for Div. 3LNO, less than 0.001 for SA2+Div.3K and 0.025 for Subdiv.3Ps. Under current F a large number of the projection runs for American Plaice in Div. 3LNO do not reach B_{lim} by the end of the projection period (48 years). The maximum F that would result in reaching a level where the populations and DU no longer meet COSEWIC's listing criteria was less than F=0.15 for Div. 3LNO, near F=0.06 for SA2+Div.3K and less than F=0.137 for Subdiv.3Ps.

RÉSUMÉ

On a évalué l’état récent des trois populations de l’unité désignable (UD) de plies canadiennes de Terre-Neuve et du Labrador, les tendances connexes et les projections de l’effectif selon divers niveaux d’exploitation. Les projections ont également été évaluées pour l’ensemble de l’UD.

Pour la sous-zone 2+div. 3K, on a observé une certaine augmentation du nombre d’adultes depuis 2005, mais la moyenne des trois dernières années ne demeure qu’à 16 % de celle de 1980-85. Pour la div. 3LNO, le nombre d’adultes a augmenté depuis la fin des années 1980, mais on estime que les chiffres de 2010 ne correspondent qu’à 25 % de la moyenne de 1980-85. Dans la sous-div. 3Ps, on a observé une augmentation de l’effectif; la moyenne du nombre d’adultes de 2007 à 2009 représente 30 % de celle de 1983-85.

La plie canadienne occupait la majeure partie de l’habitat disponible dans chacune des trois zones et était présente dans 80 % ou plus de la zone couverte par des relevés la plupart des années, dans toutes les zones.

Les projections concernant l’effectif montrent qu’il est possible de prendre des mesures de gestion pour faciliter le rétablissement puisque les trois populations (ainsi que l’ensemble de l’UD) connaissent une hausse avec les scénarios ne prévoyant pas de mortalité par la pêche (F). On estime que la mortalité par la pêche actuelle (moyenne des trois dernières années) est de 0,172 pour la div. 3LNO, de moins de 0,001 pour la sous-zone 2+div. 3K et de 0,025 pour la sous-div. 3Ps. Selon la valeur de F actuelle, un grand nombre de projections sur les plies canadiennes dans la div. 3LNO n’atteignent pas la valeur de B_{lim} à la fin de la période de projection (48 ans). La valeur de F maximale qui mènerait à un niveau auquel les populations et l’UD ne respecteraient plus les critères d’inscription du COSEPAC est inférieure à F=0,15 pour la div. 3LNO, d’environ F=0,06 pour la sous-zone 2+div. 3K et inférieure à F=0,137 pour la sous-div. 3Ps.

INTRODUCTION

Considering the sharp decline of Newfoundland and Labrador American Plaice (approximately 96% for the COSEWIC (the Committee on the Status of Endangered Wildlife in Canada) Designatable Unit (DU) as a whole) over the last three generations, it was designated as “threatened” in April 2009 by COSEWIC.

As part of this "post-COSEWIC" process, scientific information is needed to support the development of social and economic cost assessment scenarios for recovery, to better inform public consultations and to support other entities involved in the decision of adding the species to Schedule 1 of the SARA. The recovery team also requires this information to develop a recovery strategy, and if necessary, one or more action plans.

American Plaice populations that make up the Newfoundland and Labrador designatable unit (DU) extend from the northern tip of Labrador to the south coast of Newfoundland. There are 3 populations in the area: Subarea (SA) 2 + Div. 3K, Div. 3LNO and Subdiv. 3Ps. SA 2 + Div. 3K is managed exclusively by Canada. Subdiv. 3Ps is managed by Canada with bilateral consultations with France. Div. 3LNO is managed by NAFO.

Information is presented for each population separately and for the DU as a whole.

CURRENT/RECENT STATUS

STATUS AND RANGE

Recent status and trends were determined from research vessel surveys for SA 2 + Div. 3K and Subdiv. 3Ps and from the most recent assessment based on Virtual Population Analysis for Div. 3LNO (Dwyer et al 2010). The number of adults was computed using estimates of proportion mature at age or length by sex and population. These estimates were then applied to the research vessel swept area estimates of population numbers at length and sex for SA 2 + Div. 3K and Subdiv. 3Ps. For Div. 3LNO the proportion male and female was estimated and applied to the VPA population numbers at age to produce numbers of male and female. These were then multiplied by the estimated proportion mature at age to produce number of adults.

For SA 2 + Div. 3K, data are only available for Div. 2J and 3K. The number of adults declined steeply from the mid 1980’s to 1995 (Fig. 1). The decline continued to about 2003. There has been some increase in the number of adults since 2005 but the average of the last 3 years remains at only 16% of the 1980-85 average (period before major declines began in all 3 areas).

Total biomass from the survey showed a similar steep decline as the number of adults (Fig. 2). As with adult abundance there has been some increase in recent years. The average of the last 3 years is only 11% of the 1980-85 average.

For Div. 3LNO, the number of adults declined steeply starting in the mid to late 1980s, reaching a minimum in 2002 (Fig. 3). The number of adults has increased since then but the number in 2010 is estimated to be only 25% of the 1980-85 average.

The total biomass in Div. 3LNO also showed a large decline starting in the mid to late 1980’s (Fig. 4). In 2010 the total biomass is estimated to be only 18% of the average total biomass from 1980-85. The SSB in 2010 is estimated to be 29% of the average SSB from 1980-85. This is greater than the total biomass percentage (and similar to adult abundance) because there has been a large increase in the proportion mature at age (see below).

In Subdiv. 3Ps, the number of adults declined steeply from the mid 1980's to 1995 (Fig. 5). There has been some increase since then and the average number of adults in 2007-09 is 30% of the 1983-85 average.

The trend in total biomass index in Subdiv 3Ps was similar to the trend in number of adults for that area (Fig. 6). The average biomass index from 2008-10 is 24% of the 1983-85 average.

Range was calculated as the design weighted area occupied (DWAO):

$$A_t = \sum_{i=1}^{S}\sum_{j=1}^{n} \frac{a_i}{n_j} I \ \ where\ I = \begin{cases} 1\ if\ Y_j > 0 \\ 0\ otherwise \end{cases}$$

where A_t is the DWAO in year t, S is the number of strata, n is the number of sets in stratum i, a_i is the area of stratum i, and Y_j is the number of fish caught in set j. Using this metric, the proportion of the area occupied was calculated.

Over the 1978-2010 period American Plaice in each of the 3 areas occupied most of the available habitat (Fig. 7). The smallest proportion was 56% in Subdiv. 3Ps in 1994. Whereas 80% or more of the survey area was occupied in most years in all areas and in many years more than 90% of the area was occupied. There is no indication of a trend to decreased area occupied in recent years. On average the SA 2 + Div. 3K population occupied 156000 Km^2, the Div. 3LNO population 243000 Km^2 and the Subdiv. 3Ps population 46000 Km^2. There was a change in survey gear which seems to have some effect on the estimates of area occupied. This occurred in 1995 in SA 2 + Div. 3K and in 1996 in Div. 3LNO and Subdiv. 3Ps. Area occupied is greater starting in the year of the gear change; however, trends will not be affected.

FISHERY

All populations are currently under moratorium to directed fishing. The moratorium on directed fishing began in 1994 for SA 2 +Div. 3K and Div. 3LNO and in September 1993 in Subdiv. 3Ps.

In SA 2 + Div. 3K, bycatch has averaged about 35 tons since the beginning of the moratorium on directed fishing. In 2008 and 2009 bycatch was less than 10 tons, mainly in the Greenland halibut fishery (Fig. 8). In Subdiv. 3Ps, bycatch has averaged 575 t over the moratorium period and in 3 years (2001-03) was over 1000 t, mainly taken in the directed cod fishery (Fig. 10). Bycatch in Div. 3LNO has been much greater, averaging 3600 t, but from 2000-04 bycatch averaged more than 6000 t (Fig. 9). Bycatch in Div. 3LNO comes mainly from the directed Yellowtail Flounder, Skate and Greenland Halibut fisheries.

LIFE HISTORY PARAMETERS

Maturity

Age and length at 50% maturity were produced from research vessel data. Estimates were produced by sex and cohort for each population using generalized linear models with a logit link function and binomial error.

Males and females in all 3 populations are maturing at a younger age and a smaller size.

In SA2+Div.3K, age at 50% maturity (A50) has declined from just under 11 years to around 7 years of age for females (Fig. 11). For males, A50 has declined from around 7 to just over 4 years of age. There has been some increase in A50 for males of recent cohorts, but such a short term increase has been seen in the time series previously and this will need to continue before it can be considered a reversal of the decline. Length at 50% maturity (L50) has also declined for both sexes in Div. 2J3K (Fig. 12). For males, L50 was about 22 cm at the beginning of the time series and for recent cohorts is about 18 cm. Female L50 declined from about 38 cm at the beginning of the time series to about 31 cm recently.

In Div. 3LNO, male A50 was around 6 years at the beginning of the time series and for recent cohorts has been about 4.5 years (Fig. 13). Female A50 has declined from about 11 years to about 8 years. At the beginning of the time series female L50 was around 40 cm, but for more recent cohorts it has been about 35 cm (Fig. 14). The L50 for males in Div. 3LNO showed most of its decline up to the cohorts of the early 1990's by which time it had declined from 23 cm to less than 15 cm. It has subsequently increased, and male L50 for recent cohorts is only about 1 cm less than for those at the beginning of the time series.

American Plaice in Subdiv. 3Ps show a similar decline in A50 and L50 as the other 2 populations (Fig. 15 and 16). Male A50 has declined from about 7 to less than 4.5 years, while female A50 has declined from about 11 to just under 9 years. Male L50 has declined from about 27 cm to less than 19 cm and female L50 has declined from about 40 cm to around 36 cm.

Fecundity

Ovaries were collected from American Plaice in Div. 3LNO and Subdiv. 3Ps during spring research vessel surveys. Samples were available for 1993-98 and 2005 for both areas and for 2007 in Subdiv. 3Ps. Females were designated as ripening for the upcoming spawning season based on macroscopic inspection of the ovaries. Only ovaries containing opaque oocytes but no clear oocytes were included, since the presence of clear oocytes would indicate that spawning has already started (and therefore egg counts may not be accurate). Whole weight was also recorded for most fish. Ovaries were fixed and fecundity determined after fractionation down to a countable number using a modified whirling vessel. Relative fecundity was calculated as the number of eggs divided by the total body weight of the fish.

Median relative fecundity was lower in both areas for the earlier samples but there was no significant difference in relative fecundity over time in either Div. 3LNO or Subdiv. 3Ps (Fig. 17).

Recruitment

For Div. 2J3K and Subdiv 3Ps recruitment was estimated from survey data in the same fashion as in Dwyer et al. (2003). Relative cohort strengths were estimated using the following model for Div. 2J3K:

$\log(N_{a,y}) = \mu + Y_y + \varepsilon_{a,y}$,

where:

μ = intercept

a = age subscript, age 3 to 5

y = cohort subscript

N = survey index (Abundance in millions)

Y = cohort effect

ε = error.

For Subdiv. 3Ps there was a pattern in the residuals when Campelen and equivalent data were used, so as in Morgan et al. (2005), a model using Campelen and original Engel data was chosen which eliminated the pattern in the residuals:

$$\log(N_{s,a,y}) = \mu + Y_y + (SA)_{s,a} + \varepsilon_{s,a,y} ,$$

where:

μ = intercept

s = survey subscript, Engel or Campelen

a = age subscript, age 2 to 5

y = cohort subscript

N = survey index (Abundance in millions)

Y = cohort effect

SA = Survey * Age effect, and

ε = error.

In both cases only those cohorts that were observed at least twice in the data were used.

For Div. 3LNO American Plaice, recruitment was taken from the accepted assessment model (Dwyer et al 2010).

In Div. 2J3K recruitment declined from the mid 1980s to the late 1990s. There has been an increase in recruitment since (Fig. 18). In Div. 3LNO there was a long decline in recruitment from the 1970s to the mid 1990s (Fig. 19). There has been some increase in recruitment since that time but recruitment remains very low compared to the 1980s. Recruitment declined in Subdiv. 3Ps from

1980 until 1995 (Fig. 20). Since then it has increased fairly steadily to reach levels similar to the beginning of the time series.

Mortality

Estimates of total mortality (Z) were calculated from survey data for each population as the log of the number of age 6 to 8 in one year divided by the number of age 7 to 9 in the next year.

The average Z in Div. 2J3K over the time period was 0.45 (Fig. 21). Total mortality was above this average for most of the years since 1989. It has been more variable in recent years because of the presence of at least 2 year effects in the data (when there are more fish at age a+1 in year y+1 than there were at age a in year y). Catch has been thought to have been low in this area (see below) and such high levels of total mortality indicate a high natural mortality.

Total mortality in Div. 3LNO was above the series average of 0.41 in most years from the late 1980’s to the mid 1990’s (Fig. 22). Total mortality has been substantially reduced since that period. In Subdiv. 3Ps the average total mortality over the time series was 0.43 (Fig. 23). The total mortality was quite variable in Subdiv. 3Ps but it was generally higher in the first half of the time series than in the second half. Z that were negative were not included in this comparison of mortality from the two halves of the time period in 3Ps.

Targets

To satisfy COSEWIC’s assessment criteria to declare that a species is not threatened a recovery goal for American Plaice might be based on a rate of decline in the total number of mature individuals. This would be a reduction of less than 30% over 3 generations (48 years) assuming that the causes of the decline have not ceased or are unknown. For SA 2 + Div. 3K and Subdiv. 3Ps there are no models of number of mature individuals. A proxy is the biomass from surplus production modeling. Further recovery goals could be based on fisheries management targets and would be at least B_{lim}. This precautionary approach reference point (B_{lim}) is only available for the Div. 3LNO population and is 50 000 t of SSB.

PROJECTIONS

Several scenarios were explored using 48 year (3 generation) stochastic projections. For Div. 2J3K and Subdiv. 3Ps projections were done using surplus production modeling (Bailey 2011). For Div. 3LNO projections were based on the accepted VPA (Dwyer et al 2010).

For Div. 3LNO an ‘expanding window’ strategy was used resample biological inputs and partial recruitment to the fishery to account for the fact it is anticipated that the conditions in the near future should be similar to recent conditions, but that conditions may deviate from recent as time goes on (DFO 2010). As each year of projection was added an additional year of data was added to the data set of inputs from which values can be randomly resampled with replacement starting with the most recent and moving backwards in time. The first projection year takes 2009 conditions, second projection year randomly takes either 2008 or 2009 conditions, the 3rd third randomly selects from 2007-09 and so on until the last year of the projection which randomly selects from all years from 1960-2009. This means that for the first few years of the projection input data are sampled randomly from the most recent data. It also means that we assume that the stock conditions will have an increasing probability of being like the past conditions as the selection window expands into the past. The resampling was done by picking a year at random and then using all the data (weights, maturities, natural mortality, partial recruitment) in that year, as all of these metrics are likely to be interrelated. Recruitment was resampled from three sections of the estimated stock recruit scatter from the 2010 assessment, depending on SSB. The three sections were 50 000 tons of SSB and below (only low recruitment), greater than 50 000 tons to 155 000 tons (low and high recruitment), and greater than 155 000 tons (only high recruitment). The projections were age disaggregated and contained a plus group at age 15. Ten thousand iterations were conducted for each projection.

SA 2 + Div. 3K and Subdiv. 3Ps do not have currently accepted VPA models. Recent catch at age data are not considered representative of the fishery for Subdiv. 3Ps and recent catches have been extremely low for SA 2 +Div. 3K. Therefore a different approach was used for the projections for these populations. Population dynamics of American Plaice were modeled using a Bayesian state-space implementation of the Schaefer Surplus-Production model for NAFO divisions 3Ps and 2J3K from 1960-2009. The posterior distributions for r (the intrinsic rate of population growth), K (carrying capacity), and Sigma (process error) from the surplus production model were used in order to project 3 generations (48 years). The projection samples from the posterior distributions and utilizes the process error, inputting these into the surplus production model in order to predict future biomass. The precision of these predictions (i.e. process error) decreases as more predictions are made, resulting in expanding credible intervals. Ten thousand iterations were completed for each projection.

In all cases, the proportion of biomass (and number of adults for 3LNO) in each year in the 48 year projection to the first year in the projection was calculated. This is to explore the COSEWIC criterion that designates a population as 'threatened' if it declines by greater than 30% over 3 generations. For Div. 3LNO a B_{lim} exists (50 000 t of SSB) and the ratio of SSB in each year of the projection to B_{lim} was also calculated.

The results of the projections for each of the populations were combined to examine trends for the entire DU. An examination of the biomass from surveys showed that in the 1980's (before the major decline in the late 1980s that occurred in all of these stocks) the biomass in Div. 3LNO was 5 times that in Div. 2J3K and 9 times that in Subdiv. 3Ps. The ratios of biomass from the surplus production modelling for Div. 2J3K and Subdiv. 3Ps and VPA for Div. 3LNO were similar. To produce the result for the DU combined the results for each population were combined in a weighted average where the weightings were based on the relative population sizes in the 1980's (weightings: Div. 3LNO 1, SA 2+Div. 3K 0.2, Subdiv. 3Ps 0.11).

Projections were carried out under current fishing mortality (average of the last 3 years) to explore the potential for growth at that exploitation level. In addition projections at F=0 were conducted to explore the potential growth of the populations with no exploitation to assess the potential for management measures to facilitate recovery. For 3Ps and 3LNO projections were also conducted at half current F (F is so low in Div. 2J3K that this projection was not attempted). In order to determine allowable harm projections were run at a series of F.

PROJECTION RESULTS

<u>Current conditions</u>

Projections were run at current levels of fishing mortality to explore the scope for recovery under current conditions. Projections of population biomass show that in Div. 3LNO biomass could be from 6.5 times to only 45% of 2009 biomass by the end of the 48 year projection. This means that there is some probability that by the end of the projection period biomass will have decreased (Fig. 24). For spawning stock numbers (SSN) results of the projection show that most of the area encompassed by the 95% confidence intervals is above the level of SSN in 2009 (Fig. 25). The distribution of model projected runs is not symmetrical and it should be noted that at current F a substantial proportion of the projected spawning stock biomasses (SSB) are below B_{lim} (Fig. 26).

For SA 2 + Div. 3K current F is estimated to be very low at less than 0.001. At this level of F, the 95% upper and lower credible intervals are both above 1, indicating an increase in biomass compared to 2009. The range of increase is from 10% to 24 times (Fig. 27).

The current F in Subdiv. 3Ps is estimated to be 0.025. At this level of F, the 95% upper and lower credible intervals are both above 1, indicating an increase in biomass compared to 2009. The range of increase is from 4 to 9 times the biomass in 2009 (Fig. 28).

For the DU as a whole, results of projections of population biomass over 48 years at current fishing mortality range from an increase of more than 7 times to a decrease in biomass to reach less than 50% of the biomass in 2009. Most of the range encompassed by the 95% of the results is above the level of biomass at the beginning of the projection period. It should be noted that current F varies greatly across the different populations with Fcurrent=0.0005 in SA 2+Div. 3K, 0.172 in Div. 3LNO and 0.025 in Subdiv. 3Ps. There is no B_{lim} for the DU as a whole (Fig. 29).

<u>No fishing mortality</u>

Projections at F=0 were conducted as described above to explore the potential growth of the populations without exploitation to assess the potential for management measures to facilitate recovery.

For Div. 3LNO American Plaice biomass (Fig. 30) and SSN (Fig. 31) are projected to increase well above the level of biomass in 2009. The management goal of exceeding B_{lim} is also projected to be reached under an F=0 fishing scenario (Fig. 32).

For SA 2+Div. 3K there is also an increase in biomass in projections at F=0. However, the lower bounds of the 95% credible interval only increase by about 12%, indicating that there is some probability of only a small increase in this population even with no fishing (Fig. 33).

For Subdiv. 3Ps American Plaice biomass (Fig. 34) is projected to increase well above the biomass in 2009.

For the DU as a whole there is a substantial increase in biomass over 48 years with an F=0 (Fig. 35).

<u>Half of current F</u>

To further explore the scope for management measures to facilitate recovery, projections were conducted at half current F for Div. 3LNO and Subdiv. 3Ps. Since current F was so small for SA 2+Div. 3K, no projection at half of current F was conducted for that stock. This meant that results were not combined for the DU as a whole.

For Div. 3LNO American Plaice half of current F is 0.086. At this level of fishing mortality most results show an increase in population biomass (Fig. 36). Most results for SSN are also projected to increase relative to 2009 levels (Fig. 37). For SSB most of the range encompassed by the 95% confidence intervals shows SSB to be above B_{lim} although some of the results show SSB remaining below B_{lim} (Fig. 38).

For Subdiv. 3Ps half of current F is 0.0125. At this level of F the entire area encompassed by the 95% credible intervals shows an increase in biomass relative to 2009 (Fig. 39).

Allowable harm

To determine maximum allowable harm, projections at various levels of F were conducted and evaluated against the COSEWIC criterion for assessing a species as threatened. Here we have used a decline of >30% over 3 generations in biomass (from the beginning to the end of the projection period) as this criterion as a proxy for the number of mature individuals.This exercise was conducted for each population separately and not combined for the DU as the level of F that can be sustained will be very different for the different populations.

For Div. 3LNO the maximum F for allowable harm is less than F=0.15. At this level of F, most of the area encompassed by 95% confidence intervals shows an increase in biomass (Fig. 40) and in SSN relative to 2009 (Fig. 41). However, a substantial number of the results do not reach B_{lim} (Fig. 42).

For SA2+Div.3K the maximum F for allowable harm is near F=0.06. At this level of F, most of the area encompassed by the 95% credible intervals shows increase in biomass relative to the biomass in 2009. However, some of the projection results showed a more than 30% decline in biomass relative to 2009 (Fig. 43).

For Subdiv. 3Ps the maximum F for allowable harm is less than F=0.137. At this level of F, most of the area encompassed by the 95% credible intervals shows increase in biomass relative to the biomass in 2009. However, some of the projection results showed a more than 30% decline in biomass relative to 2009 (Fig. 44).

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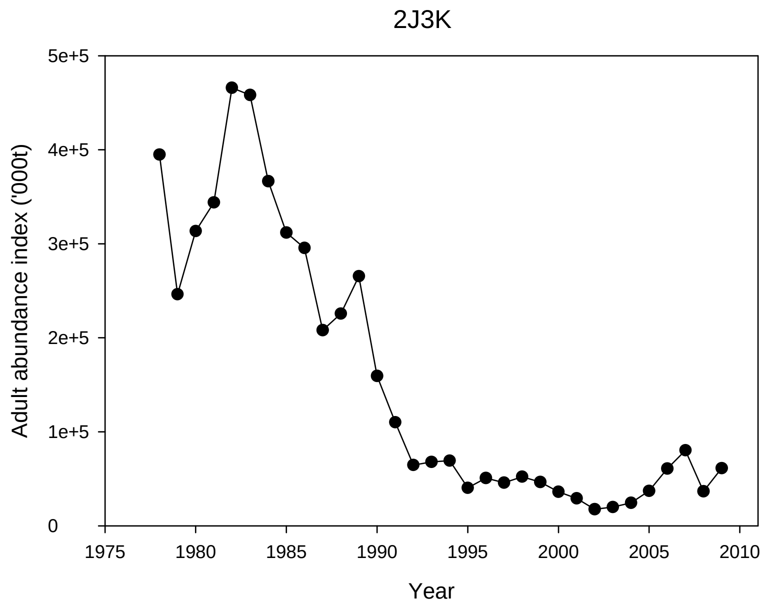

Figure 1. Number of adults in Div. 2J3K from research vessel surveys.

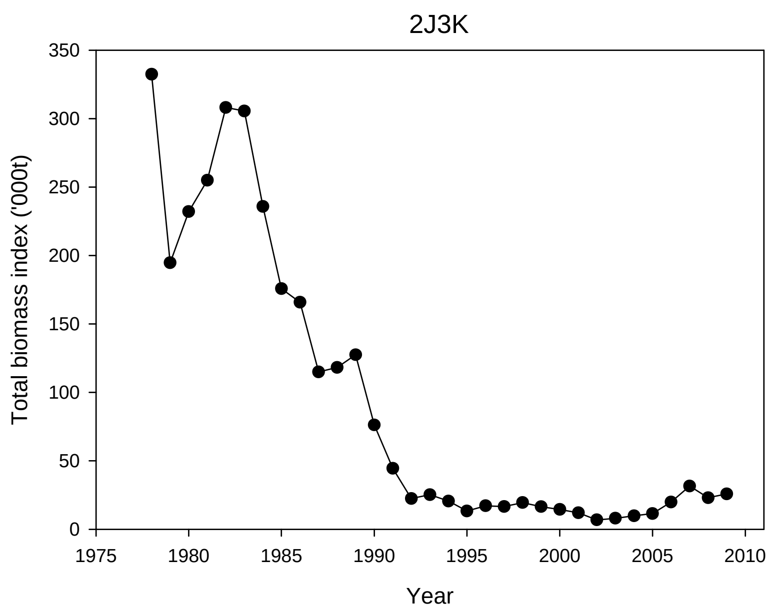

Figure 2. Total biomass index in Div. 2J3K from research vessel surveys.

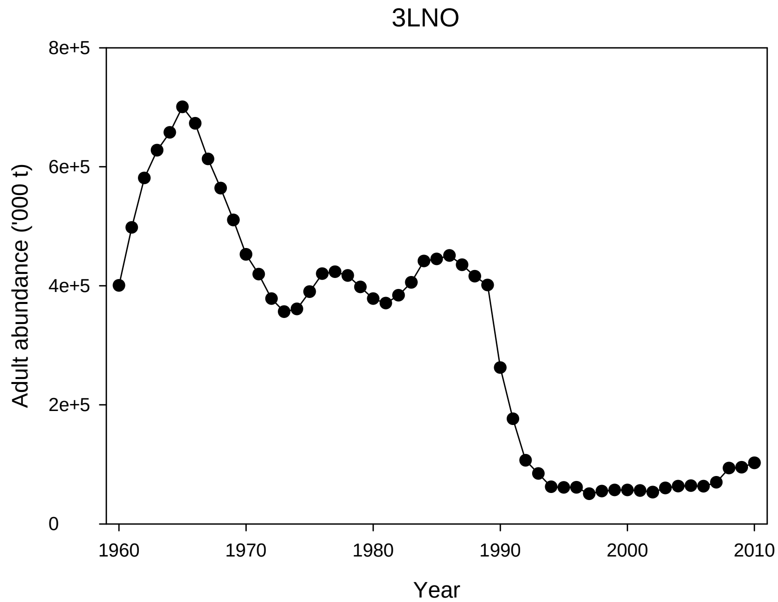

Figure 3. Number of adults in Div. 3LNO from VPA.

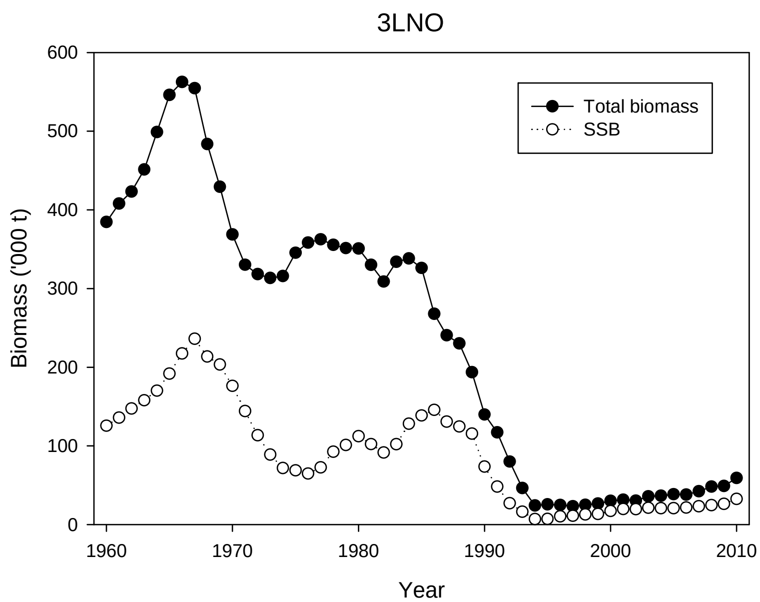

Figure 4. Total and spawning stock (SSB) biomass in Div. 3LNO from VPA.

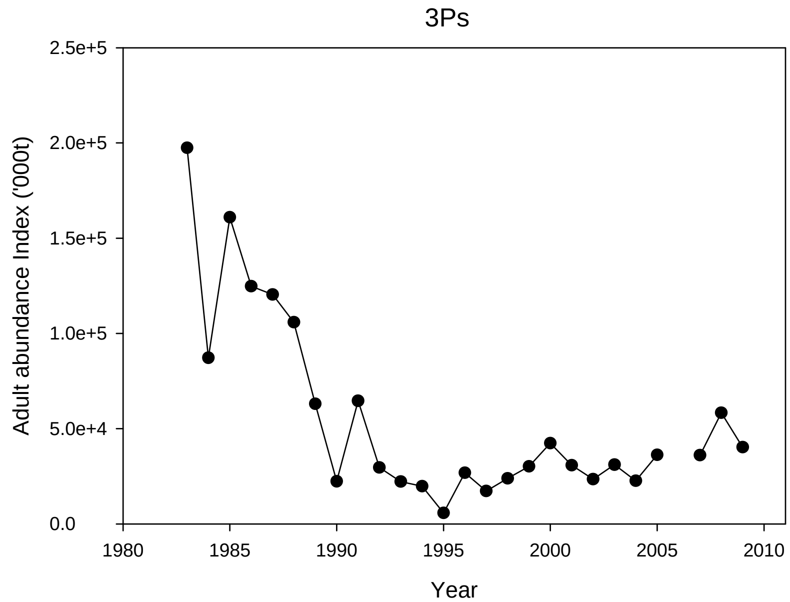

Figure 5. Number of adults in Subdiv. 3Ps from research vessel surveys.

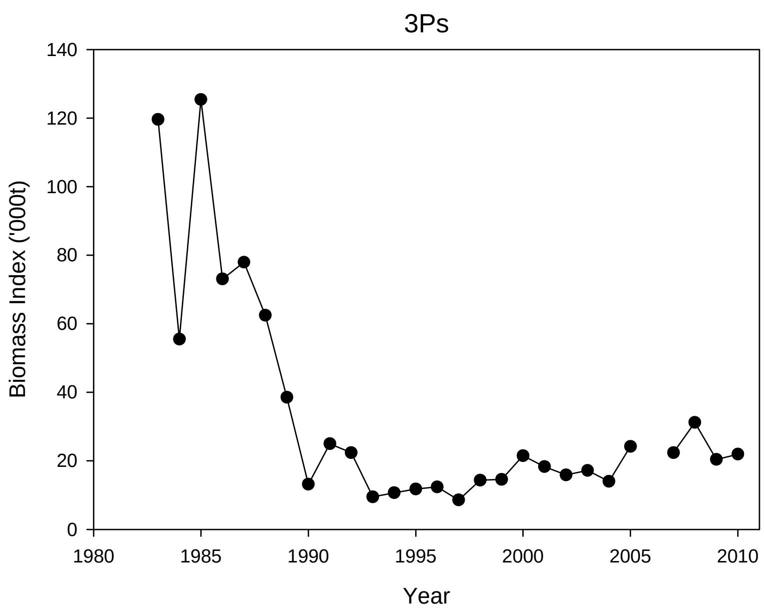

Figure 6. Total biomass index in Subdiv. 3Ps from research vessel surveys.

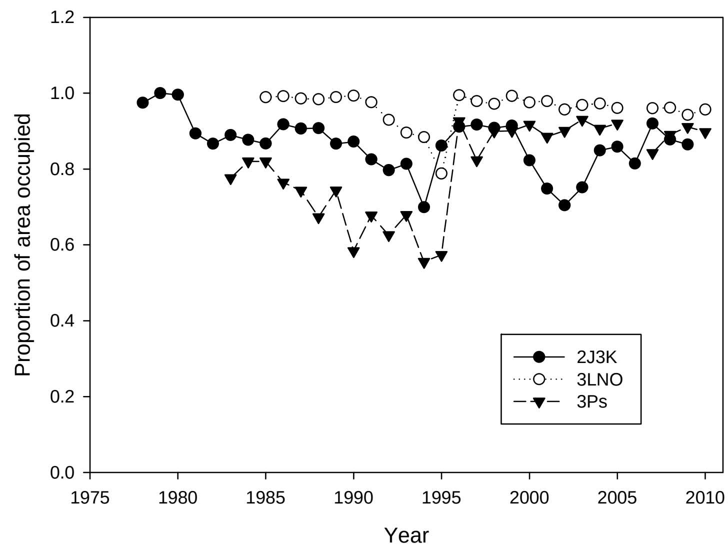

Figure 7. Proportion of survey area occupied by American Plaice in each population.

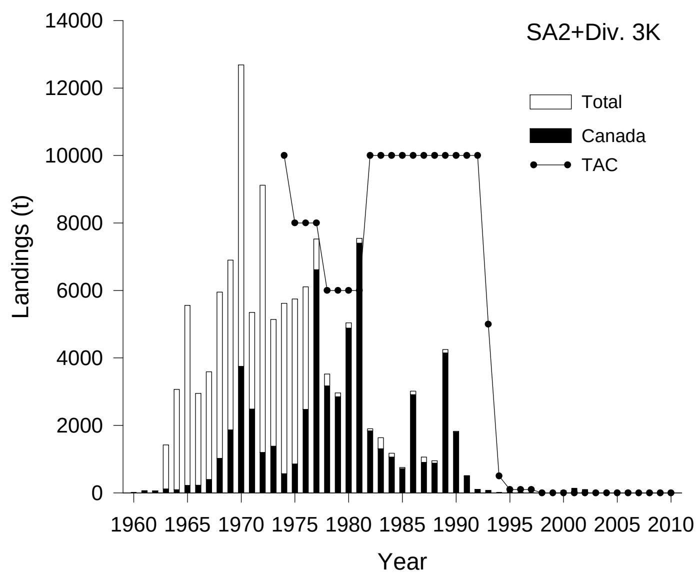

Figure 8. Catch and TAC history for American Plaice in SA 2 + Div. 3K. Catch figures for 2010 are preliminary.

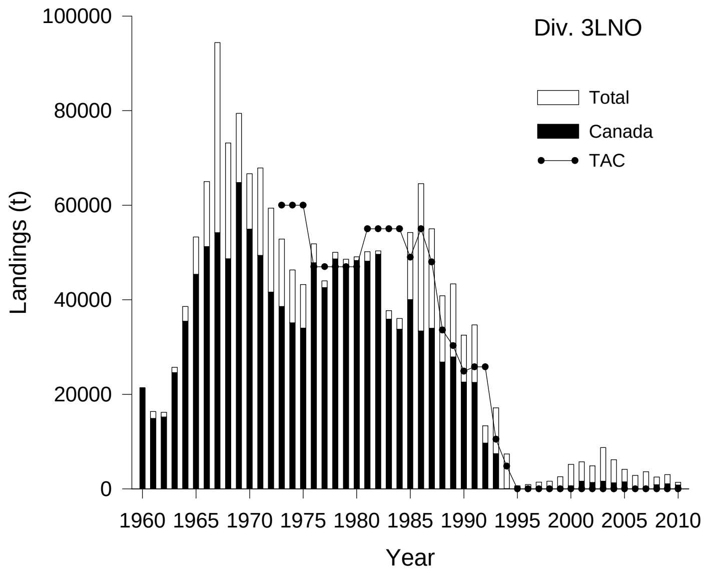

Figure 9. Catch and TAC history for American Plaice in Div. 3LNO. Catch figures for 2010 are preliminary.

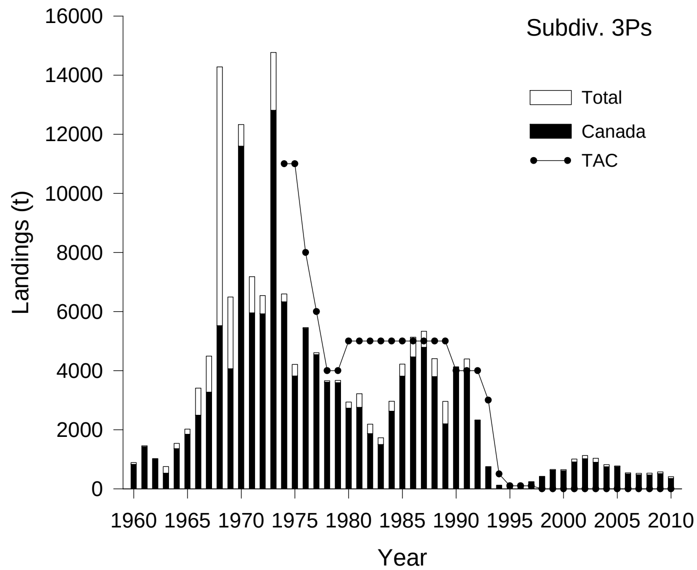

Figure 10. Catch and TAC history for American Plaice in Subdiv 3Ps. Catch figures for 2010 are preliminary.

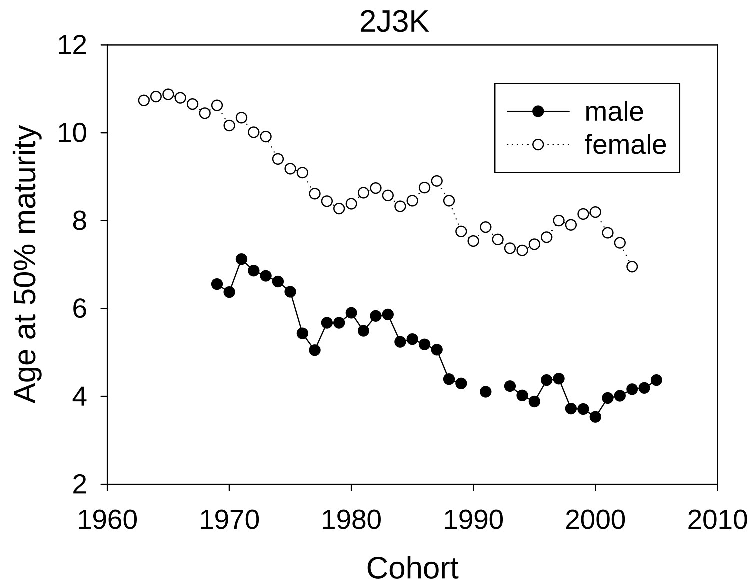

Figure 11. Age at 50% maturity for male and female American Plaice from Div. 2J3K.

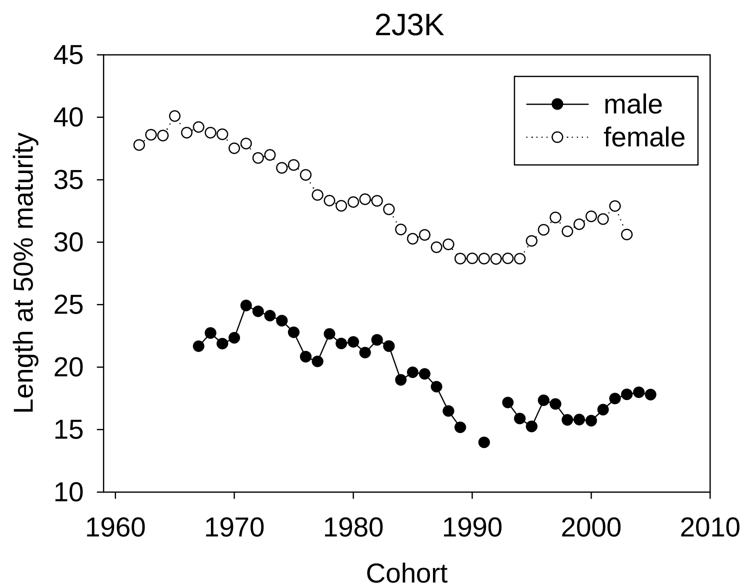

Figure 12. Length at 50% maturity for male and female American Plaice in Div. 2J3K.

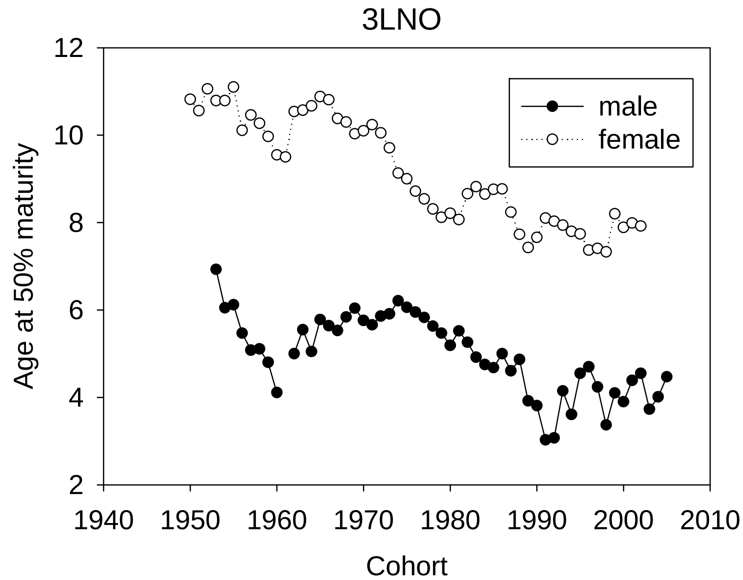

Figure 13. Age at 50% maturity for male and female American Plaice from Div. 3LNO.

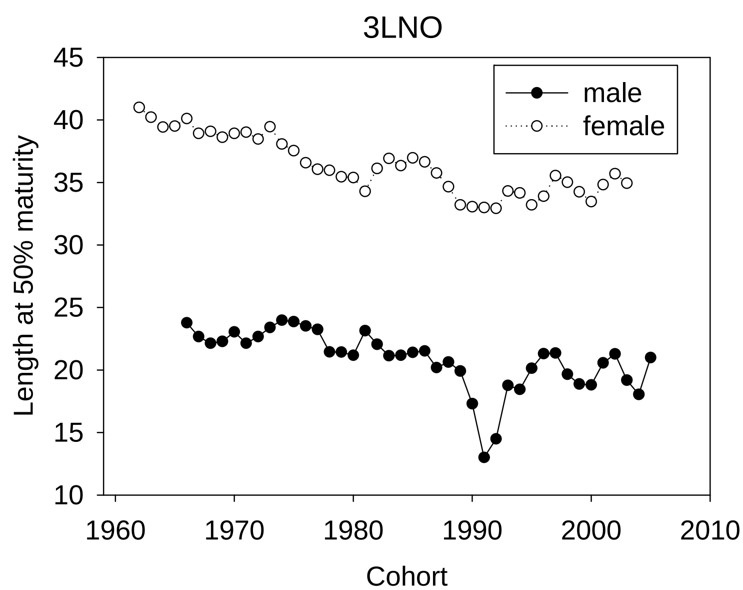

Figure 14. Length at 50% maturity for male and female American Plaice in Div. 3LNO.

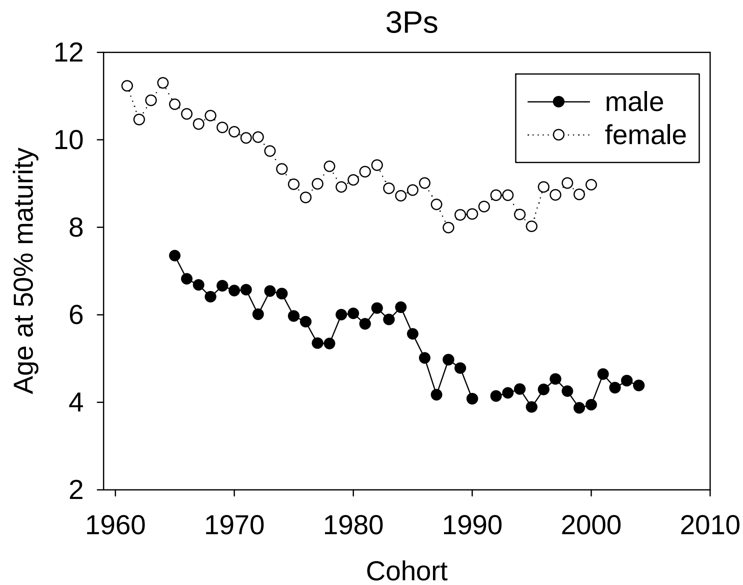

Figure 15. Age at 50% maturity for male and female American Plaice from Subdiv. 3Ps.

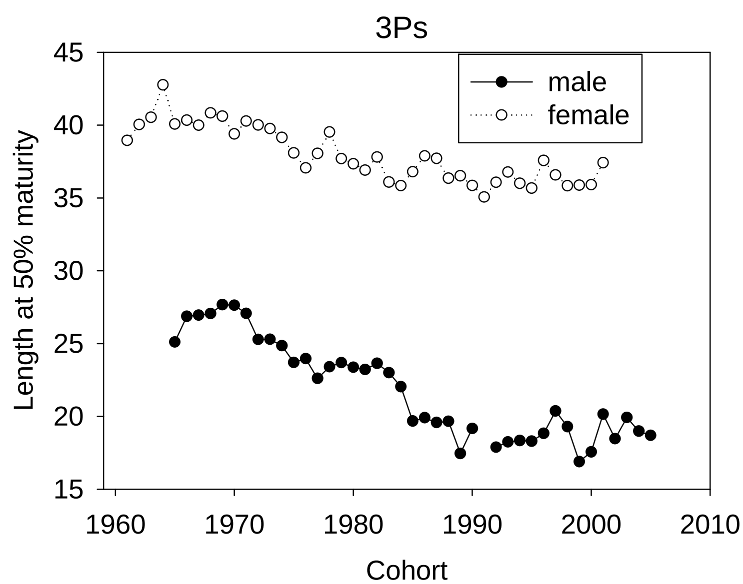

Figure 16. Length at 50% maturity for male and female American Plaice in Subdiv. 3Ps.

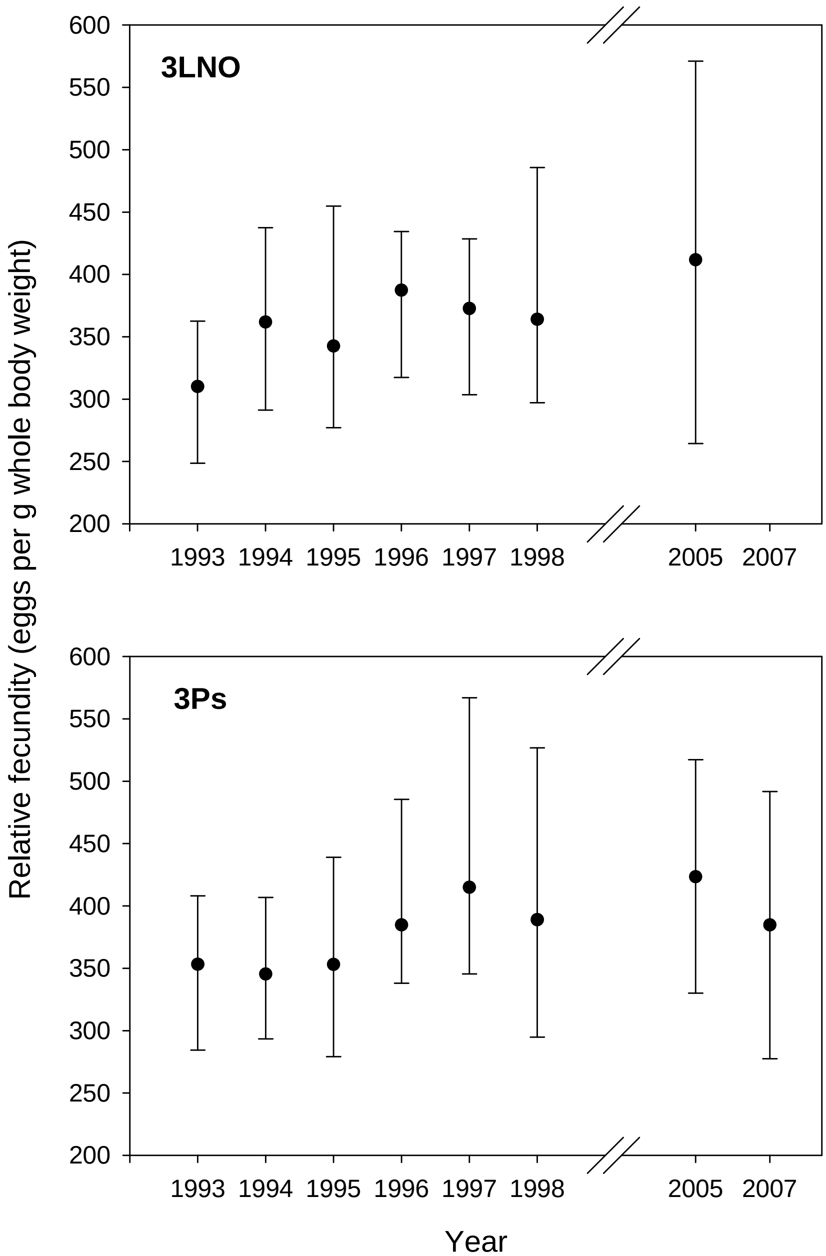

Figure 17. Relative fecundity (number of eggs per gram of whole body weight) for American Plaice in Div. 3LNO and Subdiv. 3Ps.

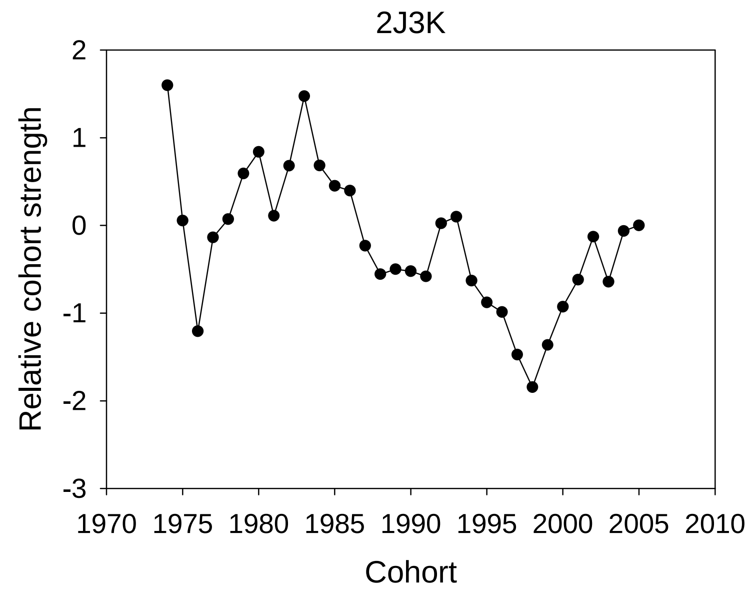

Figure 18. Recruitment as relative cohort strength from research vessel data for American Plaice in Div. 2J3K. Estimates are relative to the 2005 cohort.

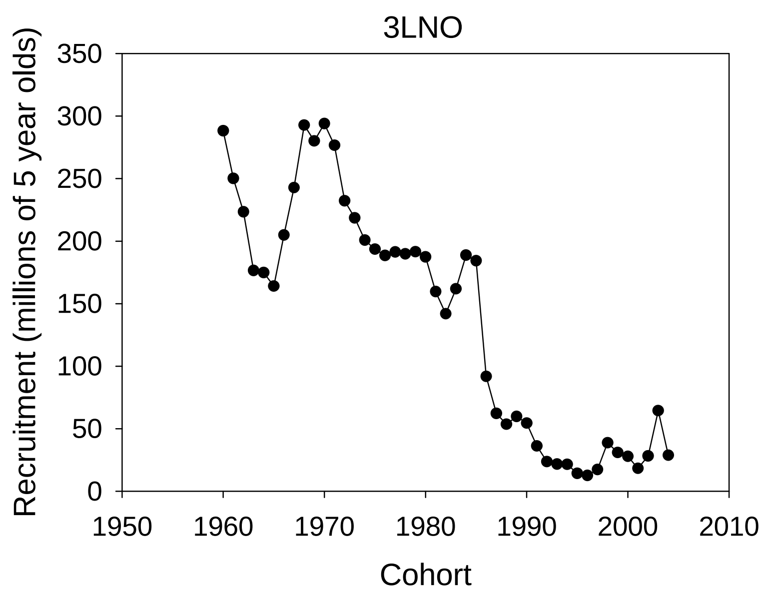

Figure 19. Recruitment (millions of 5 year olds) from VPA for Div. 3LNO American Plaice.

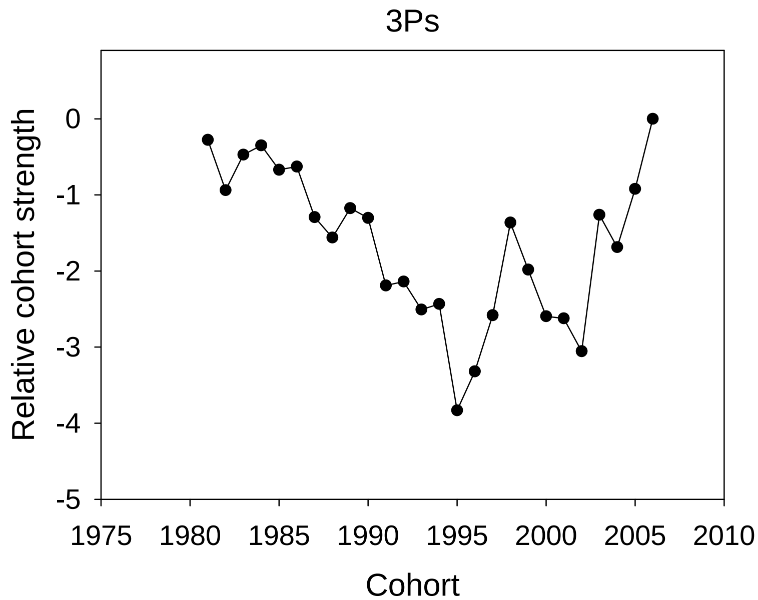

Figure 20. Recruitment as relative cohort strength from research vessel data for American Plaice in Subdiv. 3Ps. Estimates are relative to the 2005 cohort.

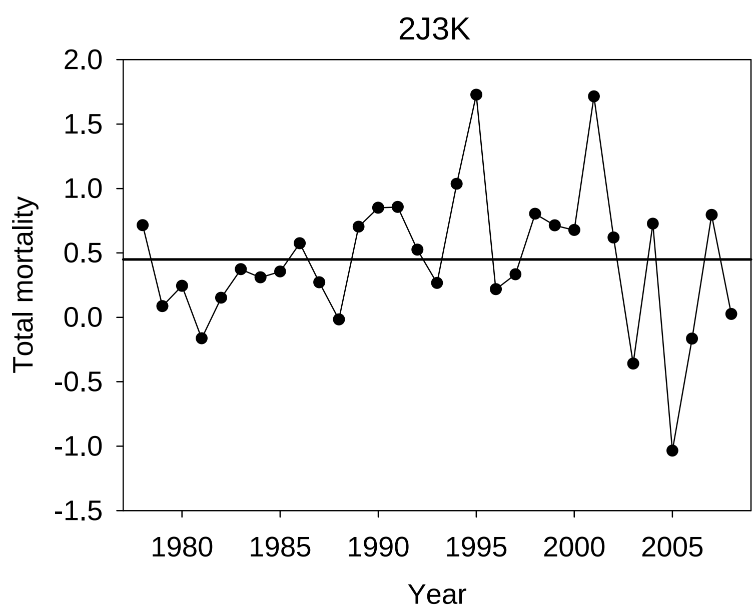

Figure 21. Trends in the annual instantaneous mortality rate (Z) of American Plaice aged 5-7 calculated using data from the research vessel surveys in Div. 2J3K. For example, the value in 1995 is the mortality experienced by the 1988-1990 year-classes from ages 6-8 in 1995 to ages 7-9 in 1996. The horizontal line is the time-series average 0.45.

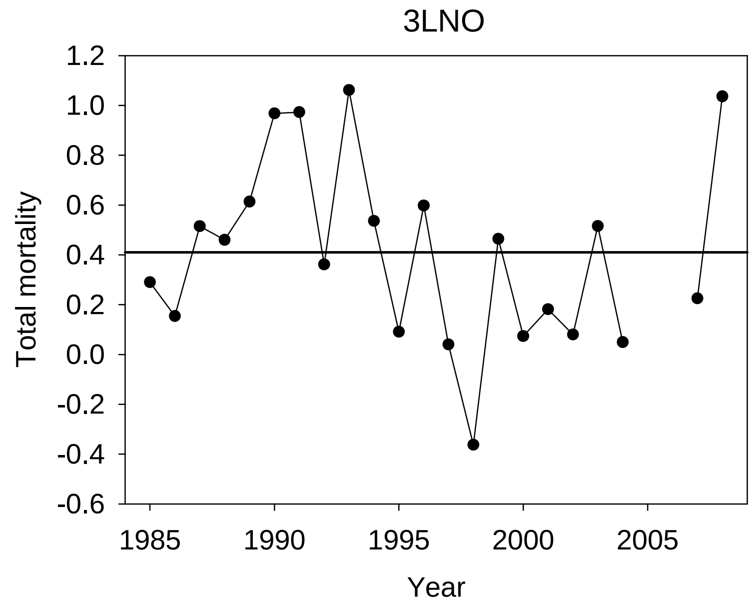

Figure 22. Trends in the annual instantaneous mortality rate (Z) of American Plaice aged 5-7 calculated using data from the research vessel surveys in Div. 3LNO. For example, the value in 1995 is the mortality experienced by the 1988-1990 year-classes from ages 6-8 in 1995 to ages 7-9 in 1996. The horizontal line is the time-series average 0.41.

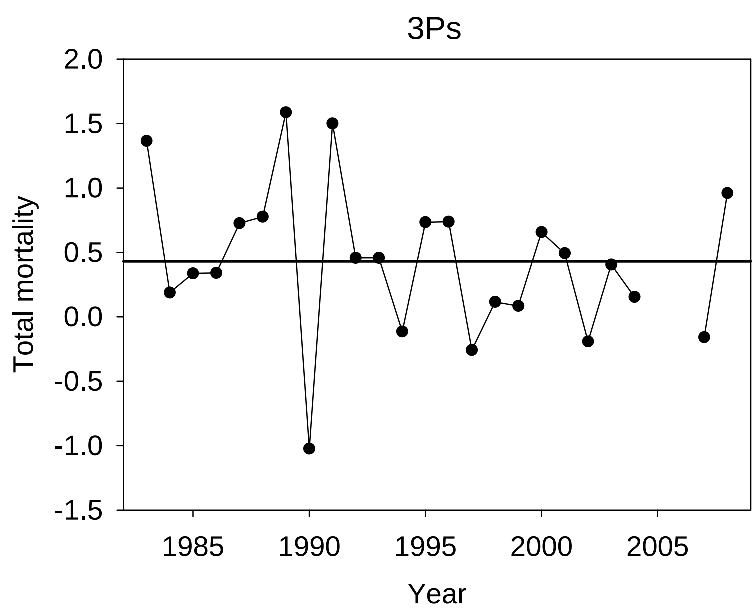

Figure 23. Trends in the annual instantaneous mortality rate (Z) of American Plaice aged 5-7 calculated using data from the research vessel surveys in SubDiv. 3Ps. For example, the value in 1995 is the mortality experienced by the 1988-1990 year-classes from ages 6-8 in 1995 to ages 7-9 in 1996. The horizontal line is the time-series average 0.43.

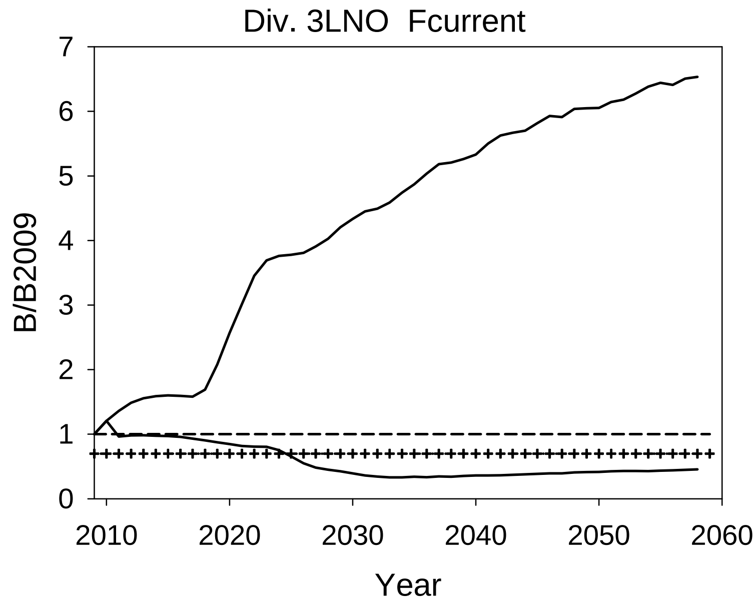

Figure 24. Ratio of biomass to biomass in 2009 over the 48 year projection period for Div. 3LNO American Plaice. Projection is at current levels of F. The solid lines are the 95% confidence intervals. The dotted line is 1:1. The horizontal line of crosses indicates a 30% decrease in biomass relative to 2009.

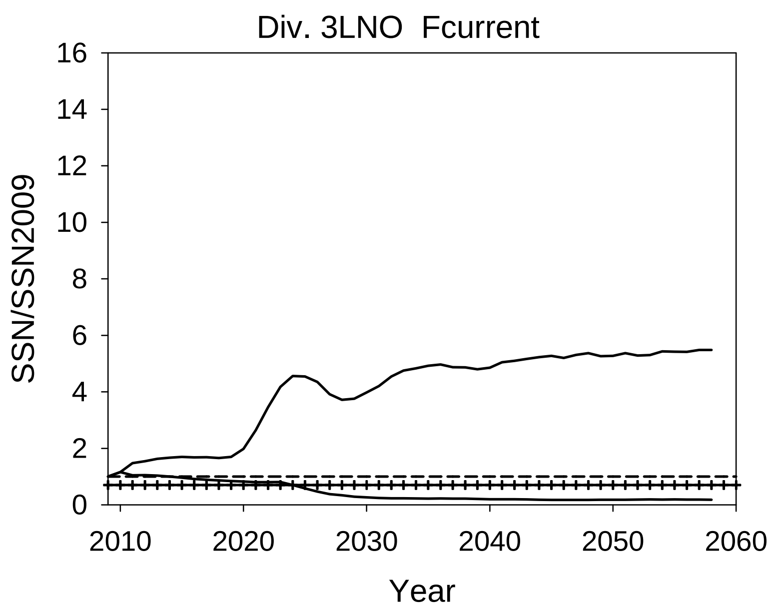

Figure 25. Ratio of spawning stock numbers (SSN) to SSN in 2009 over the 48 year projection period for Div. 3LNO American Plaice. Projection is at current levels of F. The solid lines are the 95% confidence intervals. The dotted line is 1:1. The horizontal line of crosses indicates a 30% decrease in biomass relative to 2009.

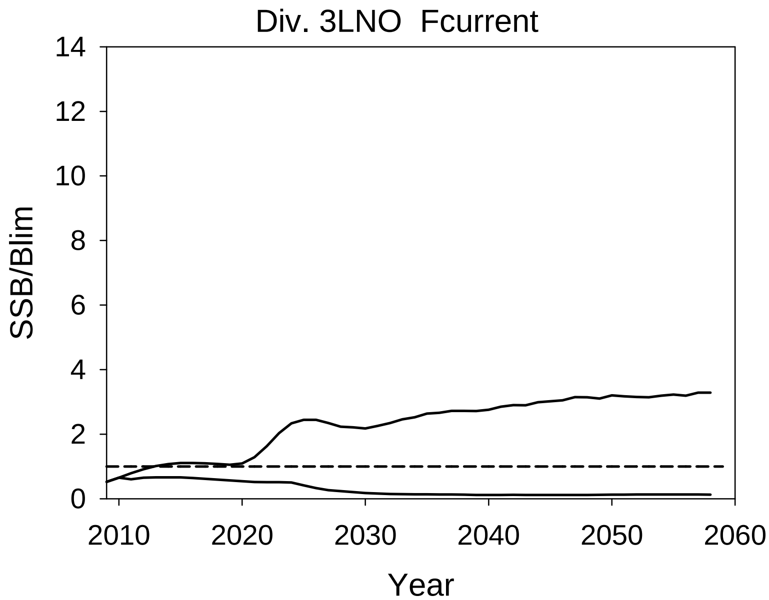

Figure 26. Ratio of SSB to B_{lim} over the 48 year projection period for Div. 3LNO American Plaice. Projection is at current levels of F. The solid lines are the 95% confidence intervals. The dotted line is 1:1.

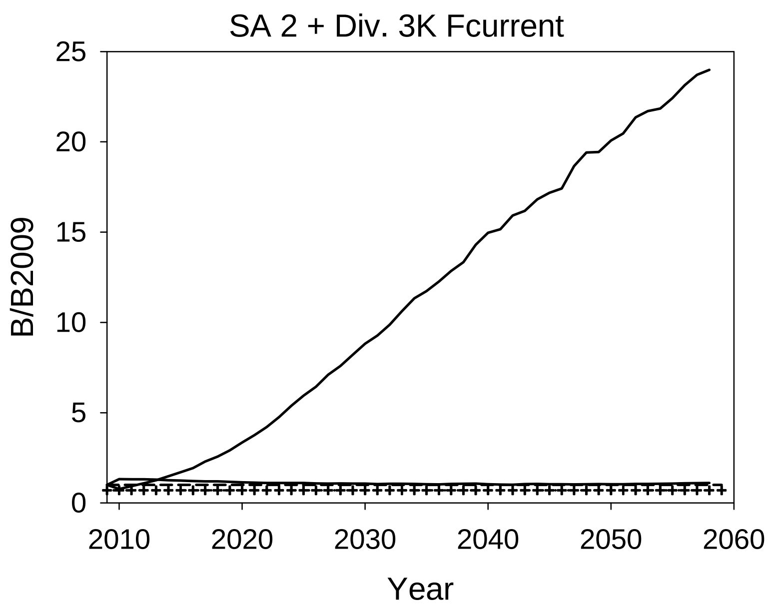

Figure 27. Ratio of biomass to biomass in 2009 over the 48 year projection period for SA2+Div. 3K American Plaice. Projection is at current levels of F. The solid lines are the 95% credible intervals. The dotted line is 1:1. The horizontal line of crosses indicates a 30% decrease in biomass relative to 2009.

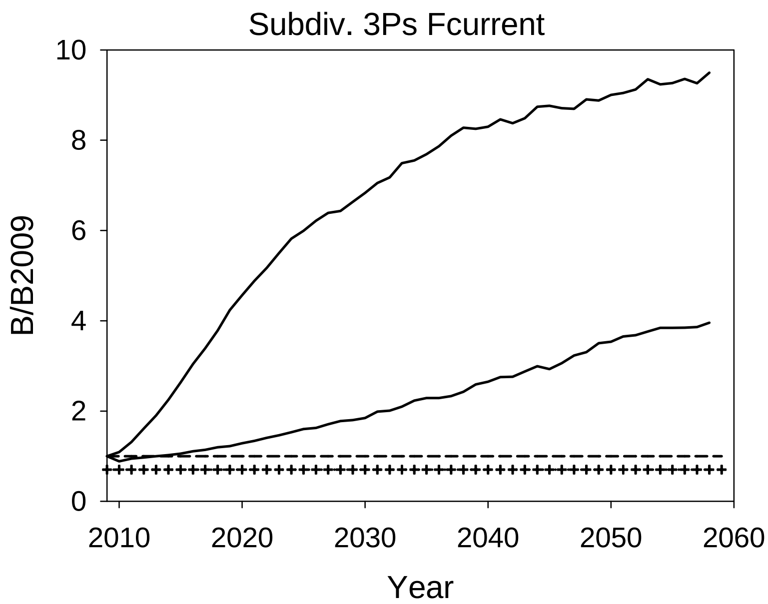

Figure 28. Ratio of biomass to biomass in 2009 over the 48 year projection period for Subdiv. 3Ps American Plaice. Projection is at current levels of F. The solid lines are the 95% credible intervals. The dotted line is 1:1. The horizontal line of crosses indicates a 30% decrease in biomass relative to 2009.

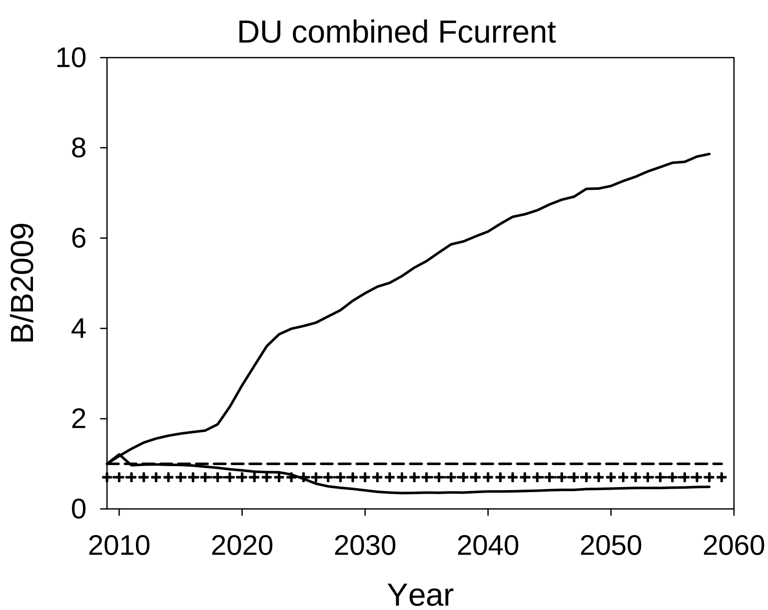

Figure 29. The result of 48 year separate projections of population biomass for each population at current levels of F combined for the entire DU. Results are shown relative to the biomass in 2009. The solid lines give the range of approximately 95% of the results. The dashed horizontal line shows where biomass is equal to biomass in 2009. The horizontal line of crosses indicates a 30% decrease in biomass relative to 2009.

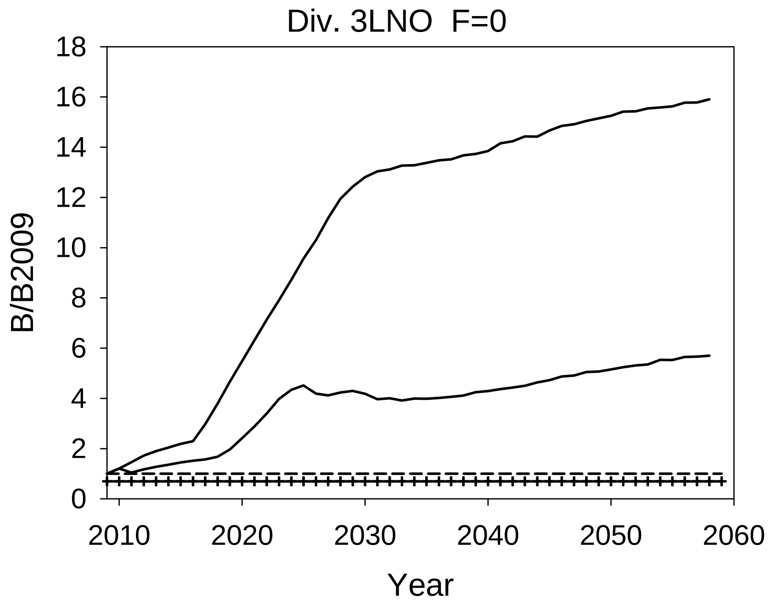

Figure 30. Ratio of biomass to biomass in 2009 over the 48 year projection period for Div. 3LNO American Plaice. Projection is at F=0. The solid lines are the 95% confidence intervals. The dotted line is 1:1. The horizontal line of crosses indicates a 30% decrease in biomass relative to 2009.

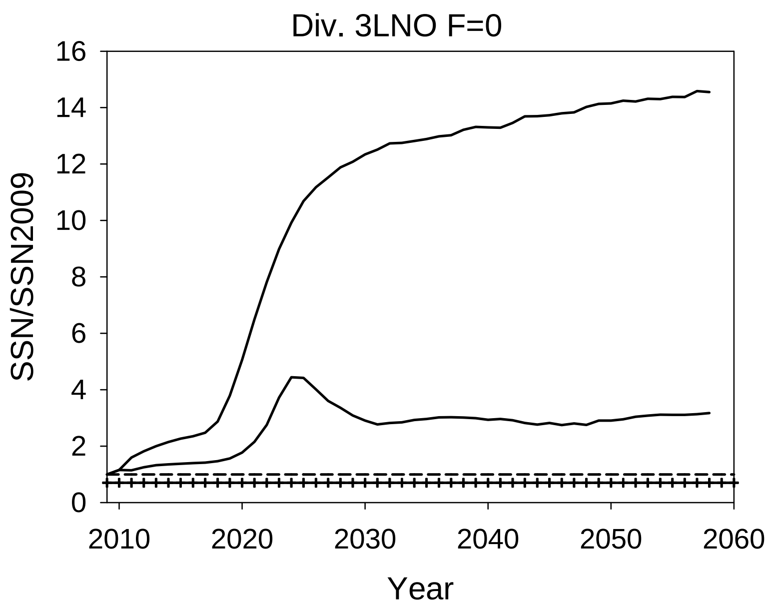

Figure 31. Ratio of spawning stock numbers (SSN) to SSN in 2009 over the 48 year projection period for Div. 3LNO American Plaice. Projection is at F=0. The solid lines are the 95% confidence intervals. The dotted line is 1:1. The horizontal line of crosses indicates a 30% decrease in biomass relative to 2009.

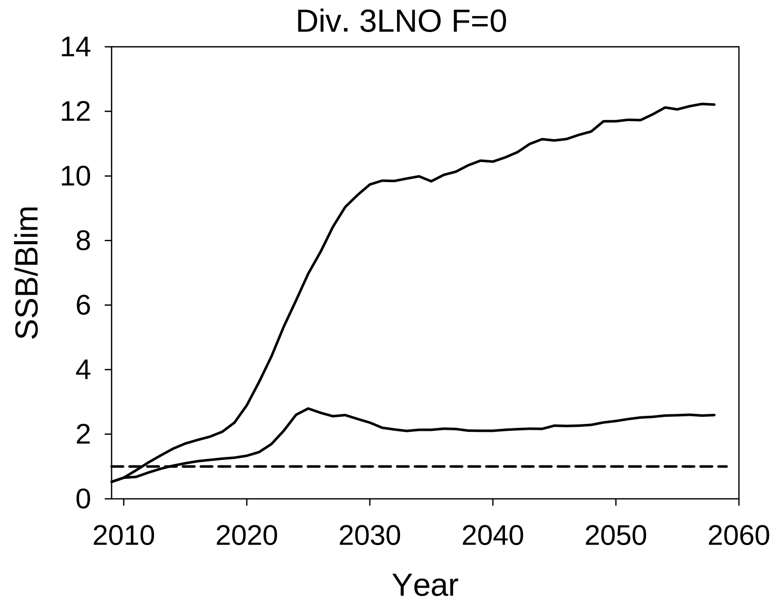

Figure 32. Ratio of SSB to B_{lim} over the 48 year projection period for Div. 3LNO American Plaice. Projection is at F=0. The solid lines are the 95% confidence intervals. The dotted line is 1:1.

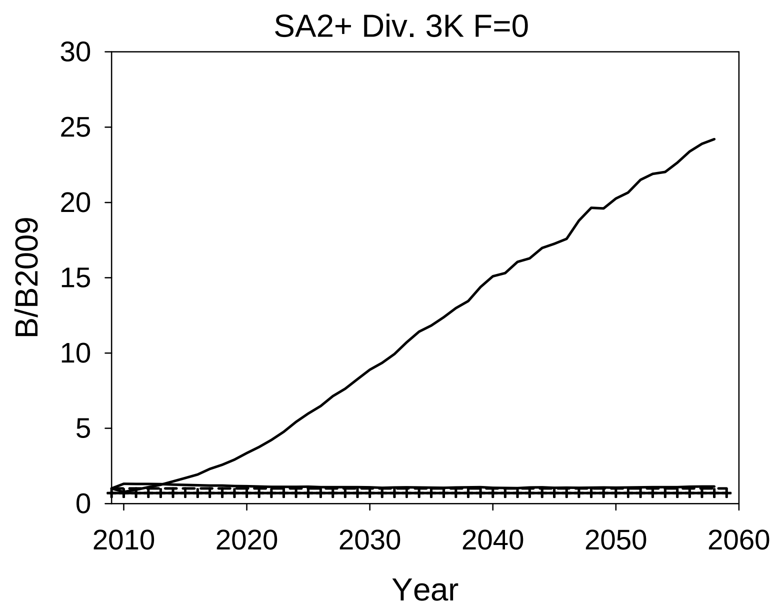

Figure 33. Ratio of biomass to biomass in 2009 over the 48 year projection period for SA2+Div. 3K American Plaice. Projection is F=0. The solid lines are the 95% credible intervals. The dotted line is 1:1. The horizontal line of crosses indicates a 30% decrease in biomass relative to 2009.

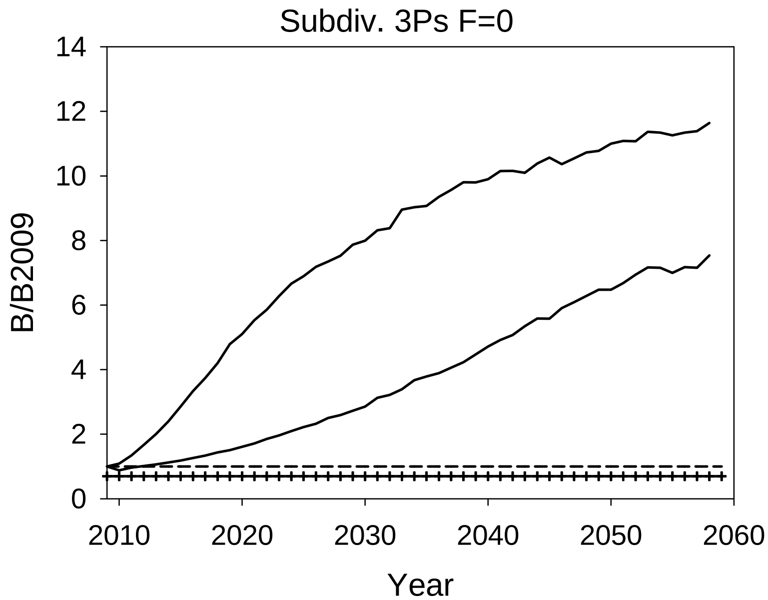

Figure 34. Ratio of biomass to biomass in 2009 over the 48 year projection period for Subdiv. 3Ps American Plaice. Projection is at F=0. The solid lines are the 95% credible intervals. The dotted line is 1:1. The horizontal line of crosses indicates a 30% decrease in biomass relative to 2009.

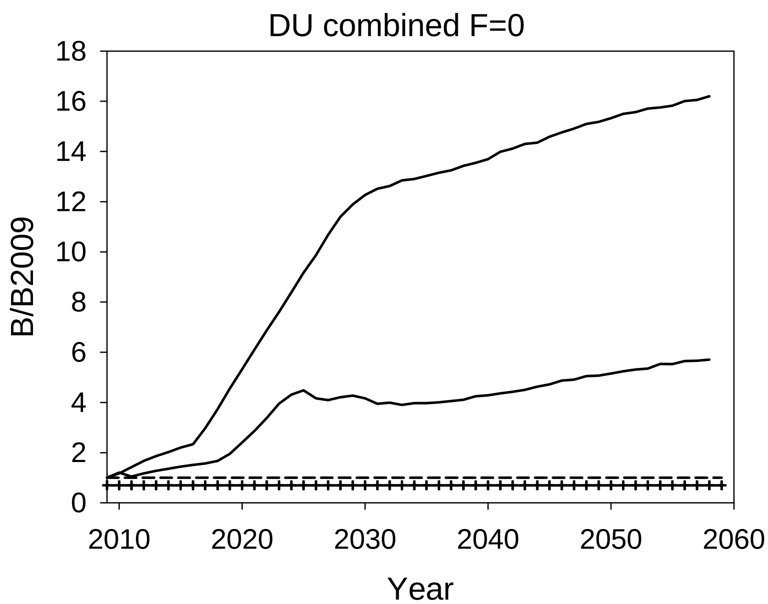

Figure 35. The result of 48 year separate projections of population biomass for each population at F=0 combined for the entire DU. Results are shown relative to the biomass in 2009. The solid lines give the range of approximately 95% of the results. The dashed horizontal line shows where biomass is equal to biomass in 2009. The horizontal line of crosses indicates a 30% decrease in biomass relative to 2009.

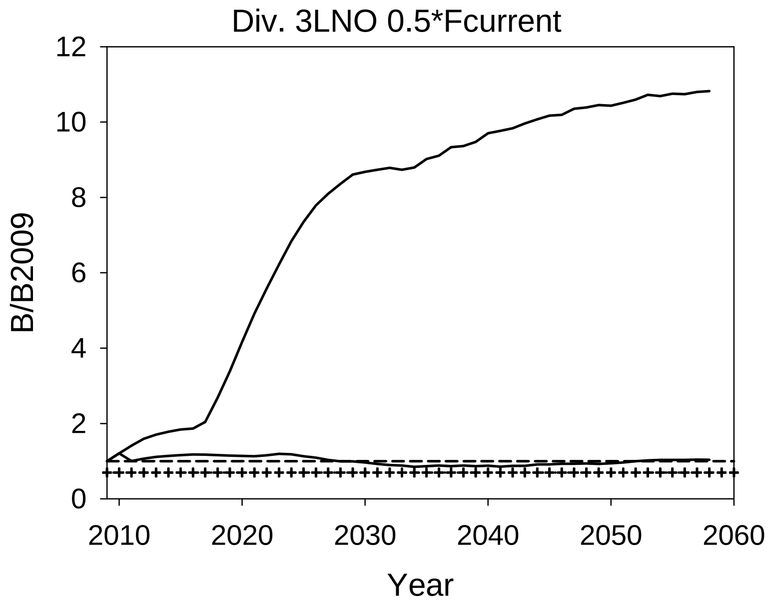

Figure 36. Ratio of biomass to biomass in 2009 over the 48 year projection period for Div. 3LNO American Plaice. Projection is at half current levels of F. The solid lines are the 95% confidence intervals. The dotted line is 1:1. The horizontal line of crosses indicates a 30% decrease in biomass relative to 2009.

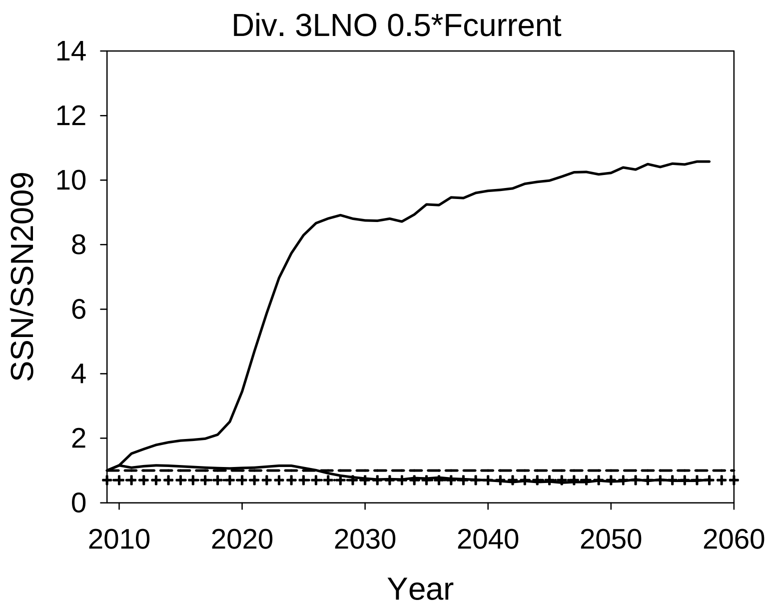

Figure 37. Ratio of spawning stock numbers (SSN) to SSN in 2009 over the 48 year projection period for Div. 3LNO American Plaice. Projection is at half current levels of F. The solid lines are the 95% confidence intervals. The dotted line is 1:1. The horizontal line of crosses indicates a 30% decrease in biomass relative to 2009.

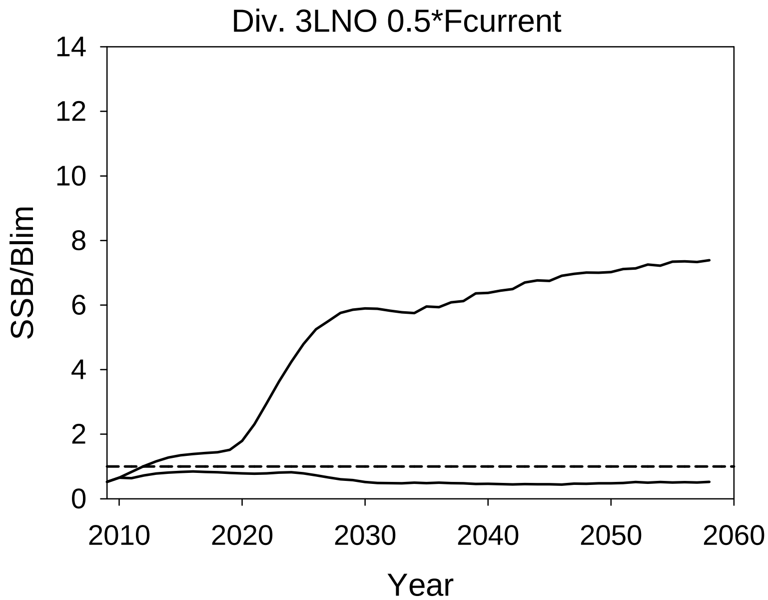

Figure 38. Ratio of SSB to B_{lim} over the 48 year projection period for Div. 3LNO American Plaice. Projection is at half current levels of F. The solid lines are the 95% confidence intervals. The dotted line is 1:1.

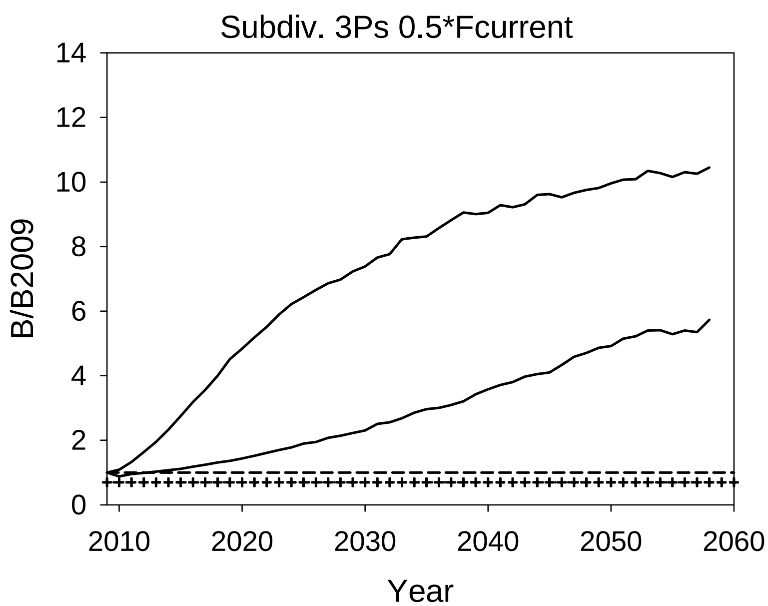

Figure 39. Ratio of biomass to biomass in 2009 over the 48 year projection period for Subdiv. 3Ps American Plaice. Projection is at half current levels of F. The solid lines are the 95% credible intervals. The dotted line is 1:1. The horizontal line of crosses indicates a 30% decrease in biomass relative to 2009.

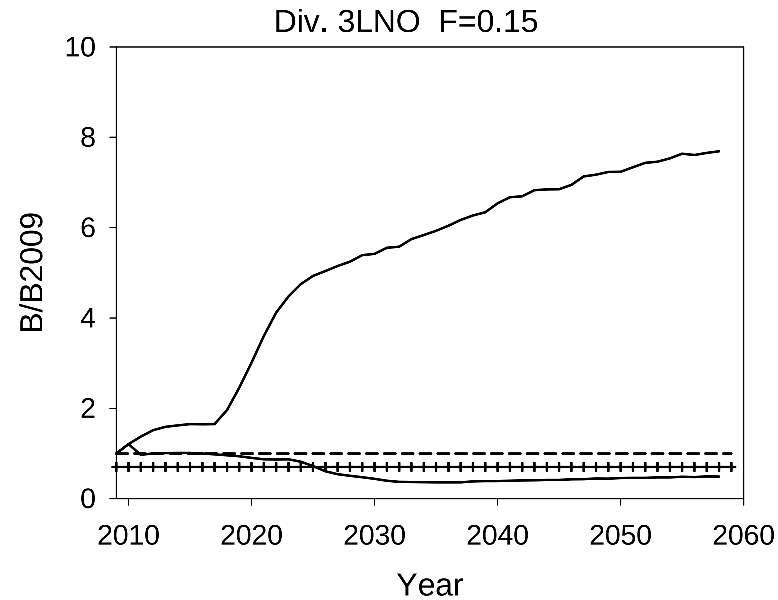

Figure 40. Ratio of biomass to biomass in 2009 over the 48 year projection period for Div. 3LNO American Plaice. Projection is at a level of F that could be considered near the 'maximum allowable harm'. The solid lines are the 95% confidence intervals. The dotted line is 1:1. The horizontal line of crosses indicates a 30% decrease in biomass relative to 2009.

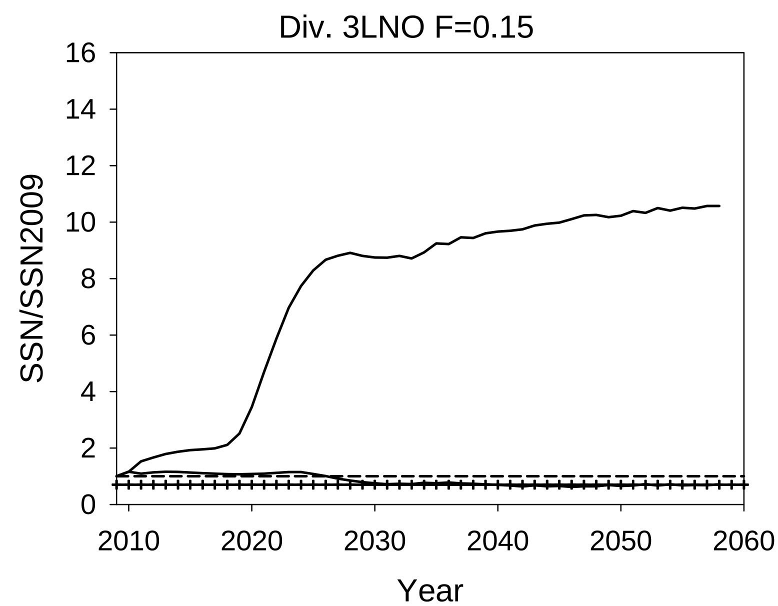

Figure 41. Ratio of spawning stock number (SSN) to SSN in 2009 over the 48 year projection period for Div. 3LNO American Plaice. Projection is at a level of F that could be considered near the 'maximum allowable harm'. The solid lines are the 95% confidence intervals. The dotted line is 1:1. The horizontal line of crosses indicates a 30% decrease in biomass relative to 2009.

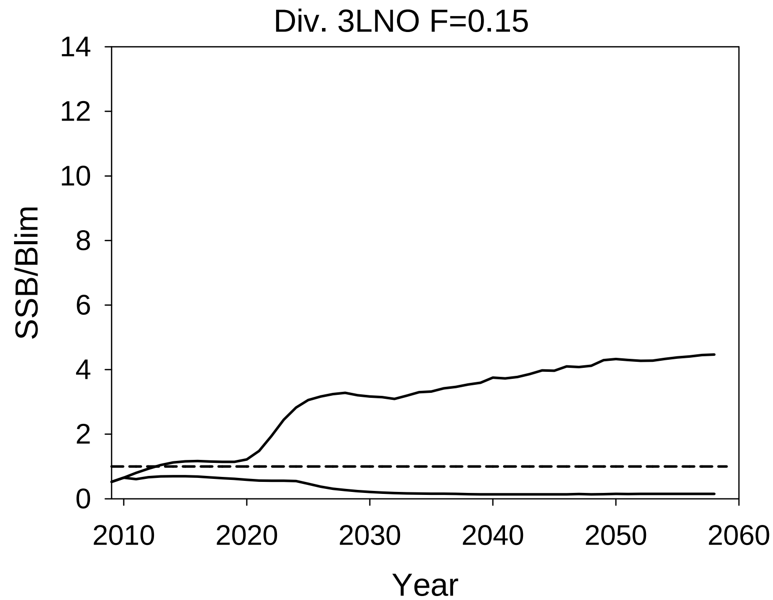

Figure 42. Ratio of SSB to B_{lim} over the 48 year projection period for Div. 3LNO American Plaice. Projection is at a level of F that could be considered near the 'maximum allowable harm'. The solid lines are the 95% confidence intervals. The dotted line is 1:1. The horizontal line of crosses indicates a 30% decrease in biomass relative to 2009.

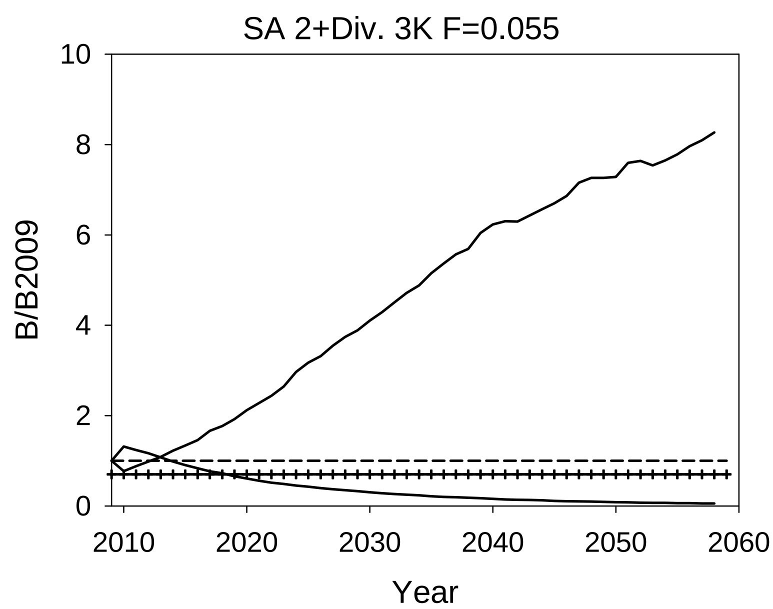

Figure 43. Ratio of biomass to biomass in 2009 over the 48 year projection period for SA2+Div. 3K American Plaice. Projection is at a level of F that could be considered near the 'maximum allowable harm'. The solid lines are the 95% credible intervals. The dotted line is 1:1. The horizontal line of crosses indicates a 30% decrease in biomass relative to 2009.

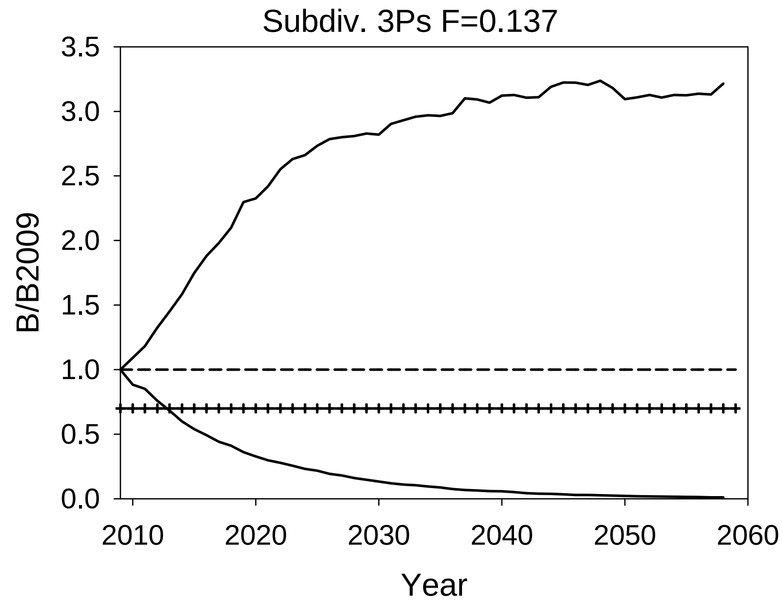

Figure 44. Ratio of biomass to biomass in 2009 over the 48 year projection period for Subdiv. 3Ps American Plaice. Projection is at a level of F that could be considered near the 'maximum allowable harm'. The solid lines are the 95% credible intervals. The dotted line is 1:1. The horizontal line of crosses indicates a 30% decrease in biomass relative to 2009.