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# A biomass limit reference point for NAFO subareas 3 and 4 Atlantic mackerel (*Scomber scrombus*)

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**Foreword**

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## ABSTRACT

Biomass limit reference points were estimated for NAFO subareas 3 and 4 Atlantic mackerel based on a few commons methods that use productivity information from the stock-recruit relationship, the lowest biomass from which there has been a recovery ($B_{recover}$ or $B_{rec}$) and 40%$B_{msy}$. The estimates of these $B_{lim}$ candidates vary between 49,000 t and 156,000 t. The current biomass ($B_{2014}$) is estimated to be about 4000 t thereby placing the stock well into the precautionary approach critical zone at between 2.5% and 8% of $B_{lim}$ (i.e. $B_{2014}/B_{lim}$ is between 0.025 and 0.08). Unreported catch from recreational and bait fisheries are likely lead to underestimates of both $B_{2014}$ and $B_{lim}$ but a more precise estimate of their ratio. We note that declines observed in subareas 3 and 4 mackerel biomass are similar to those of the larger Northwest Atlantic mackerel stock complex and therefore the current relative stock state ($B_{2014}/B_{lim}$) for subareas 3 and 4 mackerel may apply to the entire stock complex.

**Point de référence limite de la biomasse du maquereau bleu (*Scomber scrombus*) des sous-régions 3 et 4 de l'Organisation des pêches de l'Atlantique Nord-Ouest (OPANO)**


## RÉSUMÉ

Les points de référence limites de la biomasse ont été estimés pour le maquereau bleu des sous-régions 3 et 4 de l'OPANO selon quelques méthodes communes utilisant de l'information sur la productivité découlant de la relation stock-recrutement, soit la biomasse la plus faible pour laquelle il y a eu un rétablissement ($B_{rétalissement}$ ou $B_{rec}$) et une $B_{rms}$ de 40 %. Les estimations de ces candidats à la $B_{lim}$ varient entre 49 000 t et 156 000 t. La biomasse actuelle ($B_{2014}$) est estimée à environ 4 000 t, ce qui signifie que le stock est bien dans la zone critique selon l'approche de précaution, soit entre 2,5 % et 8 % de la $B_{lim}$ ($B_{2014}/B_{lim}$ se situe entre 0,025 et 0,08). Les prises non déclarées provenant des pêches récréatives et d'appât sont vraisemblablement à l'origine des sous-estimations de la $B_{2014}$ et de la $B_{lim}$, mais elles permettent une estimation plus précise de leur ratio. Nous notons que des diminutions observées dans la biomasse du maquereau des sous-régions 3 et 4 sont semblables à celles des grands stocks de maquereau de l'Atlantique Nord-Ouest et, par conséquent, l'état relatif du stock actuel ($B_{2014}/B_{lim}$) du maquereau des sous-régions 3 et 4 pourrait s'appliquer à l'ensemble des stocks.

# INTRODUCTION

Western Atlantic mackerel is considered one stock ranging from Cape Hatteras to Southern Labrador. There are two known spawning components in this population, one spawning between Virginia and Rhode Island and the other mainly in the Gulf of St Lawrence however individuals from each spawning component intermingle and overwinter together in the shelf-edge waters off Cape Cod .

The mackerel stock is commercially fished in the USA and Canada which is quota regulated; however, there are large and unaccounted catches in recreational and bait fisheries in Canada. Commercial quotas for 2013 were 36,000 t each for the USA and Canada but only 7,000 t were taken by Canada and just over 5,000 t taken by the USA. Though there is no clear handle on the magnitude of unregulated recreational and bait fishery catches, they may sum to more than the reported commercial fishery catch.

In 2010 a TRAC (Transboundary Resources Assessment Committee) mackerel assessment in Woods Hole, USA showed the entire stock complex had been in severe decline for the preceding 10 years, but no single estimate of median stock biomass was provided and the TAC was defined as status quo (mean of previous three years) (Deroba et al. 2010). The 2012 and 2014 assessments for the Canadian portion (NAFO subareas 3 and 4) of the stock showed a similar decline over the same period and continued decline after 2010 until 2014 when the stock biomass reached its lowest biomass (DFO 2014). Although the assessment model for mackerel may underestimate absolute biomass because of unaccounted-for catches, the trend is likely to be more robust. In addition, other indicators such as the paucity of individuals older than 4 years and poor recent recruitment are classic indicators of a stock which is overfished and is showing recruitment impairment as a result.

The present analysis is an exploration of some potential estimates for a biomass limit reference point for Canadian (NAFO subareas 3 and 4) mackerel. Because the trend in stock biomass is more robust than the absolute value in the assessment, we consider that $B_{2014}/B_{lim}$ may be a useful indicator of present stock status in a precautionary approach framework. Furthermore, we speculate on the stock status of the entire stock complex based on the similarity in trend between the Canadian portion and the whole stock.

# METHODS

We explored three main methods for deriving biomass limit reference points: (1) rule of thumb (RT) points based fitting stock-recruit relationships and determining the biomass giving 50% of the maximum recruitment from these relationships (2) Empirical points based on the lowest biomass from the assessment from which there has been a stock recovery ($B_{rec}$) (3) an RT reference point based on 40% of $B_{msy}$ where $B_{msy}$ is estimated from $F_{msy}$, which in turn is assumed to be F40% as suggested from a yield per recruit analysis (Clark 1993, Mace 1994).

Both the RT stock-recruitment based and $B_{rec}$ limit reference points have been described earlier (Duplisea and Fréchet 2009). 40% $B_{msy}$ as an estimate of $B_{lim}$ comes from the Canadian Precautionary Approach (PA) framework definition for default reference points (DFO 2006).

For Stock-recruitment based RT points we explored estimates from a Beverton-Holt model, Ricker model, Hockey Stick model as credible candidates for RT stock recruitment points.

## RESULTS AND DISCUSSION

The stock-recruit scatter for this stock shows little overall indication of adhering to theoretical recruitment dynamics (Figure 1) and resembles more a scatter. However, closer scrutiny does suggest that recruitment of 1 year olds of more than about $2x10^8$ can appear from a variety of different stock sizes while recruitment points below that level would appear to conform more closely to theoretical stock-recruitment dynamics. We therefore conducted our estimates of reference points using all the data as well as confining it to data where recruitment was < 2.05 x 108 individuals at age 1.

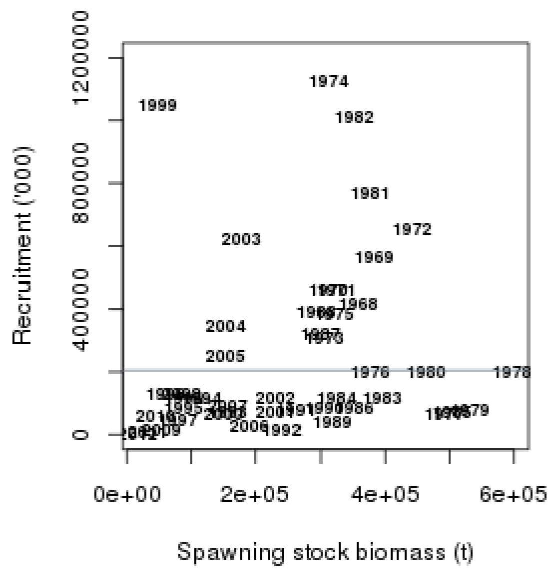


*Figure 1: Recruitment versus spawners biomass for subareas 3 and 4 mackerel. Each point is depicted as the spawning biomass in the year which produced the recruitment one year later. The horizontal line at 205,000 represents the split between what is considered conventional and large recruitments.*

The underlying premise of conducting the analysis in this way is that it allows for the possibility that there are regular underlying stock-recruit dynamics that may conform generally to one of the classic models. The high recruitment points may come from conditions where the environment favoured for good recruitment and therefore represent recruitments where simple supply of larvae from the adult population has less to do with the realized recruitment than at other times. We note, however, that these good recruitments do appear to be more slightly common when the stock size is larger and thus presumably the number of larvae available to take advantage of these favorable environmental conditions.

Stock recruitment rule of thumb reference points were estimated by fitting three different stock-recruit curves (Table 1, Figure 2). The points estimated were calculated as the biomass giving a recruitment of 50% of the maximum from that model fit.

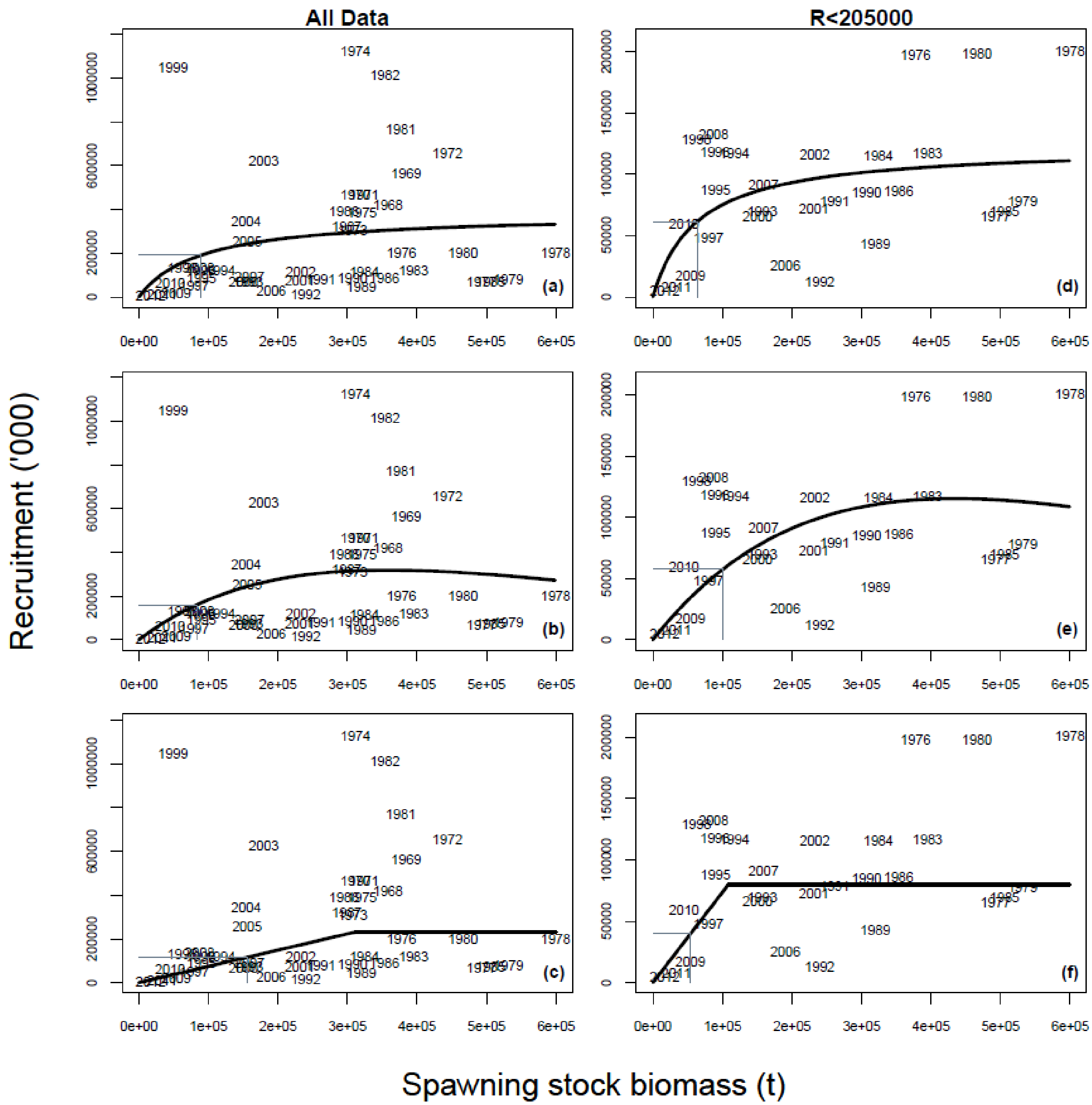


*Figure 2: Stock-recruit based rule of thumb reference points for subareas 3 and 4 mackerel. Estimates are considered candidates for the biomass limit reference points and were calculated as the biomass giving 50% of the maximum recruitment from the fitted model. The left column represents model fits to all the data while the right column shows the model fits to only data where recruitment was less than2.05 x $10^8$. Beverton-Holt fit (a, d), Ricker (b,e), hockey-stick (c, f). For both data sets, the Beverton-Holt asymptotic recruitment parameter fit was not significant. Both parameters were significant for the Ricker model fits.*

The $B_{lim}$ candidates derived from the various models fits in Figure 2 vary between 54,000 t and 156,000 t (Table 1). Despite that when using all data the stock is more productive, these estimated $B_{lim}$ candidates were larger on average. This is a reflection of the fact that good recruitments tend to occur when stock size is larger and therefore stock-recruitment fittings pull the maximum R towards larger stock sizes and hence the $B_{lim}$ estimate. $B_{lim}$ for the subset data are all below 101,000 t (Table 1) and probably better represent recruitments which are more predictably attainable based on stock size and therefore reflect the low end of the long term dynamics of the stock.

We also estimated the $B_{recover}$, or the smallest spawner biomass from which there was a stock recovery (Fig 3). $B_{recover}$ is a commonly used estimate of $B_{lim}$ for two main reasons: (1) it is relatively easy to explain to all stakeholders and is defensible in simple observation without recourse to more difficult arguments based on stock productivity, (2) it represents the exploration limit of safe stock dynamics although there is no guarantee that a stock can always return from that biomass level if external circumstances that affect stock production have changed.

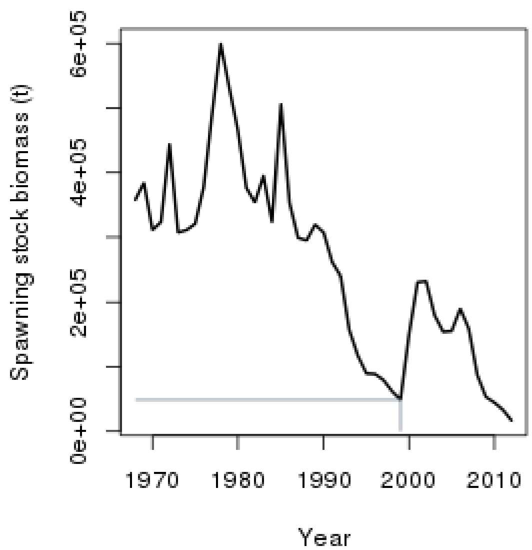


*Figure 3: Spawners biomass for subareas 3 and 4 mackerel from the accepted assessment model for this stock. The lowest biomass from which the stock has previously recovered ($B_{recover}$) was observed in 1999 and was 49,000 t which is depicted as grey lines on the plot.*

We did not calculate $B_{recover}$ for the subset of data as $B_{recover}$ is a “limit of knowledge” reference point and therefore it does not make sense to calculate it for only a limited set of the exploration of stock-recruitment space. We do acknowledge however that $B_{recover}$ which comes from 1999, represents a year where a very large recruitment was produced by only a very small stock size (Figure 1) and therefore this represents a chance event which recovered the stock. We therefore caution that $B_{recover}$ as $B_{lim}$ is not a conservative estimate of a limit reference point.

40% of $B_{msy}$ as a limit reference point proxy was also calculated here. $B_{msy}$ was calculated from $F_{msy}$ from a yield per recruit analysis and therefore does not represent the long term $B_{msy}$ which is what has come to be associated with reference points based on this thinking but we have calculated it to round out the range of methods explored. 40% of $B_{msy}$ was about 70,000 t which is within the estimates of calculated limit reference points.

Estimates for $B_{lim}$ for subareas 3 and 4 mackerel using the various methods explored here ranged from 49,000 t for $B_{recover}$ to 156,000 for the SSB giving 50% of maximum recruitment from the Hockey-Stick model (Table 1).

*Table 1: Estimates of limit reference points for subareas 3 and 4 mackerel. Points are based on the biomass giving 50% of the maximum recruitment from a common stock-recruitment model fit, and $B_{recover}$ which is the lowest biomass from which there has been a recovery. 40% $B_{msy}$ is a default reference point in the Canadian PA framework where $B_{msy}$ was approximated from a yield per recruit analysis where F40% is considered a proxy for $F_{msy}$.*

| Model | All data | R<205000 |
|---|---|---|
| Beverton-Holt | 90,000 | 63,000 |
| Ricker | 83,000 | 101,000 |
| Hockey-stick | 156,000 | 54,000 |
| 40% $B_{msy}$ | 70,000 | |
| $B_{rec}$ (1999) | 49,000 | - |

Given that the current estimated biomass for subareas 3 and 4 mackerel is about 4,000 t (retrospective corrected with Mohn's rho (NFT software)), the stock is estimated to be between 2.5% and 8% of it biomass limit reference point presently. Even if the current estimate is not corrected by average retrospective error, SSB in 2014 was just under 10,000 t. Therefore, regardless of which method is chosen for the $B_{lim}$ estimate or even if one ignored retrospective bias, the stock is well into the critical zone.

## IMPACT OF UNREPORTED CATCH ON STOCK STATUS AND PA-ZONE DESIGNATION

Large underestimates in mackerel catches input to the VPA means that mackerel stock size is likely underestimated presently. However, the trend in the VPA is likely far more robust than the absolute biomass estimate, thus biomass in 2014 would still be the lowest assessed stock size. Catch underestimates are not due to mis-reporting of commercial catch but non-reporting from unregulated fisheries. Therefore, we do not see strong reason to believe there would be a trend in the non-reporting rate. This suggests that the unreported catch impacts on the VPA would be in terms of scaling the trend rather than changing it and relative stock status indicators such a $B_{2014}/B_{lim}$ would be more robust than both $B_{2014}$ and $B_{lim}$ individually.

## APPLICABILITY TO THE ENTIRE NORTHWEST ATLANTIC STOCK COMPLEX

The trend in subareas 3 and 4 mackerel was duplicated in the entire Northwest Atlantic stock complex (Figure 4) while the total biomass is greater as would be expect as subareas 3 and 4 mackerel is constituent of the entire complex. Given that these trends are very similar, we expect that the relative reference points would also scale similarly if we assume that the subareas 3 and 4 proportion of the complex has not changed considerably. Therefore the dimensionless value of $B_{2014}/B_{lim}$ found for subareas 3 and 4 mackerel may be more generally applicable to the entire stock complex.

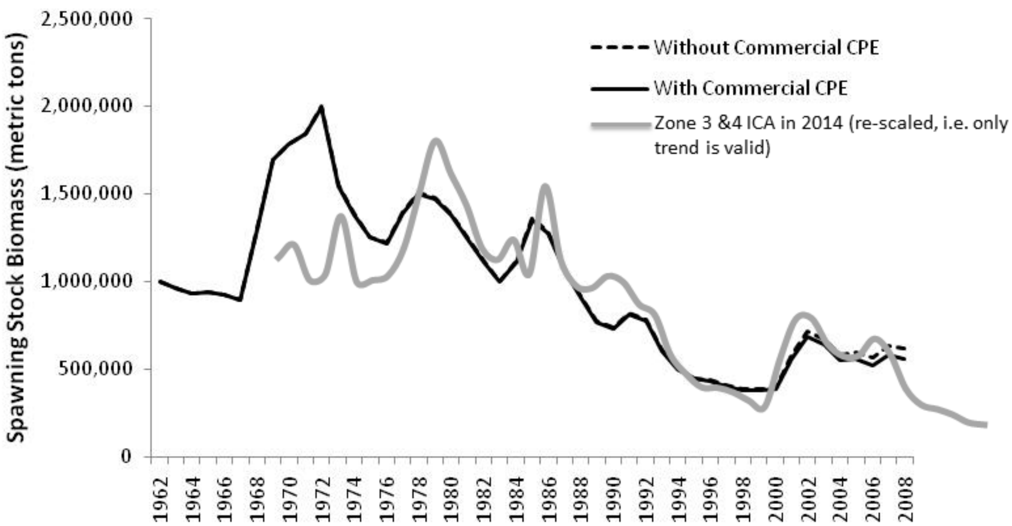


*Figure 4: Trends in Northwest Atlantic Mackerel from a VPA run explored during the 2010 Mackerel assessment with a rescaled (i.e. the absolute biomass values on y-axis do not apply to the grey line) overlay of the subareas 3 and 4 mackerel ICA run from 2014. The 2010 runs considered tuning series that included and excluded commercial indices for VPA tuning.*

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# APPENDIX

*Appendix 1: Data used for biomass limit reference point estimation for NAFO subareas 3 and 4 mackerel. Values are estimates from a sequential population analysis model fitting in 2014 (DFO 2014). The models fitting shows a downward revised retrospective pattern but these data do not reflect a correction for this in the final year. The spawning biomass estimated in 2014 was 9,586 t and if corrected for mean retrospective error it is estimated to be 3,949 t.*

| YEAR | Recruits ('000) | Total Biomass (t) | Spawning | Landings (t) |
|---|---|---|---|---|
| 1968 | 964800 | 500413 | 358090 | 20854 |
| 1969 | 418200 | 505828 | 384457 | 18636 |
| 1970 | 564100 | 415751 | 311145 | 21006 |
| 1971 | 463700 | 423159 | 323580 | 24496 |
| 1972 | 465100 | 553857 | 443653 | 22361 |
| 1973 | 655900 | 421199 | 307247 | 38603 |
| 1974 | 306600 | 398809 | 311116 | 44655 |
| 1975 | 1123800 | 424608 | 320708 | 36262 |
| 1976 | 386600 | 437607 | 377479 | 33065 |
| 1977 | 197600 | 522829 | 492481 | 23275 |
| 1978 | 65200 | 610072 | 599234 | 25899 |
| 1979 | 200500 | 585892 | 531259 | 30612 |
| 1980 | 78000 | 475659 | 465865 | 22297 |
| 1981 | 198100 | 396388 | 376364 | 19355 |
| 1982 | 767900 | 468908 | 353766 | 16383 |
| 1983 | 1011400 | 496678 | 394902 | 19806 |
| 1984 | 116600 | 397547 | 324113 | 18233 |
| 1985 | 115300 | 526038 | 505534 | 30906 |
| 1986 | 69500 | 364475 | 353092 | 31097 |
| 1987 | 85800 | 312569 | 298924 | 27559 |
| 1988 | 320500 | 336577 | 294992 | 25016 |
| 1989 | 390900 | 363120 | 319564 | 21142 |
| 1990 | 42400 | 321340 | 307102 | 23044 |
| 1991 | 84900 | 279740 | 261229 | 26195 |
| 1992 | 78300 | 254832 | 239515 | 26724 |
| 1993 | 12300 | 162215 | 157070 | 26749 |
| 1994 | 69400 | 130614 | 117208 | 20613 |
| 1995 | 116800 | 111422 | 89697 | 17706 |
| 1996 | 87400 | 111281 | 88935 | 20394 |
| 1997 | 117500 | 107829 | 79452 | 21309 |
| 1998 | 47600 | 70808 | 62236 | 19334 |
| 1999 | 128700 | 72402 | 48820 | 16561 |
| 2000 | 1048300 | 270503 | 150163 | 16080 |
| 2001 | 65800 | 250813 | 231085 | 24429 |
| 2002 | 72100 | 241398 | 232503 | 34662 |
| 2003 | 115800 | 198420 | 179567 | 44736 |
| 2004 | 622900 | 271670 | 154244 | 53777 |
| 2005 | 344200 | 234824 | 155456 | 54621 |
| 2006 | 252900 | 238459 | 190175 | 53649 |
| 2007 | 25000 | 167498 | 158847 | 53016 |
| 2008 | 91100 | 101383 | 87108 | 29671 |
| 2009 | 132200 | 82986 | 53472 | 42231 |
| 2010 | 16700 | 58913 | 44546 | 38753 |

| YEAR | Recruits ('000) | Total Biomass (t) | Spawning | Landings (t) |
|---|---|---|---|---|
| 2011 | 59200 | 42195 | 33296 | 11400 |
| 2012 | 7700 | 19358 | 16876 | 6468 |
| 2013 | 4700 | 13435 | 12547 | 7431 |
| 2014 | 77100 | | | |