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Canadian Biomass Reference Points for Eastern Georges Bank (5Zjm) Haddock

Niveaux de référence pour la biomasse canadienne de l'aiglefin de l'est du banc de Georges (5Zjm)

Y. Wang and L. Van Eeckhaute

Fisheries and Oceans Canada / Pêches et Océans Canada
St. Andrews Biological Station / Station biologique de St. Andrews
531 Brandy Cove Road / 531, rue Brandy Cove
St. Andrews
New Brunswick / Nouveau-Brunswick
Canada E5B 2L9

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ABSTRACT

The Terms of Reference for the 2012 Maritimes Region Reference Point Regional Peer Review requested that a Limit Reference Point (LRP) and an estimate of B_{MSY} be developed for Eastern Georges Bank (EGB; unit areas 5Zj and 5Zm) haddock. The methodology for calculating LRP and Spawning Stock Biomass at MSY (SSB_{MSY}) for Eastern Georges Bank haddock were reviewed at the meeting.

Based on the conclusion that EGB haddock has not experienced productivity regime changes during 1931 to 2011, the long-term time series for weights at age and recruit/SSB and population weighted partial recruitment from 1995 (when gear changes were introduced) to 2010 were used for the reference point calculations. SSB_{MSY} was calculated using the Sissenwine-Shepherd production model to be 78,000 mt with a 95% confidence interval of 60,000 mt to 91,000 mt. The LRP, based on $B_{recover}$, was determined to be 10,340 mt with a 95% confidence interval of 10,250 mt to 10,430 mt. These recommendations were accepted at the 2012 Maritimes Region Reference Point Regional Peer Review meeting.

RÉSUMÉ

Dans le cadre de référence de l'examen régional des niveaux de référence par des pairs pour la région des Maritimes de 2012, on a demandé qu'un niveau de référence limite soit établi et qu'une estimation de la B_{rms} soit faite pour l'aiglefin de l'est du banc de Georges (zones unitaires 5Zj et 5Zm). La méthodologie servant au calcul du niveau de référence limite et de la biomasse du stock reproducteur de la PMS (BSR_{pms}) pour l'aiglefin de l'est du banc de Georges a été examinée à la réunion.

Selon la conclusion que l'aiglefin de l'est du banc de Georges n'avait pas connu de changements dans le régime de productivité entre 1931 et 2011, la série chronologique à long terme pour les poids selon l'âge et les recrues/la BSR ainsi que le recrutement partiel pondéré selon la population entre 1995 (lorsque des changements aux engins ont été apportés) et 2010 a été utilisée aux fins du calcul des niveaux de référence. La BSR_{pms} qui était de 78 000 tonnes métriques a été calculée en utilisant le modèle de production de Sissenwine-Shepherd avec un intervalle de confiance de 95 % (entre 60 000 et 91 000 tonnes métriques). Le niveau de référence limite, basé sur le $B_{rétablissement}$, était de 10 340 tonnes métriques avec un intervalle de confiance de 95 % (entre 10 250 et 10 430 tonnes métriques). Ces recommandations ont été acceptées à la réunion d'examen régional des niveaux de référence par les pairs pour la région des Maritimes de 2012.

BACKGROUND

The Terms of Reference for the 2012 Maritimes Region Reference Point Regional Peer Review request that a Limit Reference Point (LRP) and an estimate of B_{MSY} be developed for Eastern Georges Bank (EGB; unit areas 5Zj and 5Zm) haddock. The estimate of B_{MSY} may be used subsequently by the Gulf of Maine Advisory Committee (GOMAC) for other requirements.

As a transboundary species, the Canadian Department of Fisheries and Oceans (DFO) and the USA National Marine Fisheries Service (NMFS) have assessed haddock on the eastern portion of Georges Bank jointly under the Transboundary Resources Assessment Committee (TRAC) peer review process since 1998. In 2003, the Transboundary Management Guidance Committee (TMGC), which provides joint management advice for this stock to Canadian and USA management authorities, adopted a harvest strategy to maintain a low to neutral risk of exceeding the F_{ref}=0.26. It also specifies that when stock conditions are poor, fishing mortality rates should be further reduced to promote rebuilding. Because of the transboundary nature of this stock, the removal reference was not addressed in the 2012 Maritimes Region Reference Point Regional Peer Review. A Limit Reference Point has not been developed by TRAC or requested by TMGC.

The haddock on Georges Bank have supported a commercial fishery since the early 1920s (Clark *et al*. 1982). Catches from EGB during the 1930s to 1950s were relatively stable and generally ranged between 20,000 mt and 40,000 mt (Figure 1; Schuck 1951). Record high landings of approximately 60,000 mt were reported from EGB during the early 1960s. Prior to mid-1990s, EGB haddock had been over-fished for decades. A calibrated Virtual Population Analysis (VPA) for 1969-2011 was available from the 2011 assessment (Van Eeckhaute and Brooks 2011). Only an approximate age composition of the catch from EGB for 1931-1955 could be obtained but it was considered suitable for an illustrative VPA. The stock had experienced long-term declines in spawning biomass and recruitment. Improved recruitment in the late 1990s and the strong 2000 year class, lower exploitation, and reduced capture of small fish in the fisheries allowed the biomass to increase from near a historical low of 10,300 mt in 1993 to 82,600 mt in 2003 (Figure 1). The increase of the biomass after 2005 was due to the exceptional 2003 year class. The preliminary estimate for the 2010 year class is outstanding, which would make it is the largest in the assessment time series: 1931-1955 and 1969-2010.

PRODUCTIVITY REGIME CHANGES

The primary processes that comprise the production response are growth, age at maturity, natural mortality and recruitment. As this may be used to evaluate harvest strategies, the fisheries exploitation pattern or Partial Recruitment (PR) by age is also a factor.

There is no evidence for this stock of natural mortality and age at maturity changes. The relationship between length at age and year class strength has shown density dependent effects on fish growth. With management regulations intended to reduce the catch of younger fish after 1994 and with fish size changes since the early 2000s, the fishery fully recruited age shifted from age 3 in 1969-1994 to age 4 in 1995-2002, and age 5 in 2003-2010. If recent changes in size at age are assumed to be a density dependent effect, then these effects are transient, meaning that the stock may return to earlier conditions and no productivity regime change is considered to have occurred.

Examination of the SSB (age 3+) and recruitment relationship shows that recruitment has been highly variable. There is no evidence of a change in recruitment productivity based on different levels of productivity at the same biomass for two different time periods (Figure 2). Comparison of surplus production ($Biomass_{t+1}$-$Biomass_t$+$Catch_t$) during 1931-1955 to recent years also exhibits no productivity regime changes (Figure 2). Therefore, data from the long time period (1931-present) is more appropriate for calculating reference points. The population weighted PR from 1995 to 2010 was used to take into account changes in fishing gear.

B_{MSY}

Parametric methods of deriving B_{MSY} can be classified as age-aggregated surplus production models and age-disaggregated production models. The assessment is conducted using an age structured VPA. For consistency, the age-disaggregated Sissenwine-Shepherd production model (Sissenwine and Shepherd 1987) is used for derivation of Spawning Stock Biomass at MSY (SSB_{MSY}) instead of B_{MSY} for EGB haddock. SSB_{MSY} is determined by using a stock-recruitment curve to derive equilibrium levels of catch and SSB for a range of fishing mortality rates. The average PR for 1995-2010, average fishery weight at age for 1931-2010 and spawning stock weight at age from the DFO spring survey from 1986-2011 are used for the yield and spawner per recruit analysis. The extremely large 2003 and 2010 year classes are excluded as outliers from the analysis. For the SSB and recruitment relationship analysis, the traditional parametric Beverton-Holt (BH) and Ricker (RK) stock-recruit models were fit to recruitment and SSB. Both models fit the data poorly, with strong time-series patterns in the residuals (Figure 3). A non-parametric Lowess smoother (Cleveland 1979) was applied (Figure 3) and used to calculate SSB_{MSY}. A non-parametric bootstrapping approach results in a bias-adjusted SSB_{MSY} of 78,000 mt with a 95% confidence interval of 60,000 mt to 91,000 mt (Efron and Tibshirani 1993; Figure 4).

LIMIT REFERENCE POINTS

At the *2002 National Workshop for Reference Points for Gadoids* (DFO 2002), five computational methods were retained for defining Limit Reference Points in terms of Spawning Stock Biomass. These five methods were (DFO 2002, p. 10):

1. $B_{recover}$: the lowest historical biomass level from which the stock has recovered readily.

2. $Sb_{50/90}$: the SSB corresponding to the intersection of the 50th percentile of the recruitment observations and the replacement line for which 10% of the Stock-Recruitment (S-R) points are above the line.

3. BH_{50}: the SSB at which expected average recruitment is one half of the maximum recruitment predicted by assuming an underlying Beverton-Holt stock-recruit relationship (i.e. the recruitment that is 50% of the value at the asymptote).

4. RK_{50}: the lower SSB at which expected average recruitment is one half of the maximum recruitment predicted by assuming an underlying Ricker-type stock-recruit relationship (i.e. the recruitment that is 50% of the value at the peak of the dome).

5. NP_{50}: the estimate of the lowest SSB where the expected median recruitment is one half of the maximum recruitment calculated by non-parametric analysis (i.e. the recruitment that is 50% of the largest median recruitment achievable at any SSB within the range of historic observations).

At the workshop, it was felt that a comparison amongst the five B_{lim} candidates provided insight into the certainty of advice. If the results were clustered into one region, some level of confidence might be attributed to the result. These methods were applied to EGB haddock.

For EGB haddock, BH_{50} and RK_{50} were not considered due to the unreasonable fit of Ricker and Beverton-Holt stock-recruit models (Figure 3). At the *National Meeting on Precautionary Approach in Fisheries Management* (DFO 2004), it was pointed out that NP_{50} looked promising as an estimator of the Healthy/Cautious boundary for stocks having two stock/recruit clouds like EGB haddock (Figure 2), but not for the LRP boundary. $Sb_{50/90}$ was calculated as 11,000 mt for this stock (Figure 5). EGB haddock experienced a secure recovery from a low biomass of 10,340 mt in 1993 ($B_{recover}$, Figure 5). The 95% confidence interval for $B_{recover}$ is 10,250 mt to 10,430 mt, which is derived from the 2011 VPA assessment result using conditional non-parametric bootstrapping of model residuals **(**Efron and Tibshirani 1993).

A $B_{recover}$ of 10,340 mt is recommended as the LRP for EGB haddock. The LRP is defined as the biomass level below which serious harm is occurring and secure recovery cannot be achieved. From the biomass history, EGB haddock has been exposed to full exploitation over an extended time series and has recovered twice from low stock levels, in 1974 and in 1993 (Figure 5). Under the assumption of no productivity regime changes, $B_{recover}$ reflects the stock biomass dynamics and its resilience under different fishing pressure. The $Sb_{50/90}$, which is very close to this value, provided insight into the reliability of this metric.

CONCLUSION

Based on the conclusion that EGB haddock has not experienced productivity regime changes between 1931 and 2011, the long-term time series for weights at age and recruit/SSB and population weighted PR from 1995 to 2010 (due to gear changes) were used for the reference point calculations. Spawning Stock Biomass at MSY (SSB_{MSY}) was calculated using the Sissenwine-Shepherd production model to be 78,000 mt with a 95% confidence interval of 60,000 mt to 91,000 mt. The LRP based on $B_{recover}$ was determined to be 10,340 mt with a 95% confidence interval of 10,250 mt to 10,430 mt. These recommendations were accepted at the 2012 Maritimes Region Reference Point Regional Peer Review meeting.

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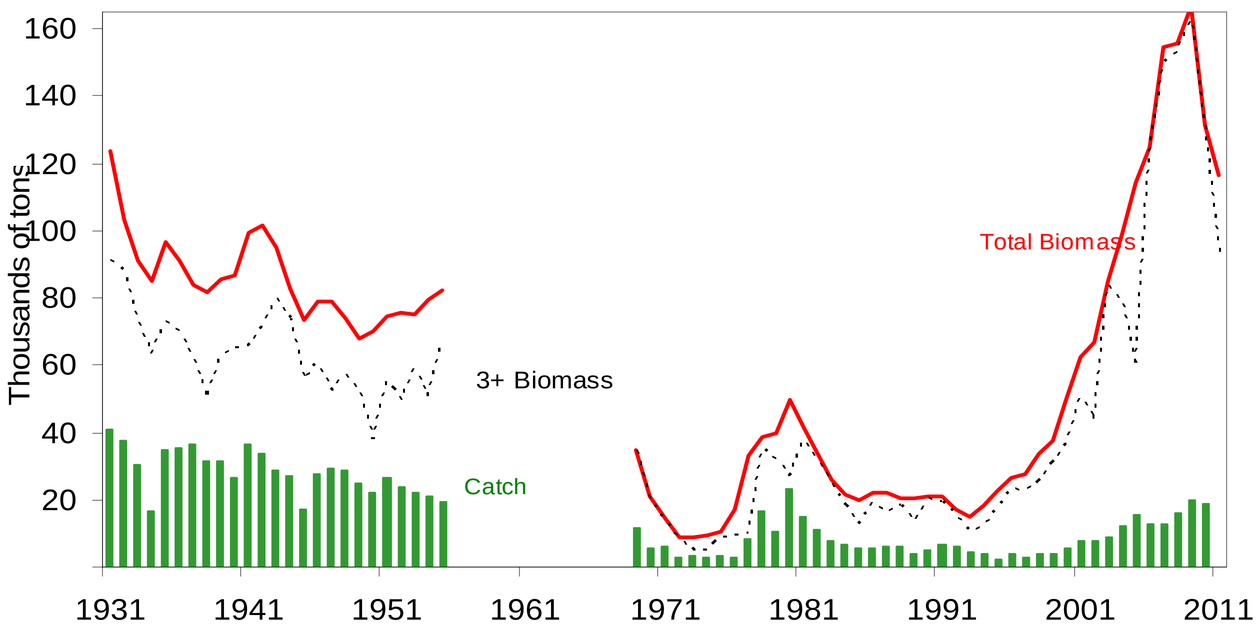

Figure 1. 3+ biomass and total catches of Eastern Georges Bank (EGB) haddock for 1931 to 2011.

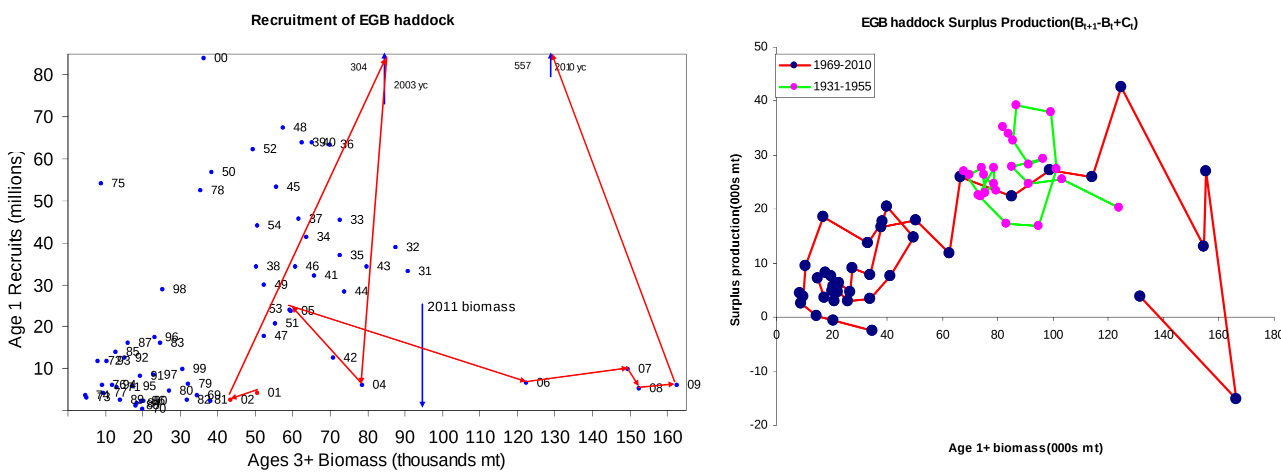

Figure 2. Relationship between Spawning Stock Biomass (SSB) and recruitment (left) and the surplus production (right; 1931-1955 and 1969-2010) of EGB haddock. The red arrows (left) show recruitment after the year 2000.

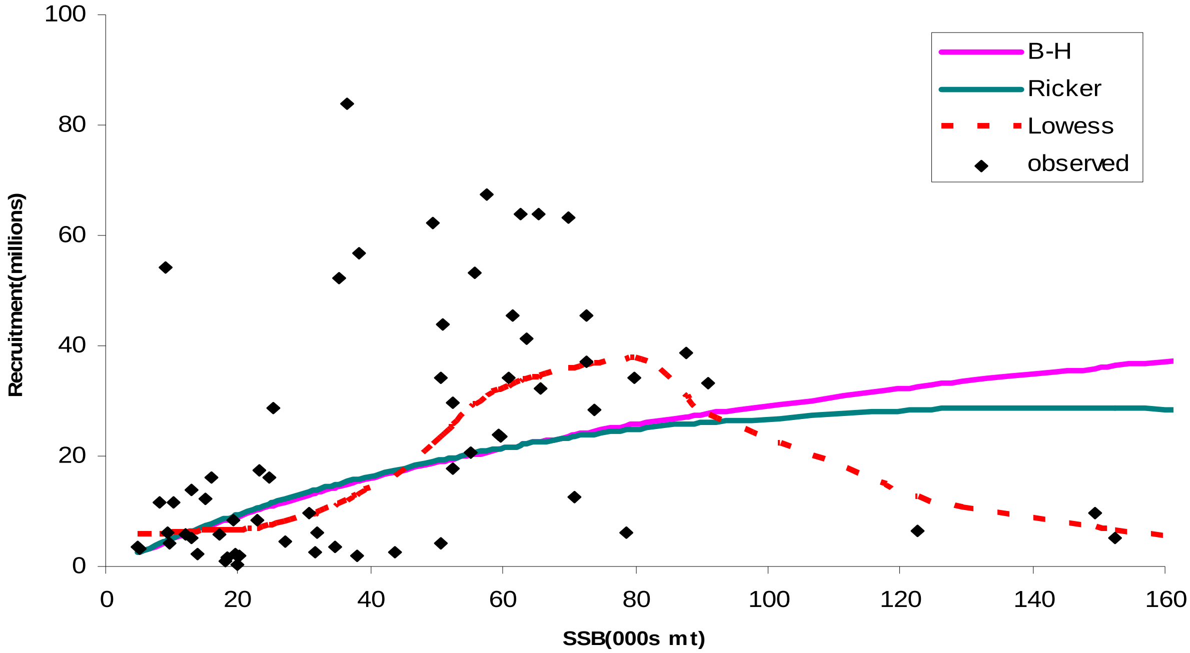

Figure 3. Parametric Beverton-Holt, Ricker, and non-parametric Lowess smooth stock recruitment curves fitted to EGB haddock Stock-Recruitment (S-R) data for 1931 to 1955 and 1969 to 2011. The 2003 and 2010 year classes were excluded as outliers.

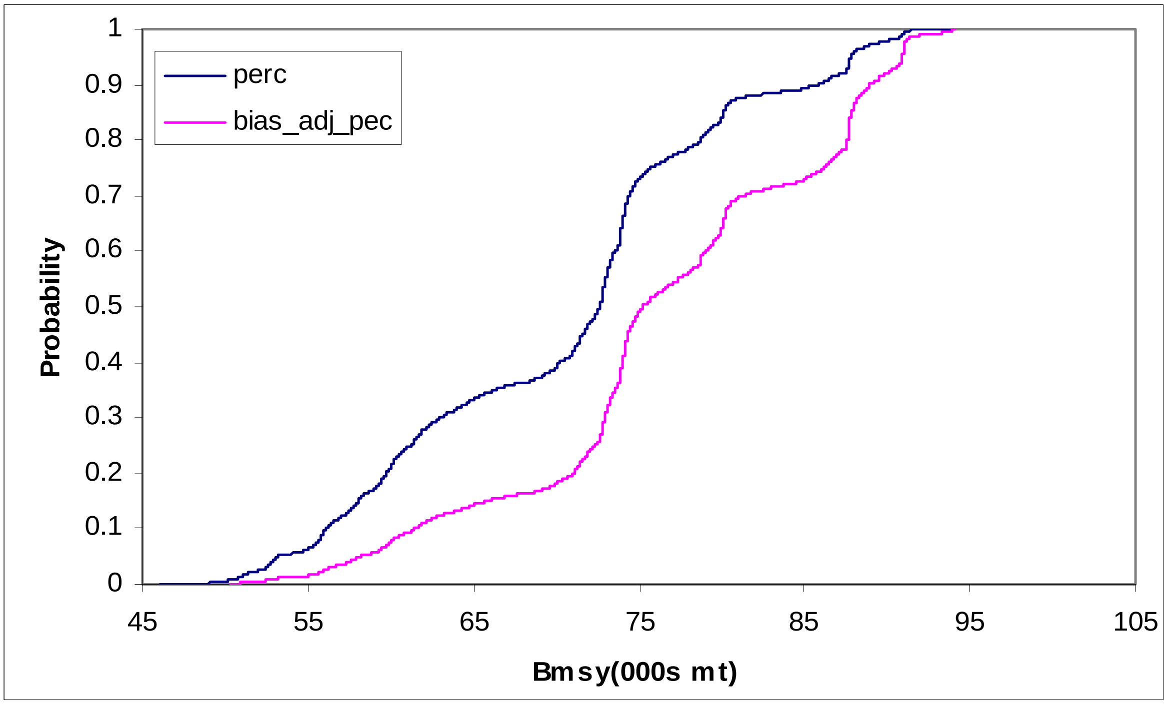

Figure 4. The cumulative probability distribution for EGB haddock B_{MSY} using a non-parametric bootstrapping approach.

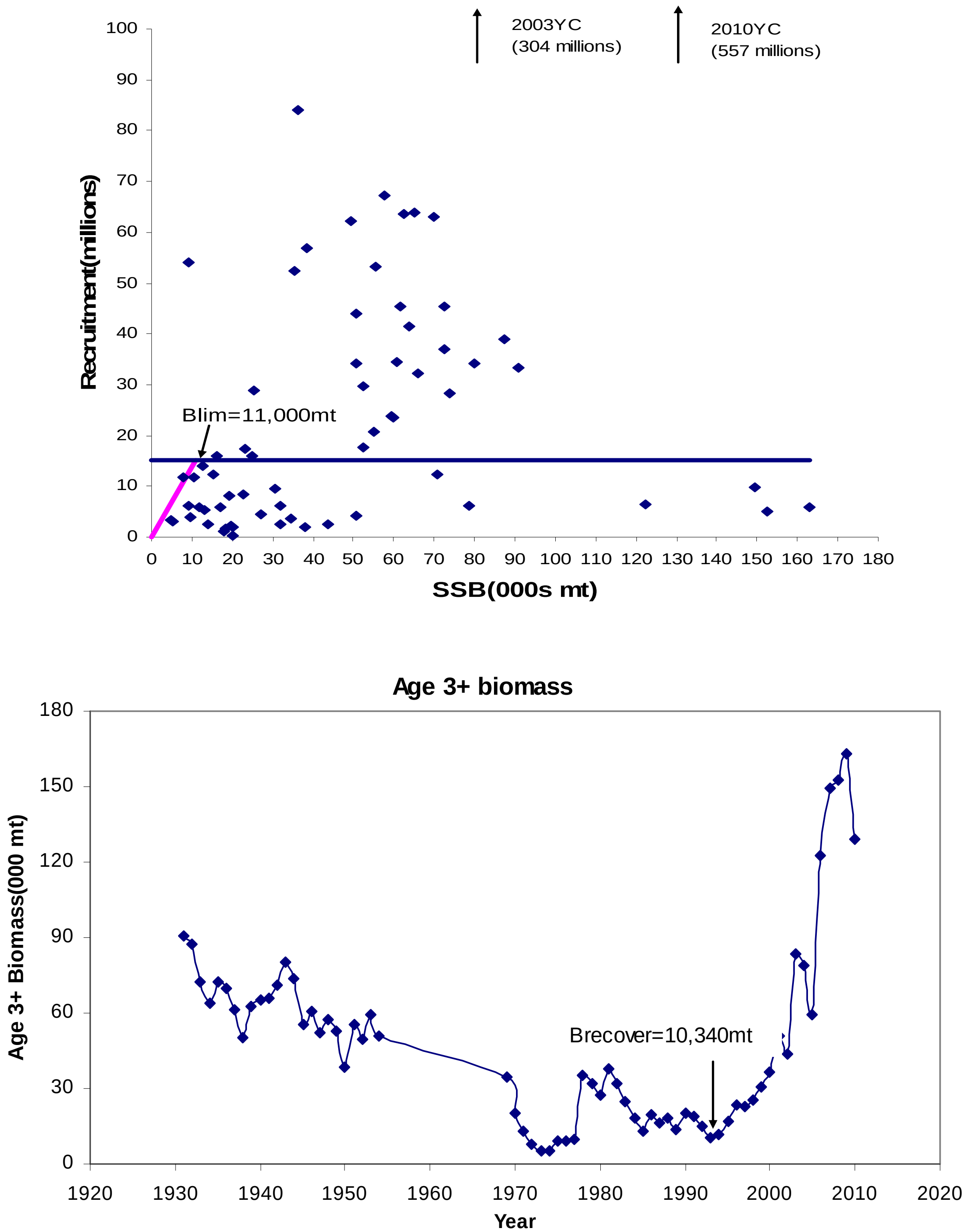

Figure 5. The $B_{recover}$ (top) and $Sb_{50/90}$ (bottom) for EGB haddock.