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An ASPIC Based Assessment of Redfish (*S. mentella and S. fasciatus*) in NAFO Divisions 3LN (*can a surplus production model cope with bumpy survey data?*)

by

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## Abstract

There are two species of redfish in Divisions 3L and 3N, the deep-sea redfish (*Sebastes mentella)* and the Acadian redfish (*Sebastes fasciatus*) that have been commercially fished and reported collectively as redfish in fishery statistics. Redfish in Div. 3LN is regarded as a management unit composed of two Grand Bank populations from those two very similar redfish species. The present ASPIC assessment is based on the logistic form of a non-equilibrium surplus production model (Schaeffer, 1954; Prager, 1994), adjusted to a standardized catch rate series (Power, 1997) and to most of the stratified-random bottom trawl surveys conducted in various years and seasons in Div. 3L and Div. 3N from 1978 onwards. These surveys were framed according to the input formulation previously adopted on the 2nd take of the ASPIC 2008 assessment (Ávila de Melo and Alpoim, 2010a).

The assessment was preceded by an exploratory analysis to check the response of the model to the inclusion of the Spanish spring survey series on Div. 3N and to the 2010-2011 update of the remaining three Canadian survey series that are at present the backbone input of this assessment. Each of these series includes recently high points that are well above their overall increasing trends, observed 2002 onwards. The analysis point out that in terms of consistency with previous assessments and the past history of the redfish fishery, as well as performance of the model, the ASPIC 2012 option with the exclusion of the Spanish survey and the removal of the recent outliers from the respective Canadian series represents the better update of the survey data input framework. The chosen input formulation run afterwards with different last year survey results and different starting guesses for key parameters and different random number seeds, in order to test the robustness of ASPIC results to turbulence in the inputs used to initialize the model deterministic run. A 2012 *versus* 2010 ASPIC comparative assessment (both on FIT and BOT modes) and a 2012-2010 retrospective analysis were also carried out to check the consistency between the two last full assessments and the magnitude of bias on relative biomass and fishing mortality in response to the general increase of the still standing survey series.

Regardless the input formulations, the starting guess region, the mode of the ASPIC runs or the retrospective patterns, the 2012 assessment reiterates the main conclusion of the previous ones: the biomass of redfish in Div. 3LN is above $B_{msy}$ , while fishing mortality is well below $F_{msy}$ . Most recent catches continue to be at a low level on the historical context of this fishery and the answer of the stock to a direct fishery of the magnitude of years between the mid 1960's and the mid 1980's is unknown. Projections were made on the short term, in order to select a 2013-2012 catch roof large enough to consolidate the reopening of a redfish direct fishery on divisions 3L and 3N but keeping a high probability of the stock staying above $B_{msy}$. This high probability is defined by the lower 80% confidence limit of the projected relative biomass trajectory being at or above $B_{msy}$ in 2013-2015.

## Introduction

There are two species of the genus *Sebastes* that have been commercially fished in Div. 3LN, the deep sea redfish (*Sebastes mentella)*, with a maximum abundance at depths greater than 300m, and Acadian redfish (*Sebastes fasciatus*), preferring shallower waters of less than 400m. Due to their external resemblance *S. mentella* and *S. fasciatus* are commonly designated as beaked redfish.

Beaked redfish are viviparous with the larvae eclosion occurring right before or after birth, long living and slow growing, with females attaining size of 50% maturity at 30-34cm (Power, 2001). Both species have pelagic and demersal concentrations as well as a long recruitment process to the bottom. Their external characteristics are very similar, making them difficult to distinguish. Therefore they are reported collectively as “redfish” in the commercial fishery statistics. *S. mentella* and *S. fasciatus* are also treated as a single species in the Grand Bank surveys carried out by Canada, Russia and more recently by EU-Spain.

Beaked redfish in Div. 3LN is regarded in the present work as a management unit composed of two Grand Bank fish populations of two very similar species. Nevertheless, it is accepted that in this management unit *S. mentella* is the dominant population, representing almost 100% of the commercial catch and the major proportion of the exploitable redfish biomass in Divisions 3L and 3N.

This assessment is a revised follow up of the previous one (Ávila de Melo *et al.*, 2010b). The logistic Schaefer production model (1954) incorporated in the new ASPIC version 5.34.9 (Prager, 1994) is adjusted to most of the stratified-random bottom trawl surveys series available for various intervals and seasons in Div. 3L and Div. 3N. An exploratory analysis precede the assessment for rearrangement of the surveys framework to the better possible fit, coupled with a sensitivity analysis to evaluate the robustness of the selected framework against variability on last year survey data and start user guesses for key model inputs.

The consistency of the biomass and fishing mortality trajectories is checked by comparison both with ASPIC 2010 assessment and 2012-2010 retrospective results. Finally the bootstrap results are used in short term projections for several fishing mortality options.

## Commercial Fishery

### Nominal catches and TAC’s

Between 1959 and 1964 reported catches declined from 45 000 to 10 000 t, oscillating over the next 21 years (1965-1985) around an average level of 21 000 t. Catches jump afterwards to a 79 000 t high in 1987 and fall steadily to a 450 t minimum reached in 1996. Catches were kept at a low level since then (450-3 000 t), until 2009.

The NAFO Fisheries Commission implemented a moratorium on directed fishing for this stock in 1998. During the moratorium years, redfish from divisions 3L and 3N was primarily taken as by-catch in the Greenland halibut fishery pursued by EU-Portugal and EU-Spain. In June 2008 the Scientific Council recognized that there was enough evidence to allow a small amount of direct fishing (not exceeding 3 500 t in 2009), taking into account the high biomass and very low fishing mortality indices observed (NAFO, 2008). Despite this recommendation the Fisheries Commission decided to continue the ban on direct fishing for redfish in Div. 3LN in 2009 but allowed an increase to 10% redfish by-catch rate in other fisheries. In June 2009 the Scientific Council confirmed that the levels of catches have not altered the upward trend of the stock, as shown by spring and autumn surveys (NAFO, 2009), and Fisheries Commission finally reopen the fishery with a TAC for 2010 of 3 500 t. Next year, in 2010, the Fisheries Commission endorsed the Scientific Council recommendation from the 2010 analytical assessment and set the TAC for 2011 and 2012 at 6 000 t.

Catches increased in 2010 and 2011 to 4 100 t and 5 768 t (Table 1, Fig. 1). The 2011 catch was extracted from the NAFO Database STATLANT 21A on 22 May 2012.

Description of the fishery

In the early 1980's the former USSR, Cuba and Canada were the primary fleets directing for redfish in Div. 3LN. The rapid expansion of the fishery was due to the entry of EU-Portugal in 1986 and South Korea in 1987, along with various re-flagged fleets. In the early 1990's Russia and the Baltic mid-water trawlers, together with South Korea and Portuguese bottom trawlers, were still responsible for the bulk of fishing effort, concentrated by that time on the "Beothuk Knoll" (Div. 3LMN border, southwest of the Flemish Cap).

South Korea left the area by the end of 1993 and from 1994 onwards the other fleets reduced effort substantially on Div. 3LN. The quick decline of redfish catch rates was the main reason for this reduction of redfish fishing effort, and justified its partial shift southwest to Div. 3O. Since 1994 most of the redfish catches in NAFO Divisions 3L and 3N were taken as by-catch of the Greenland halibut fishery pursued from the northern slopes of the Sackville Spur in Div. 3L through Flemish Pass till the canyons of southern Grand Bank in Div. 3N. The EU-Portugal and EU-Spain bottom trawl fleets were the main fleets responsible for the 3LN redfish by-catch during the moratorium years. Catches from EU-Portugal, Russian and Canadian fleets justified most of the increase on the redfish catch observed on both divisions 3L and 3N in 2010 and 2011.

Catch and Effort

On the 1997 assessment (Power, 1997) catch/effort data for Div. 3L and Div. 3N from 1959 to 1995 were analyzed with a multiplicative model (Gavaris, 1980) in order to derive a catch rate series for each division standardized for country-gear-tonnage class, NAFO division, month, and amount of by-catch associated with each observation. Both CPUE series shows much within year variability over time, with no statistically difference between the catch rates for most of the years. That assessment considered that *catch rate indices for Div. 3L and Div. 3N were not reflective of year to year changes in population abundance but they may be indicative of trends over longer periods of time*.

The assessment recovers the predicted effort series in fishing hours for Div. 3L and Div. 3N from the 1997 multivariate analysis, in order to derive a single annual catch rate for Div. 3LN. For each year of the 1959-1994 interval this standardized catch rate is given by the ratio between the sum of Div. 3L and Div. 3N Statlant catch (thousand tons) and the sum of Div. 3L and Div. 3N predicted effort (fishing hours). The catch rates for Div. 3LN are presented on Table 2 and Fig. 2 (normalized to the mean in the figure). Catch rate for Div. 3LN increased on the first years of the time series, 1959 till 1967, oscillated around the average on the intermediate years and declined after 1987. On the final years of this CPUE series, 1990-1994, catch rates were stable at a minimum level.

Commercial fishery sampling

Most of the commercial length sampling data available for the 3LN beaked redfish came, since 1990, from the Portuguese fisheries and has been annually included in the Portuguese research reports on the NAFO SCS Document series (Vargas *et al.*, 2012). Taking into account that the majority of the length sampling was from depths greater than 400m, these data should represent *S. mentella* catches. Length sampling data from Spain and Russia were used to estimate the length composition of the commercial catches for those fleets in several years (González *et al*., 2012; Skryabin *et al*., 2010). The 1990-2012 per mille length composition of the Portuguese trawl catch was applied to the rest of the commercial catches (Table 3a). In all cases the 3LN beaked redfish length weight relationships used to derive the absolute length frequency vectors of the commercial catch were based on the redfish sampling on board of Portuguese vessels fishing on divisions 3L and 3N (Table 3b).

The overall mean length of the 1990-2011 catch (arithmetic mean of the annual mean lengths of the commercial catch) was used to derive length anomalies of the 3LN catch over this period (Table 3a, Fig. 3). The proportion of small redfish (less than 20cm) in the catch is presented as well on the bottom of Table 3a. The purpose of the length anomalies was to detect eventual shifts in the length structure of the catch that could reflect changes in the length structure of the exploitable stock. An important increase on the numbers of small redfish in the catch could reflect the income of one ore more good recruitments.

Above average mean lengths, an apparent stable catch at length with no clear trends towards smaller or larger length groups and proportions in numbers of small redfish usually below 1%, are observed on most of the years of the 1990-2005 interval. However, well below average mean lengths occurred on most recent years, together with unusually high proportions of small redfish in the catch (Table 3a, Fig. 3). Under a low exploitation regime, such drop on the mean lengths of the redfish by-catch and catch in Div. 3LN over several years can only reflect the income of above average year classes to the exploitable stock. Clear modal lengths at 22cm observed in the 2011 Portuguese redfish catch at length from both divisions (Vargas *et al.*, 2012) illustrate well the presence of these new recruitments in the fishery.

**Research Surveys**

From 1978 till 1990 several stratified-random bottom trawl surveys have been conducted by Canada in various years and seasons in Div. 3L. However only since 1991 Canadian stratified-random surveys covered both Div. 3L and Div. 3N on a regular annual basis: a spring survey (May-Jun.) and an autumn survey (Sep.-Oct. 3N/Nov.-Dec. 3L for most years). The design of the Canadian surveys was based on a stratification scheme down to 732 m for Div. 3LN (Doubleday, 1981). From 1996 onwards the stratification scheme has been updated to include depths down to 1 464 m (800 fathoms) (Bishop, 1994), but only the autumn surveys have swept strata below 732 m depth, most on Div. 3L.

Up until the autumn of 1995 the Canadians surveys were conducted with an Engels 145 high lift otter trawl with a small mesh liner (29 mm) in the codend and tows planned for 30 minute duration. Starting with the autumn 1995 survey in Div. 3LN, a Campelen 1800 survey gear was adopted with a 12 mm liner in the codend and 15 minute tows. A comparison of the generated data with the original Engel data suggested overall trends in abundance were the same except that the relative measure of abundance estimated for the Campelen trawl conversions were higher (Power and Parsons, 1998).

All surveys on Div. 3L have Engel data converted into Campelen equivalents from 1985 onwards, with the exception of the spring survey (conversion since 1980). Abundance and biomass indices have been converted into Campelen equivalents since the start of Canadian surveys on Div. 3N, in 1991. Campelen equivalent data series extended till 1994 (autumn surveys in Div. 3L and Div. 3N) or 1995 (spring surveys in Div. 3L and Div. 3N) and are coupled with the original Campelen series starting since then. No spring survey was carried out in 2006 on Div. 3N. As regards Canadian surveys, only Campelen data and Engel data converted into Campelen equivalents are used in this assessment.

Since 1983 Russian bottom trawl surveys in NAFO Div. 3LMNO turn to stratified-random, following the above mentioned Canadian stratification for Sub area 3. On 1984 standard tows were set to half hour at 3.5 knots, with a standard gear. From 1984 till 1990, vessels conducting this survey were of the same tonnage class (the BRMT series) with the exception of 1985, when a vessel of smaller tonnage class (PST series) was employed. This smaller category was later employed on the 1991 and 1993 surveys. On 1992 and 1994 no survey was carried out in Div. 3N. On 1995 the Russian bottom trawl series in NAFO Sub area 3 was discontinued (Bulatova *et al.*, 1997).

On 1992 redfish results of the 1984-1991 stratified-random surveys in Div. 3LN by Russia were revised according to standard methodology (Power and Vaskov, 1992). Mean number and mean weight per standard tow were estimated from successful sets only, each tow being adjusted to 1.8 nmi. distance before analysis. Overall mean estimates by year and division were derived from the respective means by strata (weighted by the stratum area) and presented with associated 95% CI's. Survey abundance and survey biomass are finally tabulated by year and division. However in 1994, a Russian research document presents new figures for redfish bottom survey abundance and biomass from the same Russian survey series in Div. 3LN (1984-1991, plus the results of the 1993 survey) (Vaskov, 1994). No details are given regarding the method and the strata used to derive these new figures. The two series (Power, 1984-1991; Vaskov, 1984-1991 and 1993) are considered as alternate biomass indices for Div. 3LN combined. According to the results of the exploratory analysis preceding the 2008 ASPIC assessment (Ávila de Melo *et al.*, 2008), the model fits better to the "Power revised" 1984-1991 Russian survey series and since then this is the 3LN Russian series incorporated in the input.

In 1995 EU-Spain started a new stratified-random bottom trawl spring (May-June) survey on NAFO Regulatory Area of Div. 3NO. Despite changes on the depth contour of the survey, all strata in the NRA till 732m were covered every year following the standard stratification. From 1998 onwards the Spanish survey was extended to 1464 m (with the exception of 2001, with 1116m depth limit) and in 2004 expanded to the Regulatory Area of Div. 3L. From 1995 till 2000 the survey was carried out by the Spanish stern trawler *C/V Playa de Menduiña* using a *Pedreira* bottom trawl net. In 2001 the *R/V Vizconde de Eza* , trawling with a *Campelen* net, replaced the commercial stern trawler. In order to maintain the data series starting in 1995, comparative fishing trials were conducted in spring 2001 to develop conversion factors between the two fishing vessel and gear combinations. Former Div. 3NO redfish survey indices from C/V *Playa de Menduíña* have now been transformed to R/V *Vizconde de Eza* units (*González et al.*, 2010), and so the complete Div. 3N Spanish spring survey series is included since 2010 in the assessment framework.

Survey biomass and female spawning biomass

All available survey biomass from stratified-random bottom trawl surveys are presented in Table 4. About 95% of the survey data are included in the exploratory analysis and 77% incorporated in the ASPIC assessment input. The 1991-2011 spring and autumn survey indices for Div. 3LN combined (biomass and female SSB) are also presented on Table 4. In order to turn the survey series comparable and facilitate the detection of trends within stock dynamics, the survey biomass series used in the assessment framework and the female SSB survey series were standardized to zero mean and unit standard deviation and so presented on Figure 4a and 4b.

From the first half of the 1980s to the first half of the 1990s Canadian survey data in Div. 3L and Russian bottom trawl surveys in Div. 3LN suggests that stock size suffered a substantial reduction. Redfish survey bottom biomass in Div. 3LN remained well below average level until 1998 and started a discrete and discontinuous increase from 2002 onwards. A pronounced increase of the remaining biomass indices has been observed over the most recent years, since 2006. Considering all available bottom trawl survey series occurring in Div. 3L and Div. 3N from 1978 till 2011, 100% of the biomass indices were above the average of their own series on 1978-1985, only 13% on 1986-2005, and 68% on 2006-2011.

In order to estimate spring and autumn female spawning survey biomass by division, Div. 3L and Div. 3N female maturity at length vectors (Power 2001; Ávila de Melo et al., 2005) were applied to the 1991-2011 female abundances at length of the spring and autumn surveys. Female spawners and stock abundance at length by division were used to calculate SOP female spawning and stock biomass for Div. 3L and Div. 3N, using sex combined length weight relationships derived from data collected on board of the Canadian autumn surveys, 1997-2004 (Power, *pers. comm.*, 2005). The SOP ratios (SSB/stock biomass) by division were then applied to the respective swept area survey biomasses to give the spring and autumn female SSB in Div. 3L and Div. 3N.

Both 1991-2011 spring and autumn standardized female SSB series for Div. 3LN combined showed very similar patterns to correspondent survey biomass series, with 82% of the survey SSB's above average since 2006 (Fig.4b).

Abundance at length

Spring and autumn survey abundance at length, for Div. 3LN combined, are presented in Table 5a and 5b. The overall 1991-2011 mean length for each survey series (arithmetic mean of the annual mean lengths of the survey abundances at length) was used to derive the spring and autumn survey length anomalies for the stock over this period (Table 5a and 5b, Fig. 5a and 5b). During the first half of the 1990's on both survey series the length anomalies were negative or slightly positive. Mean lengths on most of the years between 1996 and 2007 (spring survey) or 2006 (autumn survey) were well above the mean, reflecting a shift on the stock length structure to larger individuals probably justified by a higher survival of the main year classes crossing the stock through this interval. But since 2008 mean lengths generally fall to below average, just as observed on the commercial catch at length (Fig 3). This most recent pattern on the length structure of both surveys and by catch seems to confirm the occurrence of recent pulses on recruitment, the first ones to be detected on this stock since 1991-1992.

## ASPIC assessment suite

A non-equilibrium surplus production model (ASPIC; Prager, 1994) was used to assess the status of the stock. The model was adjusted to the updated surveys series arranged under the formulation adopted on the *"The 2nd Take of the 2008 Assessment of Redfish in NAFO Divisions 3LN,"* (Ávila de Melo and Alpoim, 2010a) plus the Spanish spring survey on Div. 3N. The 2012 input series are summarized below:

| | |
|---|---|
| I1 (Statlant CPUE) | Statlant cpue for Div. 3LN,$_{1959\text{-}1994}$ & catch for Div. 3LN $_{1959\text{-}2011}$ |
| I2 (3LN spring survey) | Canadian spring survey biomass for Div. 3LN, $_{1991\text{-}2005,\ 2007\text{-}2011}$ |
| I3 (3N autumn survey) | Canadian autumn survey biomass for Div. 3N, $_{1991,\ 1993\text{-}2011}$ |
| I4 (3LN Power russian survey) | Russian spring survey biomass for Div. 3LN , $_{1984\text{-}1991}$ (Power and Vaskov,1992) |
| I5 (3L winter survey) | Canadian winter survey biomass for Div. 3L, $_{1985\text{-}1986 \text{ and } 1990}$ |
| I6 (3L summer survey) | Canadian summer survey biomass for Div. 3L$_{,\ 1978\text{-}1979,\ 1981,1984\text{-}1985,\ 1990\text{-}1991 \text{and } 1993}$ |
| I7 (3L autumn survey) | Canadian autumn survey biomass for Div. 3L, $_{1985\text{-}1986,\ 1990\text{-}1994,\ 1996\text{-}2011}$ |
| I8 (3N spring spanish survey) | Spanish survey biomass for Div. 3N, $_{1995\text{-}2011}$ |

All input series consist of annual observed values and were given equal weight in the analysis. On the rest of the analysis each Canadian series is referred by its season and division(s), while the Russian and Spanish series are referred by their country name. The model assumes that all catchability coefficients are constant over time. Because of the imprecision associated with the estimate of catchability for the various indices, absolute estimates of stock size and fishing mortality are normalized to the stock size and fishing mortality at MSY ($B_{msy}$ and $F_{msy}$ respectively). That is why normalized estimates are included in ASPIC output and used in the printer plots trajectories of biomass and fishing mortality. In a production model fishing mortality refers to catch/biomass ratio.

Basic assumptions

In this assessment the new ASPIC version 5.34.9 fit the logistic form of the production model (Schaefer, 1954). Being *K* the carrying capacity stock biomass, *r* the intrinsic rate of stock biomass increase, *C* the catch biomass, *MSY* and *Bms*y the long term yield and biomass associated with *Fmsy*, the model basic assumptions are:

1) A logistic population growth over time of the unexploited stock (Schaefer, 1954)

$$dB_t / dt = rB_t - (r / K)B_t^{\,2} \qquad (1)$$

2) For an exploited stock catch is also incorporated in the population growth

$$dB_t / dt = rB_t - (r / K)B_t^{\,2} - C_t \qquad (2)$$

3) The biological reference points are

a. $MSY = rK / 4$ (3)

b. $Bmsy = K / 2$ (4)

c. $Fmsy = r / 2$ (5)

Starting with user guesses (seeds) for the key parameters, Biomass on the first year of the assessment interval (as a ratio to *Bmsy*), *K*, *MSY* and catchability coefficients for each biomass index, ASPIC generate iteratively estimates of expected biomass indices for each series of observed indices. The key parameters of the model are found by a minimization routine for log squared residuals of *cpue* and biomass from each input survey series.

A summary of the ASPIC model (Prager, 1994) can be found on the 2003 assessment of redfish in Div. 3M (Ávila de Melo *et al.*, 2003).

Input file settings

ASPIC model requires from the user a set of initial definitions/starting guesses /constraints that need to be specified in the input file as follows:

Line 1: Both FIT and BOT program modes were used. Starting guesses and minimum and maximum bounds were kept constant from FIT to BOT mode.
Line 2: Fit the LOGISTIC (Schaefer) model with condition fitting on YLD (yield) and SSE (sum of squared errors) as objective function.
Line 4: 1000 Number of bootstrap trials when running on BOT mode.
Line 11: 0d0 No penalty term in objective function for B1>K (biomass on the 1st year of the assessment greater than carrying capacity biomass).
Line 12: 8 (maximum number of) data series are to be analyzed as biomass index of the stock (Statlant CPUE, five Canadian, one Russian and one Spanish survey).
Line 13: 1d0 1d0 1d0 1d0 1d0 1d0 1d0 1d0 When computing the objective function the squared residuals of each one of the 8 data series have equal weight.
Line 14: 0.5d0 Starting guess for *B1/K* = 0.5, the biomass on the 1$^{st}$ year of the assessment was assumed to be at $B_{msy}$ level.
Line 15: 2.0d4 Starting guess for *MSY* = 20000 t. Between 1965 and 1985 catches oscillated with no trend around 21000, catch rates declined when catches were raised above that level.
Line 16: 5.000E+05 Starting guess for carrying capacity *K* = 500 000 t, perhaps a rather conservative guess, roughly corresponding to the most recent high observed level of survey biomass (Table 5, 2011 autumn survey biomass on Div. 3LN) after 15 years of very low fishing mortality.
Line 17: Catchability starting guess were kept constant from the 2010 ASPIC assessment,

- STATLANT cpue, 9.007E-06 (*q* of Statlant CPUE for Div. 3M redfish ASPIC assessment, Ávila de Melo *et al.* 2003);
- spring survey on Div. 3LN combined, 0.658d0 (average 1991-2009 3LN spring /3LN autumn survey biomass ratio, assuming that autumn survey biomass is a proxy of absolute stock biomass);
- autumn survey on Div. 3N, 0.759d0 (average 1991-2009 3N/3LN autumn survey biomass ratio);
- Russian survey on Div. 3LN combined, 0.658d0 (same as for the correspondent Canadian spring survey);
- winter survey in Div. 3L, 0.322d0 (average 1991-2009 3L/3LN spring survey biomass ratio times average 1991-2009 spring 3LN/autumn 3LN survey biomass ratio);
- summer and autumn survey in Div. 3L 0.275d0 (average 1991-2009 3L/3LN autumn survey biomass ratio);
- Spanish survey on Div. 3N 0.759d0 (the same as the correspondent Canadian autumn survey).

Line 18: 1 1 1 1 1 1 1 1 1 1 1 All key parameters of the model (*B1/K*, *MSY*, *K*, $q_{cpue}$ , $q_{spring3LN}$ , $q_{autumn3N}$ , $q_{russiann3LN}$ , $q_{winter3L}$ , $q_{summer3L,}$ $q_{autumn3L}$ $q_{spanish3N}$) are estimated by the ASPIC program and not kept constant at the starting guess.
Line 19 and Line 20: minimum and maximum bounds on the estimate of *MSY* (5 000-50 000 t) and *K* (100 000-1 000 000 t) respectively. All $\text{ASPIC}_{fit}$ 2012 framework options gave estimates of these parameters far from either constraint.
Line 22: 53 Total number of years in the data sets included in the input file, from 1959 to 2011.

The rest of the settings of the input file were kept with the default options of the new ASPIC version 5.34.9. The input file with all survey sets, including the Spanish survey on Div. 3N, is presented on Appendix 1. All 1959-2010 catches used in this assessment are the catches adopted by STACFIS for this stock. A catch of 5 768 t, taken from the NAFO STATLANT 21A on May 22$^{nd}$ 2012, was used in this assessment as the redfish catch in Div. 3LN for 2011.

<u>Exploratory analysis</u>

The 2009 Spanish spring biomass index for Div. 3N has an enormously high magnitude, corresponding to more than a ten times fold increase from the previous year (Table 5). This jump can only be compared to the isolated highs observed in autumn 1992 for Div. 3N and 1995 for Div. 3L, that have been considered outliers of the respective survey biomass series and excluded from the ASPIC framework (Ávila de Melo *et al.*, 2008 and 2010b). But on recent years smaller bumps have also been observed in the other actual series, disturbing the gradual survey biomass increase observed in all of them:

- On 2007 the 3LN spring survey records a 3.3 fold increase from 2005 (no 2006 survey on Div. 3N).
- On 2010 the 3L autumn survey records a 3.7 fold increase from 2009, and
- On 2011 the 3N autumn survey records a 3.6 fold increase from 2010

These bumps are justified by one or two large redfish hauls within a few strata that represent a large proportion of the swept area biomass (Power, *pers. comm.*) and the likelihood of their occurrence is expected to increase as stock gets bigger.

The *cpue* series and the short survey series (Russian survey, summer and winter surveys on Div. 3L), basically represent the abundance of the stock during the former period prior to 1990, while the 3L and 3N autumn surveys and spring survey in Div. 3LN combined basically represent the abundance of the stock during the more recent period of the 1990's and 2000's. The negative correlations occasionally found between "old" and "new" surveys have been disqualified to halt the ASPIC assessment. Therefore only negative correlations between the model and any of the input series of biomass indices, or between surveys overlapping most of the years, were considered a violation of the fundamental assumption of ASPIC that all indices reflect the abundance dynamics of the stock and should be correlated.

Four ASPIC 2012 framework options, corresponding to four possible arrangements related with the Spanish survey and with the above mentioned jumps on the spring and both autumn series, were used to test the goodness of fit of the model to the available survey data:

### ASPIC 2012A *with 3N Spain*

I1 (Statlant CPUE) + I2 (3LN spring survey) + I3 (3N autumn survey) + I4 (3LN Power russian survey) + I5 (3L winter survey) + I6 (3L summer survey full series) + I7 (3L autumn survey) + I8 (3N spanish survey)

### ASPIC 2012B *without 3N Spain*

I1 (Statlant CPUE) + I2 (3LN spring survey) + I3 (3N autumn survey)+I4 (3LN Power russian survey) + I5 (3L winter survey) + I6 (3L summer survey) + I7 (3L autumn survey)

### ASPIC 2012C *with 3N Spain but 2009, 3L autumn but 2010 and 3N autumn but 2011*

I1 (Statlant CPUE) + I2 (3LN spring survey 1991-2005, 2007-2011) + I3 (3N autumn survey 1991, 1993-2010) + I4 (3LN Power russian survey) + I5 (3L winter survey) + I6 (3L summer survey) + I7 (3L autumn survey, 1985-1986, 1990-1994,1996-2009,2011) + I8 (3N spanish survey 1995-2008, 2010-2011)

### ASPIC 2012D *without 3N Spain, with 3LN spring but 2007, 3L autumn but 2010 and 3N autumn but 2011*

I1 (Statlant CPUE) + I2 (3LN spring survey 1991-2005, 2008-2011) + I3 (3N autumn survey 1991, 1993-2010) + I4 (3LN Power russian survey)+I5 (3L winter survey) + I6 (3L summer survey) + I7 (3L autumn survey, 1985-1986, 1990-1994,1996-2009,2011)

Besides the correlation between ASPIC estimated and observed annual values for each data series (R squared in CPUE), other parameters were used as diagnostics of the FIT outputs for the four arrangements considered:

- Number of restarts required for convergence: The routine used in ASPIC to minimize the objective function can stop at a local minima. In order to find a true minimum of the objective function, which is kept constant regardless the initial values of the key parameters, ASPIC program has a restarting algorithm that requires the same solution to be found several times in a row before it is accepted (Prager, 2004). The shorter the number of restarts the quicker is the convergence and the better is the fit of the model to the data series.

- Estimated contrast index (ideal = 1.0): C* = (Bmax-Bmin)/K. A wider contrast on the biomass trajectory reflects wider coverage by the stock exploitation history of the Yield/Biomass curve defined by the ASPIC underlying surplus production model.

- Estimated nearness index (ideal = 1.0): N* = 1 - |min(B-Bmsy)|/K. Being a production model centred on *MSY*, the biomass trajectory given by ASPIC should pass at least once through $B_{msy}$. Otherwise the ASPIC will set $B_{msy}$ at the first guess given by the user.

- TOTAL OBJECTIVE FUNCTION. Measuring the overall size of the of *cpue* and survey residuals the least squares objective function points out how close model estimates are to observed data.

An overview of the exploratory analysis under a traffic light rating frame (quantifying the best, intermediate, worst and unacceptable results for the four survey framework options, see Table 6a) lead to the conclusion that so far the model will perform better without the Spanish survey on Div. 3N and the recent outliers of the 3LN spring survey (2007), of the 3L autumn survey (2010) and of the 3N autumn survey (2011). If not, the main series supporting the older part of the stock dynamics (Statlant CPUE, 1959-1994) will cease to have a positive correlation with the model results (Table 6a).

Either other options will result on an overall depression to below $B_{msy}$ of the relative biomass trajectory, with $B_{msy}$ raised to the maximum allowed by the user (half of *K* maximum constraint set in the input file). In return initial 2012 biomass will be still below $B_{msy}$ and both *MSY* and the equilibrium yield available in 2012 will be much higher (Table 6b). The model adjusts late big jumps on the observed survey series into expected survey series, the actual ones reflecting a stock increasing at an increasing speed. The underlying logistic production model has no option but to assume that the stock is in nowadays still below $B_{msy}$.

The traffic light rating presents a clear winner for the best diagnostics option (Table 6a). Also the comparison with key parameters and trajectories from the $ASPIC_{fit}$ 2010 (Table 6b, Fig. 6a and 6b) confirms that in terms of consistency with both previous assessment and the past history of the redfish fishery, the ASPIC 2012D option represents the better update of the survey data framework adopted on the ASPIC 2008 ($2^{nd}$ take, Ávila de Melo *et al.* 2010a) and 2010 assessment (Ávila de Melo *et al.* 2010b).

So ASPIC 2012 assessment will run on both FIT and BOT mode without the Spanish survey series on Div. 3N and stripped of the late bumps that show up in the three Canadian survey series.

<u>Sensitivity analysis</u>

Different starting guesses for key parameters, different random number seeds and different magnitudes of last year surveys were used to test the robustness of the $ASPIC_{fit}$ 2012 formulation. The purpose was to investigate if the model stands still in its response to changes (within a 50% range, from -25% to +25%) in some of the required inputs (either on the starting "region" used to initialize the minimization routine or on last year survey results). Eight input options presented on Table 7a were tested against the standard adopted input option:

- 25% above and below the default random number seed
- an "optimistic start" given by -25% *cpue* and survey catchabilities together with +25% *MSY*, *K* and *B1/K*,

- and a pessimistic start given by +25% cpue and survey catchabilities together with -25% *MSY*, *K* and *B1/K*,
- 10% and 25% reduction on last year surveys,
- 10% and 25% increase on last year surveys.

The FIT parameter solutions from each of these options are compared with the standard FIT solution on Table 7b. The seed related options arrived to very similar solutions, showing that the ASPIC results given by the chosen formulation are insensitive to first guess/default inputs chosen to initialize the assessment (Table 7b, Fig. 7a). Un-skew light turbulence is induced on the trajectories of relative biomass and fishing mortality by variability on last year surveys, in line with the logistic model chosen for biomass growth and the with actual level of the stock above $B_{msy}$ (Table 7b, Fig. 7b). If the stock is in the safe zone, with biomass above $B_{msy}$ and fishing mortality below $F_{msy}$, such as the 3LN redfish stock at present,

- A change in the surveys between the last couple of years higher than expected will pull the stock backwards closer to $B_{msy}$ in order to allow a faster rate of increase.
- A change in the surveys between the last couple of years smaller than expected will push the stock frontwards closer to *K* in order to allow a slower rate of increase.

The response of the model to variability on last year surveys is well illustrated on Fig's 7c and 7d, were positive dependent ($B_{msy}$ , *MSY*, $F_{last\ year}/F_{msy}$, $Ye_{2012}$) and negative dependent (*B1/K*, $F_{msy}$, $B_{last\ year}/B_{msy}$ ) parameters (previously standardized) are plotted against the range of relative survey biomass for 2011.

Retrospective Analysis

A 2011-2009 ASPIC retrospective analysis (the 2012 framework on FIT mode with last year of the assessment one year less from 2011 to 2009) was carried out to check for retrospective patterns on relative biomass and fishing mortality (Table 8, Fig. 8a and 8b). From one year to the next ASPIC assessments over estimate biomass (and $F_{msy}$) and under estimate fishing mortality (and *MSY* and $B_{msy}$) at relatively small rates (4%-9%). As discussed in the previous section, these retrospective patterns are the model response to the general increase of the still standing survey series, recorded over the most recent years (Fig. 8c).

The observed retrospective patterns don't change the perception of the stock history or of its present exploitation state in relation to either *MSY*, $B_{msy}$ and $F_{msy}$. On the contrary from one year to the next more conservative assessments are putting the recent growth of the stock closer into context of a low population growth of long-lived and slow-growing species such as redfish, despite of the unexpected magnitude of some recent biomass survey points.

Assessment results

The $ASPIC_{2012}$ formulation runs on both deterministic (FIT) and bootstrap (BOT) mode with 1000 trials. Deterministic results are presented on Appendix 2, with a summary of diagnostics and parameters included on Table 6a and 6b under $ASPIC_{fit}$ 2012D and relative biomass and fishing mortality trajectories plotted on Fig's 6a and 6b.

Bootstrap results are presented on Tables 9a and 9b and Fig's 9a to 9d. First the consistency of the present assessment was checked against the last one from 2010: the $ASPIC_{bot}$ 2012 main results and bias corrected trajectory for relative biomass are coupled with the ones from the previous $ASPIC_{bot}$ 2010 assessment (Ávila de Melo *et al.* 2010b), extended to 2010-2011 by a short term projection with the catches from the last couple of years (Table 9a, Fig 9a). Both assessments gave very similar results and show the same stock dynamics over the last 50 years (namely over the more recent 25 years).

Despite the "negative" correlations between STATLANT *cpue* and both 3LN spring survey and 3N autumn survey, and between 3LN spring survey and 3L summer survey (conditioned by the very small number of pair-wise observations and not regarded as an assessment constraint), correlation among the majority of possible combinations of surveys is high ($r^2 > 0.7$) (Appendix 2). The model has a relative poor fit to the input series (namely the Statlant

CPUE index) "representing" the older period of the assessment interval, but correlations are higher and increasing from one assessment to the next as regards the long up to date surveys "representing" the modern years (Table 6a). Residuals between observed and model generated values also seem to be more randomly distributed than on previous assessments (Appendix 2).

Nevertheless these diagnostic features have little impact on the robustness of the $ASPIC_{bot}$ 2012 results:

- Small bias between the bias corrected and the point estimates (< 10%) for all key parameters (Table 9a),
- $B/B_{msy}$ and $F/F_{msy}$ point estimate trajectories sticking to their bias corrected ones (Table 9b, Fig. 9b),
- While keeping their un-skew track far from their 80% CL's boundaries (Fig's 9c and 9d).

The model results suggest a maximum sustainable yield (*MSY*) of 24 800 t that can be produced with a fishing mortality of 0.11 when stock biomass is at $B_{msy}$ level. The magnitude of *MSY* matches the average level of catches taken from this stock over more than two decades (21 000 t, 1965-1985) along with an apparent stability of the stock. The magnitude of $F_{msy}$ (0.11) has the some order of magnitude of $F_{0.1}$ = 0.12 given by a previous yield per recruit analysis for redfish in Div. 3LN (Power and Parsons, 1999). Relative biomass was slightly below $B_{msy}$ for most of the former years up to 1987, supporting a fishing mortality at or moderately above $F_{msy}$. Between 1986 and 1992 catches were higher than *MSY* (26 000 t - 79 000 t), pushing fishing mortality well above $F_{msy}$ from 1986 till 1993. Those eight years of heavy over-fishing determine the fall of biomass from $B_{msy}$ in 1986 to 19% $B_{msy}$ in 1994, when a minimum stock size is recorded. Long living/slow growing species such as redfish can not sustain over-fishing but for short periods of time: the quick decline of stock biomass through the second half of the 1980's – first half of the 1990's was followed by a drop on catch and fishing mortality. Since 1996 both were kept at low to very low levels. Over the moratorium years biomass was allowed to increase and is now well above $B_{msy}$ (Table 9b and Fig. 9b).

Catch versus surplus production trajectories are presented on Fig. 10. From 1960 till 1985 catches form a scattered cloud of points around surplus production curve. On 1986-1987 catches rise well above the surplus production and though declining continuously since then were still above equilibrium yield in 1993. Estimated catch has been well below surplus production levels since 1994.

**ASPIC projections**

Background

Regardless the input formulations, the starting guess region, the mode of the ASPIC runs or the retrospective patterns, the 2012 assessment reiterates the main conclusion of the previous ones: the biomass of redfish in Div. 3LN is above $B_{msy}$, while fishing mortality is well below $F_{msy}$. The status of the stock allows its exploitation and being so the fishery reopened recently, in 2010, with a 3 500 t TAC. Since then catches have moderately increase and were estimated to be last year at the 2011-2012 TAC. But most recent catches continue to be at a low level on the historical context of this fishery and the answer of the stock to a direct fishery of the magnitude of years between the mid 1960's and the mid 1980's is unknown. Furthermore projections should be on the short term, taking into account the retrospective pattern of a production based assessment of a stock above $B_{msy}$ conditioned by increasing trends on surveys, with every next assessment revising downwards recent relative biomass and upwards surplus production yield.

The purpose of the present short term projections coupled with $ASPIC_{bot}$ 2012 assessment is to select a 2013-2014 catch roof large enough to consolidate the reopening of a redfish direct fishery on divisions 3L and 3N but keeping a high probability of the stock staying above $B_{msy}$. This high probability is defined by the lower 80% confidence limit of the projected relative biomass trajectory being at or above $B_{msy}$ in 2013-2015.

Framework

For ASPIC short term projections were carried out assuming a *status quo* catch for 2012 (5 768 t), forwarded with increasing options of constant fishing mortality on 2013 and 2014, from $F_{statusquo}$ to 2/3 $F_{msy}$ (recommended by the PA surplus production framework for a stock above $B_{msy}$ such as this one at present), stopping at 1/6 $F_{msy}$ and 2/3 $F_{msy}$ in between.

ASPIC has an auxiliary program, ASPICP, to provide not only bias corrected estimates of biomass and fishing mortality on an annual basis for the assessment time interval (with associated 80% confidence limits) but also allows projections of these trajectories to future years under user preset catch and/or fishing mortality (as a multiplier of $F_{msy} / F_{last\ year}$ ratio). ASPICP reads the results from the 1000 trials of the ASPIC $_{bot}$ 2012 assessment stored in a .BIO file and project each of these runs three years ahead (2012-2014), under the scenarios considered above. Each of these scenarios is input on a .CTL file that guides each of the four adopted short term projections. Results are stored in .PRJ files and summarized on Table 10a and 10b and Fig 11.

Projection results

Any of the four fishing mortality options for the next coming years (assuming stability in the 2012 catch) will project the stock standing above $B_{msy}$ and, with the exception of the higher 2/3 $F_{msy}$ option, with marginal increases of biomass (Table 10a). Results for $F_{statusquo}$ and 1/6 $F_{msy}$ are very similar (Table 10a and 10b and Fig 11).

## Stock and fishing mortality trajectory under a Precautionary Approach framework

The ASPIC bias corrected results were put under the precautionary framework (Fig. 12). The trajectory presented shows a stock slightly below $B_{msy}$ under exploitation above $F_{msy}$ through 25 years in a row (1960-1985). The stock rapidly declined afterwards to well below $B_{msy}$ when fishing mortality rises to well above $F_{msy}$ (1987-1993). Biomass gradually aproaches and finally surpasses $B_{msy}$ after fishing mortality dropped to well below $F_{msy}$ (1993-1995) being kept at a very low level ever since.

The NAFO SC Study Group recommendations from the meeting in Lorient in 2004 (NAFO, 2004), as regards Limit Reference Points (LRP's) for stocks evaluated with surplus production models, considered $F_{lim}$ at $F_{msy}$ and $F_{target}$ at 2/3 $F_{msy}$. The Study Group also considered that the biomass giving production of 50% *MSY* was a suitable $B_{lim}$. With the Schaeffer model used in the present ASPIC assessment this limit corresponds in this stock to (roughly) 30% $B_{msy}$. The stock was at (or below) $B_{lim}$ between 1993 and 1996, prior to the implementation of the moratorium on this fishery in 1998.

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Table 1: Summary of catch and TAC's of redfish
in Div. 3LN estimated from various sources

| YEAR | 3L | 3N | TOTAL | TAC | |
|---|---|---|---|---|---|
| 1959 | 34107 | 10478 | 44585 | | |
| 1960 | 10015 | 16547 | 26562 | | |
| 1961 | 8349 | 14826 | 23175 | | |
| 1962 | 3425 | 18009 | 21439 | | a |
| 1963 | 8191 | 12906 | 27362 | | a |
| 1964 | 3898 | 4206 | 10261 | | a |
| 1965 | 18772 | 4694 | 23466 | | |
| 1966 | 6927 | 10047 | 16974 | | |
| 1967 | 7684 | 19504 | 27188 | | |
| 1968 | 2378 | 15265 | 17660 | | a |
| 1969 | 2344 | 22356 | 24750 | | a |
| 1970 | 1029 | 13359 | 14419 | | a |
| 1971 | 10043 | 24310 | 34370 | | a |
| 1972 | 3095 | 25838 | 28933 | | |
| 1973 | 4709 | 28588 | 33297 | | |
| 1974 | 11419 | 10867 | 22286 | 28000 | |
| 1975 | 3838 | 14033 | 17871 | 20000 | |
| 1976 | 15971 | 4541 | 20513 | 20000 | |
| 1977 | 13452 | 3064 | 16516 | 16000 | |
| 1978 | 6318 | 5725 | 12043 | 16000 | |
| 1979 | 5584 | 8483 | 14067 | 18000 | |
| 1980 | 4367 | 11663 | 16030 | 25000 | |
| 1981 | 9407 | 14873 | 24280 | 25000 | |
| 1982 | 7870 | 13677 | 21547 | 25000 | |
| 1983 | 8657 | 11090 | 19747 | 25000 | |
| 1984 | 2696 | 12065 | 14761 | 25000 | |
| 1985 | 3677 | 16880 | 20557 | 25000 | |
| 1986 | 27833 | 14972 | 42805 | 25000 | |
| 1987 | 30342 | 40949 | 79031 | 25000 | b |
| 1988 | 22317 | 23049 | 53266 | 25000 | b |
| 1989 | 18947 | 12902 | 33649 | 25000 | b |
| 1990 | 15538 | 9217 | 29105 | 25000 | b |
| 1991 | 8892 | 12723 | 25815 | 14000 | b |
| 1992 | 4630 | 10153 | 27283 | 14000 | b |
| 1993 | 5897 | 9077 | 21308 | 14000 | bc |
| 1994 | 379 | 2274 | 5741 | 14000 | bc |
| 1995 | 292 | 1697 | 1989 | 14000 | |
| 1996 | 112 | 339 | 451 | 11000 | |
| 1997 | 151 | 479 | 630 | 11000 | |
| 1998 | 494 | 405 | 899 | 0 | |
| 1999 | 518 | 1318 | 2318 | 0 | b |
| 2000 | 657 | 819 | 3141 | 0 | bc |
| 2001 | 653 | 245 | 1442 | 0 | b |
| 2002 | 651 | 327 | 1216 | 0 | b |
| 2003 | 584 | 751 | 1334 | 0 | |
| 2004 | 401 | 236 | 637 | 0 | |
| 2005 | 581 | 78 | 659 | 0 | |
| 2006 | 53 | 444 | 496 | 0 | |
| 2007 | 118 | 1546 | 1664 | 0 | |
| 2008 | 220 | 377 | 597 | 0 | |
| 2009 | 57 | 994 | 1051 | 0 | |
| 2010 | 260 | 3688 | 4120 | 3500 | |
| 2011 | 3796 | 1972 | 5768 | 6000 | d |

a Includes catch that could not be identified by division
b includes estimates of unreported catches
c Catch could not be precisely estimate due to discrepancies in figures from available sources: average of the range of the different catch estimates.
d Data extracted from the NAFO Database STATLANT 21A on 22 May 2012

Table 2: Redfish STATLANT catch and predicted effort for Div. 3L and Div. 3N, 1959-1994 (Power,1997). Standardized catch rate for Div. 3LN, 1959-1994.

| | 3L | | 3N | | 3LN | | 3LN |
|---|---|---|---|---|---|---|---|
| Year | STATLANT Catch | Predicted EFFORT | STATLANT Catch | Predicted EFFORT | STATLANT Catch | Predicted EFFORT | CPUE annual |
| 1959 | 34107 | 22604 | 10478 | 8659 | 44585 | 31263 | 1.426 |
| 1960 | 10015 | 5690 | 16547 | 10892 | 26562 | 16582 | 1.602 |
| 1961 | 8349 | 3610 | 14826 | 10049 | 23175 | 13659 | 1.697 |
| 1962 | 3425 | 2049 | 18009 | 11090 | 21434 | 13139 | 1.631 |
| 1963 | 8191 | 3973 | 12906 | 8958 | 21097 | 12931 | 1.632 |
| 1964 | 3898 | 1491 | 4206 | 2981 | 8104 | 4472 | 1.812 |
| 1965 | 18772 | 8190 | 4694 | 2551 | 23466 | 10741 | 2.185 |
| 1966 | 6927 | 4615 | 10047 | 4915 | 16974 | 9530 | 1.781 |
| 1967 | 7684 | 3793 | 19504 | 10569 | 27188 | 14362 | 1.893 |
| 1968 | 2378 | 1446 | 15265 | 17684 | 17643 | 19130 | 0.922 |
| 1969 | 2344 | 1354 | 22356 | 17109 | 24700 | 18463 | 1.338 |
| 1970 | 1029 | 499 | 13359 | 10026 | 14388 | 10525 | 1.367 |
| 1971 | 10043 | 5207 | 24310 | 20320 | 34353 | 25527 | 1.346 |
| 1972 | 3095 | 1877 | 25838 | 18982 | 28933 | 20859 | 1.387 |
| 1973 | 4709 | 2078 | 28588 | 18186 | 33297 | 20264 | 1.643 |
| 1974 | 11419 | 11907 | 10867 | 5374 | 22286 | 17281 | 1.290 |
| 1975 | 3838 | 2443 | 14033 | 8265 | 17871 | 10708 | 1.669 |
| 1976 | 15971 | 11335 | 4541 | 4537 | 20512 | 15872 | 1.292 |
| 1977 | 13452 | 10461 | 3064 | 2738 | 16516 | 13199 | 1.251 |
| 1978 | 6318 | 5961 | 5725 | 4925 | 12043 | 10886 | 1.106 |
| 1979 | 5584 | 3517 | 8483 | 6176 | 14067 | 9693 | 1.451 |
| 1980 | 4367 | 2873 | 11663 | 6229 | 16030 | 9102 | 1.761 |
| 1981 | 9407 | 6020 | 14873 | 9216 | 24280 | 15236 | 1.594 |
| 1982 | 7870 | 4812 | 13677 | 8160 | 21547 | 12972 | 1.661 |
| 1983 | 8657 | 4960 | 11090 | 7734 | 19747 | 12694 | 1.556 |
| 1984 | 2696 | 1804 | 12065 | 12263 | 14761 | 14067 | 1.049 |
| 1985 | 3677 | 2104 | 16880 | 16858 | 20557 | 18962 | 1.084 |
| 1986 | 27833 | 15247 | 14972 | 15057 | 42805 | 30304 | 1.413 |
| 1987 | 34212 | 22369 | 44819 | 29517 | 79031 | 51886 | 1.523 |
| 1988 | 26267 | 19629 | 26999 | 24453 | 53266 | 44082 | 1.208 |
| 1989 | 19847 | 10567 | 13802 | 14884 | 33649 | 25451 | 1.322 |
| 1990 | 17713 | 16774 | 11392 | 18513 | 29105 | 35287 | 0.825 |
| 1991 | 8892 | 12329 | 12723 | 20052 | 21615 | 32381 | 0.668 |
| 1992 | 4630 | 2452 | 10153 | 13755 | 14783 | 16207 | 0.912 |
| 1993 | 5897 | 1576 | 9077 | 17116 | 14974 | 18692 | 0.801 |
| 1994 | 379 | 410 | 2274 | 2900 | 2653 | 3310 | 0.802 |

Table 3a: Length composition (absolute frequencies in '000s) of the 3LN redfish commercial catch and by-catch, 1990-2011.

| Length | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | | | | | | | | | | | | | | | | | | | 0.09 | | | 1 |
| 11 | | | | | | | | | | | | | | 0.03 | | | | | 0.21 | 3 | 17 | 5 |
| 12 | 12 | | | | | | | | | | | | | 0.03 | | | | | 0.23 | 10 | 38 | 33 |
| 13 | 6 | | | | | | | | | | | | | 1 | | | | | 0.09 | 23 | 61 | 108 |
| 14 | 21 | | | | | | | | | | | | | 1 | | | 0.003 | | 0.09 | 33 | 191 | 184 |
| 15 | 28 | 28 | | | | | | | | | | | | 5 | | | 10 | | 3 | 51 | 332 | 353 |
| 16 | 73 | 103 | 9 | | | | | | | | | 1 | 0.3 | 8 | | | 24 | | 14 | **11844** | 626 | 442 |
| 17 | 199 | 394 | 28 | | | 2 | | | | 0.3 | 1 | 2 | 1 | 21 | 1 | 2 | 34 | | 80 | **28755** | 950 | 584 |
| 18 | 286 | 1034 | 412 | | 5 | 2 | | 0.01 | 1 | | 1 | 1 | 1 | 44 | 2 | 4 | 65 | 0.3 | 103 | **28464** | 1155 | 675 |
| 19 | 445 | 2157 | 1291 | 5 | 6 | 3 | 1 | 0.3 | 2 | 16 | 4 | 4 | 3 | 90 | 6 | 9 | 99 | 43 | 96 | **15107** | 1666 | **1203** |
| 20 | 720 | 3313 | 2375 | | 16 | 14 | 4 | 2 | 13 | 47 | 6 | 18 | 14 | 151 | 15 | 11 | **182** | 143 | 43 | 1565 | **2012** | **1968** |
| 21 | 1309 | 3780 | 2943 | 235 | 287 | 9 | | 11 | 57 | 80 | 10 | 52 | 41 | **218** | 28 | 13 | **300** | 77 | **133** | 428 | **2662** | **3051** |
| 22 | 2081 | **4922** | 3600 | 714 | 683 | 65 | 6 | 17 | **151** | 150 | 26 | 102 | 81 | **269** | 35 | 11 | **347** | 149 | **239** | 475 | **3644** | **3999** |
| 23 | 3212 | **7340** | **4358** | 1141 | 594 | 64 | 17 | 34 | **277** | 128 | 46 | 118 | 101 | **277** | 41 | 16 | **340** | 212 | **303** | 5957 | **2502** | **3083** |
| 24 | **4164** | **7575** | **5552** | 2565 | 708 | 99 | 9 | 64 | **296** | 120 | 85 | 114 | 132 | **258** | 54 | 35 | **210** | 170 | **253** | 2346 | 1245 | **1728** |
| 25 | **5216** | **6944** | **4981** | **5237** | **944** | 100 | 9 | **98** | **248** | 178 | **195** | 114 | 154 | **261** | 85 | 61 | **147** | **221** | **224** | 268 | 808 | 928 |
| 26 | **5560** | **5981** | **5145** | **5115** | **1297** | 277 | 12 | **118** | **221** | **318** | **364** | 126 | **204** | **309** | **157** | **138** | **111** | **206** | **138** | 2828 | 737 | 704 |
| 27 | **5410** | **6197** | **4579** | **5433** | **1404** | **330** | 35 | **144** | **218** | **555** | **546** | **170** | **248** | **324** | **190** | **181** | 99 | **134** | 81 | 193 | 541 | 578 |
| 28 | **5217** | **5322** | **4063** | **5004** | **1182** | **300** | **75** | **114** | **173** | **712** | **943** | **188** | **289** | **286** | **184** | **201** | 88 | **521** | 32 | 194 | 528 | 725 |
| 29 | **4712** | **3354** | **4637** | **4437** | **1188** | **263** | **76** | **114** | **154** | **673** | **1003** | **179** | **289** | **245** | **184** | **223** | 62 | **425** | 42 | 140 | 440 | 696 |
| 30 | **4751** | **4043** | **3911** | **3283** | **1011** | **310** | **182** | **114** | **120** | **520** | **1027** | **236** | **294** | **225** | **178** | **176** | 60 | **368** | 44 | 96 | 349 | 678 |
| 31 | **4551** | 2695 | 3711 | **2964** | **912** | **313** | **197** | **154** | **129** | **413** | **564** | **289** | **295** | **204** | **107** | **109** | 35 | **335** | 31 | 64 | 226 | 954 |
| 32 | **3943** | 2478 | 2187 | 2313 | **944** | **309** | **98** | **146** | **119** | **434** | **315** | **303** | **276** | 189 | **108** | **91** | 28 | **594** | 37 | 49 | 220 | 1063 |
| 33 | 3082 | 1582 | 1355 | 2291 | 596 | 226 | **67** | **131** | **110** | **383** | **237** | **298** | **216** | 196 | 95 | 83 | 19 | **316** | 58 | 40 | 190 | 845 |
| 34 | 2737 | 1179 | 1569 | 1527 | 526 | 189 | 30 | 71 | 66 | **268** | **217** | **218** | 132 | 149 | 73 | 71 | 17 | **252** | 83 | 37 | 149 | 352 |
| 35 | 2100 | 928 | 1604 | 1059 | 363 | 182 | 35 | 24 | 19 | 141 | 129 | **212** | 83 | 112 | 51 | 63 | 10 | 124 | 62 | 11 | 143 | 268 |
| 36 | 1681 | 831 | 1895 | 923 | 202 | 106 | 23 | 19 | 18 | 89 | 60 | 121 | 37 | 62 | 36 | 56 | 5 | 110 | 39 | 13 | 96 | 134 |
| 37 | 1416 | 580 | 1571 | 766 | 196 | 160 | 7 | 14 | 11 | 82 | 78 | 82 | 18 | 41 | 17 | 31 | 2 | 4 | 31 | 2 | 51 | 71 |
| 38 | 1128 | 482 | 1303 | 807 | 158 | 171 | 5 | 10 | 8 | 51 | 50 | 55 | 11 | 22 | 10 | 15 | 1 | 2 | 12 | 1 | 39 | 85 |
| 39 | 729 | 363 | 1114 | 489 | 124 | 100 | 11 | 3 | 3 | 37 | 47 | 30 | 3 | 14 | 9 | 8 | 0.01 | 23 | 9 | 2 | 17 | 29 |
| 40 | 458 | 292 | 790 | 505 | 69 | 144 | 2 | 4 | 3 | 23 | 23 | 18 | 2 | 7 | 5 | 8 | 0.3 | 22 | 1 | 0.4 | 12 | 27 |
| 41 | 321 | 188 | 558 | 320 | 49 | 63 | 3 | 1 | 2 | 19 | 12 | 10 | 1 | 2 | 2 | 4 | 0.003 | 0.4 | 1 | 0.5 | 3 | 16 |
| 42 | 255 | 117 | 420 | 306 | 23 | 1 | 1 | 1 | 0.1 | 13 | 15 | 7 | 2 | 3 | 1 | 2 | 0.003 | 0.2 | 0.1 | 0.57 | 1 | 8 |
| 43 | 227 | 68 | 203 | 137 | 15 | 3 | 2 | 2 | 0.1 | 3 | 9 | 4 | 2 | 2 | 2 | 6 | | 0.5 | 3 | 0.02 | | 8 |
| 44 | 157 | 83 | 85 | 175 | 7 | 3 | 2 | 1 | 1 | 3 | 1 | 3 | 1 | 2 | 1 | 3 | | 0.1 | 0.05 | 0.23 | | |
| 45 | 84 | 33 | 76 | 107 | 1 | 3 | 2 | 0.1 | | | 2 | 1 | | 0.1 | 1 | 1 | | 0.1 | 1 | 0.3 | | |
| 46 | 58 | 8 | 32 | 9 | 3 | | | 0.1 | 0.02 | 0.2 | 1 | 1 | | 2 | 0.2 | 0.3 | | | | 0.1 | | |
| 47 | 24 | | 9 | 47 | 0.2 | | | | | | 0.5 | 0.2 | | 0.04 | 1 | 2 | | | | | | |
| 48 | 11 | 2 | 8 | 5 | | 3 | | 0.1 | | | | | | | | 0.04 | | | | | | |
| 49 | 6 | | 1 | | 0.1 | | | | | | | | | | | | | | 1 | | | |
| 50 | | | | | | | | | | | | | | | | | | | | | | |
| 51 | 1 | 25 | | | 2 | | | | | | | | | 0.3 | | | | | | | 0.03 | |
| 52 | 2 | | | | | | | | | | | | | | | | | | | | | |
| 53 | 1 | | | | | | | | | | | | | | | | | | | | | |
| 54 | 2 | | | | | | | | | | | | | 0.3 | | | | | | | | |
| **no ('000)** | 66410 | 74421 | 66375 | 47918 | 13517 | 3815 | 910 | 1411 | 2422 | 5457 | 6020 | 3076 | 2929 | 3999 | 1681 | 1632 | 2295 | 4454 | 2199 | 99003 | 21651 | 25584 |
| **weight (tons)** | 29105 | 25815 | 27283 | 21308 | 5741 | 1989 | 451 | 630 | 899 | 2318 | 2617 | 1442 | 1216 | 1334 | 637 | 659 | 497 | 1664 | 597 | 1051 | 3948 | 5768 |
| **mean weight (g)** | 438 | 347 | 411 | 445 | 425 | 521 | 496 | 446 | 371 | 425 | 435 | 469 | 415 | 334 | 379 | 404 | 217 | 365 | 271 | 109 | 182 | 225 |
| **mean length** | 29.3 | 26.6 | 28.4 | 29.6 | 29.1 | 31.6 | 31.2 | 29.8 | 27.4 | 29.9 | 30.1 | 30.8 | 29.5 | 27.5 | 29.5 | 30.1 | 23.9 | 29.4 | 25.4 | 19.0 | 22.8 | 24.4 |
| **length anomalies** | 1.41 | -1.3 | 0.5 | 1.7 | 1.2 | 3.7 | 3.3 | 1.9 | -0.5 | 2.0 | 2.2 | 2.9 | 1.6 | -0.4 | 1.5 | 2.2 | -4.0 | 1.5 | -2.5 | -8.9 | -5.2 | -3.6 |
| **%lengths <20cm** | 1.6% | **5.0%** | **2.6%** | 0.0% | 0.1% | 0.2% | 0.1% | 0.0% | 0.1% | 0.3% | 0.1% | 0.2% | 0.2% | **4.2%** | 0.5% | 0.9% | **10.1%** | 1.0% | **13.5%** | **85.1%** | **23.3%** | **14.0%** |

Table 3b: length weight relationships from 3LN Sebastes sp. commercial sampling data used in the computation of 3LN catch parameters (Alpoim and Vargas, 2004; Vargas et al., 2005-2008)

| *Sebastes sp.* | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *a* | 0.1115 | 0.1115 | 0.1115 | 0.1115 | 0.1115 | 0.1115 | 0.1115 | 0.1115 | 0.1115 | 0.0689 | 0.0979 | 0.0769 | 0.0447 | 0.0095 | 0.0208 | 0.0208 | 0.0611 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 |
| *b* | 2.4353 | 2.4353 | 2.4353 | 2.4353 | 2.4353 | 2.4353 | 2.4353 | 2.4353 | 2.4353 | 2.5588 | 2.4602 | 2.5298 | 2.6885 | 3.1279 | 2.8851 | 2.8851 | 2.5597 | 2.8946 | 2.8946 | 2.8946 | 2.8946 | 2.8946 |

Table 4: Survey biomass from all stratified bottom trawl surveys on Div. 3L and Div.3N, 1978-2011 (shaded observations included in the ASPIC 2012 assessment).
Survey female SSB from spring and autumn Canadian surveys on Div. 3LN, 1991-2011

| | Canadian | | | | Russian | | Canadian | | | | | | | Spanish |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Div. 3LN | | Div. 3LN | | Div. 3LN | Div. 3LN | Div. 3L | Div. 3L | Div. 3L | Div. 3L | Div. 3N | Div. 3N | Div. 3N | Div. 3N |
| | I2spring | I2springSSB | I3autumn | I3autumnSSB | I4Power | I4Vaskov | I5winter | I6summer | I7autumn | I8spring | I9spring | I10autumn | I11summer | I12spring |
| 1978 | | | | | | | | 311.2 | | | | | | |
| 1979 | | | | | | | | 227.8 | | | | | | |
| 1980 | | | | | | | | | | 40.3 | | | | |
| 1981 | | | | | | | | 261.4 | | | | | | |
| 1982 | | | | | | | | | | | | | | |
| 1983 | | | | | | | | | | | | | | |
| 1984 | | | | | 215.9 | 199.4 | | 277.7 | | | | | | |
| 1985 | | | | | 94.0 | 85.9 | 90.2 | 161.0 | 98.2 | 105.3 | | | | |
| 1986 | | | | | 63.0 | 46.8 | 36.6 | | 17.1 | | | | | |
| 1987 | | | | | 70.3 | 60.8 | | | | | | | | |
| 1988 | | | | | 44.9 | 40 | | | | | | | | |
| 1989 | | | | | 12.3 | 10.9 | | | | | | | | |
| 1990 | | | | | 8.4 | 7.1 | 18.2 | 92.8 | 20.7 | | | | | |
| 1991 | 10.6 | 1.45 | 37.9 | 4.7 | 18.7 | 14.5 | | 37.6 | 13.7 | 6.3 | 4.4 | 24.2 | 47.6 | |
| 1992 | 10.1 | 1.80 | *136.4* | 15.4 | | | | | 13.4 | 7.4 | 2.7 | *123.0* | | |
| 1993 | 22.6 | 4.35 | 19.2 | 3.6 | | 30.3 | | 20.8 | 6.0 | 6.5 | 16.1 | 13.2 | 129.8 | |
| 1994 | 4.2 | 0.61 | 31.8 | 5.9 | | | | | 7.2 | 2.3 | 1.9 | 24.6 | | |
| 1995 | 5.9 | 0.85 | *90.7* | 15.9 | | | | | *50.1* | 3.3 | 2.6 | 40.7 | | 46.1 |
| 1996 | 22.8 | 11.65 | 16.0 | 2.6 | | | | | 4.7 | 16.8 | 6.0 | 11.3 | | 6.6 |
| 1997 | 14.9 | 1.77 | 70.7 | 10.7 | | | | | 19.5 | 9.3 | 5.7 | 51.1 | | 4.8 |
| 1998 | 59.4 | 11.50 | 112.2 | 14.5 | | | | | 18.5 | 27.6 | 31.8 | 93.7 | | 22.5 |
| 1999 | 61.5 | 15.22 | 72.0 | 12.6 | | | | | 38.9 | 21.3 | 40.2 | 33.1 | | 46.5 |
| 2000 | 87.8 | 17.27 | 100.5 | 16.6 | | | | | 24.9 | 36.2 | 51.7 | 75.5 | | 68.9 |
| 2001 | 41.6 | 6.97 | 132.6 | 13.8 | | | | | 28.6 | 26.2 | 15.4 | 104.0 | | 53.9 |
| 2002 | 31.0 | 5.79 | 50.1 | 9.4 | | | | | 11.9 | 9.1 | 21.8 | 38.2 | | 7.6 |
| 2003 | 27.7 | 3.68 | 71.9 | 9.6 | | | | | 15.0 | 10.5 | 17.2 | 56.9 | | 11.0 |
| 2004 | 79.6 | 26.25 | 49.9 | 11.4 | | | | | 9.3 | 14.4 | 65.3 | 40.6 | | 27.0 |
| 2005 | 66.5 | 8.51 | 58.6 | 10.9 | | | | | 16.7 | 36.5 | 29.9 | 41.9 | | 146.9 |
| 2006 | | | 91.9 | 12.9 | | | | | 27.2 | 35.3 | | 64.7 | | 87.8 |
| 2007 | *218.8* | 39.27 | 124.8 | 16.5 | | | | | 57.5 | 174.1 | 44.7 | 67.2 | | 87.6 |
| 2008 | 144.0 | 22.93 | 198.5 | 26.7 | | | | | 53.3 | 38.5 | 105.5 | 145.2 | | 68.1 |
| 2009 | 183.4 | 20.26 | 246.7 | 29.1 | | | | | 87.2 | 26.1 | 157.3 | 159.5 | | 735.7 |
| 2010 | 165.3 | 20.57 | 461.49 | 53.3 | | | | | *324.4* | | | 137.1 | | 359.5 |
| 2011 | 173.7 | 21.86 | 562.3 | 62.9 | | | | | 71.4 | | | *490.9* | | 418.3 |

Table 5a: 3LN spring survey abundance at length, 1991-2011 (thousands).

| Length | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006[(1)] | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | | | | | | | | | | | | | | | 40 | | | | | | |
| 5 | | | | | | | | | | | | 62 | | 31 | | | | 416 | 46 | 258 | |
| 6 | | | | | | 466 | | 20 | 16 | 185 | 109 | 170 | 293 | 804 | 108 | | 154 | 1966 | 479 | 137 | 559 |
| 7 | | | | | | 228 | | 40 | 656 | 795 | 1511 | 472 | 2057 | 2400 | 540 | 309 | 3452 | 2942 | 974 | 562 | 781 |
| 8 | | | | | | 149 | 685 | 8 | 3280 | 378 | 1302 | 1073 | 1682 | 1236 | 950 | 602 | 9327 | 3135 | 954 | 936 | 858 |
| 9 | 849 | | | | | 298 | 360 | 39 | 5877 | 89 | 483 | 1526 | 1524 | 2209 | 2891 | 494 | 2625 | 3381 | 371 | 1361 | 1073 |
| 10 | 1149 | | | 562 | | 296 | 251 | 113 | 1343 | 166 | 240 | 2518 | 1197 | 4107 | 4892 | 633 | 886 | 4258 | 994 | 2423 | 1342 |
| 11 | 798 | 381 | 122 | 355 | | 478 | 730 | 533 | 309 | 403 | 116 | 1085 | 417 | 2911 | 7296 | 1235 | 1683 | 5317 | 1695 | 2902 | 2464 |
| 12 | 558 | 2988 | 1304 | 540 | | 806 | 722 | 455 | 430 | 191 | 451 | 1645 | 1448 | 1653 | 8756 | 1344 | 2296 | 2432 | 3642 | 2871 | 1701 |
| 13 | 2524 | 7925 | 2396 | 500 | 108 | 920 | 540 | 172 | 517 | 412 | 345 | 838 | 1101 | 1330 | 9684 | 1575 | 1908 | 1286 | 16098 | 2256 | 2458 |
| 14 | 322 | 5192 | 5646 | 536 | 272 | 413 | 1871 | 561 | 369 | 353 | 1073 | 517 | 1278 | 639 | 7710 | 2903 | 1928 | 5396 | 12659 | 4892 | 3568 |
| 15 | 699 | 2862 | 11059 | 1329 | 278 | 716 | 1859 | 896 | 175 | 2458 | 1738 | 766 | 2609 | 1235 | 7437 | 5776 | 3631 | 3841 | 11260 | 8481 | 4481 |
| 16 | 2250 | 382 | 13647 | 1790 | 966 | 846 | 1126 | 1506 | 774 | 2199 | 1681 | 1371 | 3559 | 1335 | 7357 | 8062 | 5993 | 15866 | 75231 | 14345 | 8907 |
| 17 | 3865 | 419 | 8796 | 3123 | 2847 | 1588 | 1201 | 2046 | 703 | 2157 | 3337 | 2580 | 6189 | 2764 | 8647 | 10733 | 14186 | 45719 | 197691 | 26140 | 17787 |
| 18 | 6226 | 1111 | 2719 | 3084 | 4285 | 4356 | 1860 | 2121 | 3455 | 3525 | 5257 | 6444 | 8643 | 3668 | 16472 | 12772 | 24586 | 77478 | 325440 | 108928 | 56811 |
| 19 | 7749 | 2480 | 2474 | 1403 | 5014 | 9476 | 3280 | 2849 | 2988 | 7017 | 8267 | 8161 | 15473 | 8995 | 31506 | 14610 | 26943 | 50553 | 310284 | 219289 | 115709 |
| 20 | 4522 | 2574 | 3839 | 829 | 2703 | 10910 | 4708 | 9472 | 5379 | 13198 | 9589 | 11326 | 21089 | 11905 | 33702 | 19196 | 26003 | 48021 | 164370 | 234599 | 144823 |
| 21 | 3482 | 3559 | 5754 | 922 | 1815 | 12119 | 6367 | 24848 | 16817 | 22002 | 14393 | 13958 | 23750 | 16956 | 33182 | 26687 | 43665 | 49072 | 92564 | 178663 | 221969 |
| 22 | 5148 | 1690 | 5301 | 783 | 1335 | 13844 | 7008 | 34265 | 31067 | 42769 | 15551 | 14932 | 19290 | 16584 | 30967 | 30007 | 68143 | 78864 | 60965 | 74436 | 128066 |
| 23 | 7253 | 1732 | 5708 | 1181 | 1257 | 16629 | 8191 | 31121 | 38232 | 53557 | 15590 | 15582 | 15120 | 20423 | 30644 | 23768 | 87375 | 88837 | 65881 | 72484 | 85379 |
| 24 | 6187 | 2721 | 4756 | 1498 | 1359 | 12502 | 10669 | 28376 | 45394 | 53956 | 14839 | 16034 | 10814 | 17004 | 28561 | 19150 | 96975 | 87288 | 76912 | 66508 | 62237 |
| 25 | 3366 | 2865 | 3398 | 1748 | 1004 | 8318 | 9469 | 21275 | 21482 | 34350 | 10166 | 12606 | 8036 | 14657 | 24305 | 10687 | 78847 | 61337 | 55777 | 61001 | 46547 |
| 26 | 1963 | 3250 | 3701 | 1564 | 1600 | 5649 | 7757 | 19512 | 30227 | 27846 | 10041 | 11224 | 6889 | 24397 | 18438 | 5467 | 90996 | 54230 | 30388 | 38296 | 44947 |
| 27 | 1426 | 2411 | 4478 | 1057 | 1693 | 5106 | 4047 | 16075 | 21654 | 21918 | 11330 | 8887 | 5102 | 38936 | 20027 | 6301 | 81118 | 34946 | 17043 | 18645 | 37756 |
| 28 | 953 | 1834 | 3283 | 803 | 1437 | 4901 | 2760 | 12716 | 15663 | 13775 | 10217 | 7496 | 3552 | 43216 | 15249 | 2764 | 36969 | 28227 | 14167 | 18908 | 32300 |
| 29 | 1038 | 1506 | 2876 | 731 | 1154 | 4264 | 1871 | 9632 | 14331 | 15612 | 10385 | 6419 | 2778 | 24426 | 11907 | 3259 | 38023 | 19445 | 13076 | 11302 | 24988 |
| 30 | 607 | 1048 | 2606 | 482 | 721 | 3323 | 1797 | 6120 | 6698 | 14650 | 9523 | 3741 | 2701 | 18145 | 8832 | 2641 | 30266 | 12314 | 8659 | 10701 | 16753 |
| 31 | 534 | 1014 | 2969 | 318 | 474 | 2231 | 1354 | 6513 | 5732 | 12804 | 10450 | 3588 | 2176 | 13713 | 5769 | 2039 | 30137 | 10571 | 6011 | 4704 | 10141 |
| 32 | 417 | 809 | 3087 | 244 | 548 | 1564 | 991 | 6157 | 4322 | 10277 | 8884 | 2235 | 2356 | 9706 | 3036 | 1869 | 21974 | 7018 | 4096 | 4110 | 8774 |
| 33 | 369 | 825 | 2621 | 138 | 264 | 762 | 640 | 5687 | 3259 | 6538 | 5183 | 1382 | 1972 | 3487 | 2012 | 1328 | 9163 | 7747 | 3448 | 2908 | 4925 |
| 34 | 399 | 540 | 2161 | 156 | 144 | 337 | 438 | 3287 | 2024 | 5043 | 3035 | 996 | 1009 | 5391 | 1617 | 371 | 8158 | 4329 | 2327 | 2565 | 2999 |
| 35 | 251 | 544 | 1502 | 109 | 105 | 163 | 160 | 967 | 877 | 3301 | 990 | 455 | 640 | 2249 | 832 | 263 | 7223 | 1860 | 1609 | 1804 | 1662 |
| 36 | 190 | 366 | 880 | 135 | 113 | 105 | 77 | 660 | 534 | 895 | 296 | 227 | 227 | 476 | 592 | 139 | 9422 | 1361 | 839 | 1035 | 1367 |
| 37 | 222 | 216 | 696 | 127 | 151 | 118 | 42 | 402 | 273 | 709 | 378 | 93 | 82 | 877 | 222 | 31 | 1894 | 786 | 312 | 394 | 788 |
| 38 | 159 | 219 | 669 | 82 | 101 | 28 | 88 | 82 | 102 | 396 | 116 | 43 | 35 | 75 | 112 | 46 | 1945 | 386 | 235 | 197 | 848 |
| 39 | 130 | 300 | 726 | 31 | 70 | 55 | 4 | 82 | 67 | 186 | 155 | 59 | 35 | 43 | 86 | | 193 | 325 | 90 | 31 | 224 |
| 40 | 118 | 220 | 483 | 46 | 62 | 28 | 0 | 216 | 79 | 183 | 23 | | 94 | 23 | 12 | | 115 | 189 | 55 | 54 | 71 |
| 41 | 45 | 77 | 371 | 0 | 15 | 15 | 0 | 15 | 51 | 16 | | 15 | | 4 | 15 | 46 | 59 | | 28 | | 119 |
| 42 | 88 | 85 | 215 | 9 | 46 | 4 | 0 | 20 | 66 | 47 | 63 | 15 | | 15 | 8 | 31 | 24 | 53 | 50 | | |
| 43 | 69 | 85 | 83 | 49 | 27 | 35 | 15 | 201 | 0 | 31 | 28 | | 15 | 15 | | 46 | 8 | | | 76 | |
| 44 | 45 | 77 | 189 | 29 | 31 | | 31 | 12 | 27 | 31 | 28 | | | | 15 | | 23 | 60 | | | |
| 45 | 57 | 62 | | | | 15 | 15 | 15 | | 31 | 15 | | | 8 | | | | | | | 91 |
| 46 | | 46 | 51 | | | 15 | 46 | | 31 | | | | | | | | | 34 | | | |
| 47 | | 4 | 20 | | 15 | | 15 | | | | | | | | | | | | | | |
| 48 | 11 | 31 | 31 | | | | | | | | | | | | | | | | 15 | | |
| 49 | | 31 | | | | | | | | | | | | | | | | | | | |
| **abundance (millions)** | 66.0 | 54.5 | 110.6 | 26.3 | 32.0 | 124.1 | 83.0 | 249.1 | 285.3 | 374.5 | 187.2 | 160.5 | 175.2 | 318.1 | 384.4 | 217.2 | 868.3 | 821.3 | 1576.7 | 1199.2 | 1096.3 |
| **mean length (cm)** | 21.6 | 21.6 | 22.6 | 21.5 | 22.7 | 23.4 | 23.5 | 25.1 | 24.7 | 25.3 | 25.2 | 23.5 | 22.0 | 25.7 | 22.2 | 21.9 | 25.1 | 22.9 | 20.3 | 21.6 | 22.6 |
| **length anomalies (cm)** | -1.5 | -1.5 | -0.5 | -1.6 | -0.4 | 0.3 | 0.4 | 2.0 | 1.6 | 2.2 | 2.1 | 0.4 | -1.1 | 2.6 | -0.9 | -1.2 | 2.0 | -0.2 | -2.8 | -1.5 | -0.5 |

(1) Survey data only from Division 3L

Table 5b: 3LN autumn survey abundance at length, 1991-2011 (thousands).

| Length | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | | | | | | | | | | | | | | | | | | | | | |
| 5 | | | | 15 | 240 | 56 | 86 | 17 | | 117 | 445 | 232 | 1090 | 34 | 0 | 84 | 234 | 31 | 96 | 1384 | 57 |
| 6 | | | | | 256 | 359 | 330 | 0 | 251 | 481 | 937 | 915 | 2427 | 85 | 133 | 1418 | 512 | 641 | 624 | 1110 | 318 |
| 7 | 203 | | | | 138 | 88 | 395 | 39 | 50 | 673 | 755 | 873 | 2185 | 61 | 162 | 1831 | 2222 | 2359 | 318 | 1405 | 727 |
| 8 | 1298 | | | | 111 | 72 | 386 | 47 | 37 | 602 | 2114 | 1614 | 2714 | 620 | 908 | 466 | 2914 | 2745 | 871 | 3377 | 878 |
| 9 | 1236 | | | | 241 | 146 | 468 | 252 | 421 | 620 | 3146 | 1275 | 2095 | 1280 | 2236 | 829 | 8313 | 2359 | 3452 | 3788 | 2878 |
| 10 | 7263 | | 93 | 31 | 292 | 250 | 306 | 214 | 171 | 388 | 4323 | 1129 | 2855 | 1719 | 1574 | 1458 | 8498 | 4100 | 9932 | 4676 | 2265 |
| 11 | 22235 | 371 | 63 | 31 | 213 | 349 | 249 | 203 | 402 | 215 | 2846 | 2840 | 1839 | 1046 | 3957 | 1709 | 7527 | 5543 | 5206 | 6612 | 1841 |
| 12 | 62419 | 62 | 372 | | 241 | 106 | 175 | 275 | 786 | 202 | 1266 | 2255 | 1123 | 1131 | 9942 | 3083 | 6352 | 4861 | 4025 | 7947 | 1925 |
| 13 | 109337 | 3189 | 457 | 335 | 304 | 274 | 366 | 596 | 868 | 320 | 1056 | 2072 | 1488 | 1436 | 11090 | 3970 | 5871 | 27297 | 9473 | 10315 | 3250 |
| 14 | 33876 | 27936 | 1775 | 551 | 513 | 1419 | 728 | 912 | 2472 | 587 | 445 | 2545 | 1451 | 1015 | 10309 | 8256 | 9046 | 28768 | 20311 | 11133 | 4187 |
| 15 | 14030 | 104298 | 1333 | 2362 | 967 | 722 | 1104 | 1768 | 1548 | 3635 | 407 | 1884 | 1929 | 538 | 8461 | 13286 | 21881 | 23691 | 17750 | 8561 | 8268 |
| 16 | 7809 | 113966 | 3259 | 3697 | 1611 | 919 | 1405 | 4159 | 717 | 4671 | 11018 | 2159 | 8240 | 879 | 6083 | 20912 | 40243 | 116528 | 35720 | 12943 | 14606 |
| 17 | 7860 | 106448 | 5283 | 12985 | 9645 | 825 | 1848 | 8155 | 1144 | 5480 | 31421 | 4694 | 15193 | 1984 | 5713 | 27177 | 51164 | 228751 | 138765 | 18474 | 46427 |
| 18 | 16191 | 95896 | 8707 | 28684 | 37932 | 2227 | 2095 | 12225 | 3185 | 7035 | 57695 | 9082 | 25813 | 5468 | 7248 | 23009 | 43358 | 221311 | 396982 | 77810 | 103647 |
| 19 | 32214 | 71577 | 6425 | 29295 | 72192 | 5062 | 8438 | 17373 | 6536 | 11926 | 74228 | 13661 | 38672 | 8222 | 10928 | 24342 | 35091 | 141084 | 421539 | 269160 | 432556 |
| 20 | 27189 | 113846 | 3906 | 15292 | 78316 | 6479 | 21672 | 46005 | 9068 | 31680 | 80538 | 12568 | 45262 | 9790 | 15982 | 26793 | 45870 | 78263 | 279787 | 459453 | 996936 |
| 21 | 15810 | 148628 | 5306 | 7701 | 43397 | 6621 | 47562 | 88726 | 15347 | 50184 | 65575 | 16481 | 42849 | 13134 | 25645 | 36447 | 55971 | 63995 | 138841 | 499979 | 1198226 |
| 22 | 7915 | 153395 | 6375 | 5119 | 27652 | 6123 | 52500 | 124662 | 23121 | 66781 | 130029 | 20168 | 39683 | 13632 | 23899 | 49628 | 61550 | 55482 | 67350 | 303473 | 587045 |
| 23 | 6139 | 89704 | 6578 | 6494 | 20117 | 6743 | 44777 | 92991 | 29000 | 60123 | 118427 | 23529 | 39374 | 16732 | 29785 | 71774 | 84212 | 89011 | 53177 | 261470 | 300782 |
| 24 | 8377 | 28658 | 5164 | 5456 | 10296 | 4864 | 31865 | 56410 | 26969 | 52986 | 85149 | 25353 | 31785 | 15458 | 20362 | 67361 | 81986 | 80398 | 65248 | 260734 | 126712 |
| 25 | 8943 | 14222 | 3947 | 6808 | 12898 | 4429 | 24356 | 30123 | 29819 | 50534 | 64519 | 21326 | 21398 | 13066 | 15824 | 34947 | 57418 | 66252 | 46806 | 165444 | 97731 |
| 26 | 6602 | 13410 | 4120 | 8670 | 8517 | 4370 | 21375 | 23090 | 27515 | 40188 | 39693 | 19872 | 18032 | 10432 | 12713 | 32335 | 39981 | 49866 | 39922 | 120859 | 82802 |
| 27 | 4022 | 14699 | 4361 | 7830 | 17364 | 2890 | 21141 | 20596 | 25585 | 21851 | 33743 | 16470 | 17605 | 9397 | 10857 | 19109 | 26128 | 48823 | 34957 | 95155 | 49339 |
| 28 | 3776 | 8768 | 4240 | 8402 | 17495 | 2707 | 14031 | 18336 | 24801 | 17424 | 20396 | 10503 | 13962 | 12135 | 12471 | 11651 | 19087 | 37469 | 24861 | 72543 | 35075 |
| 29 | 2526 | 4855 | 3503 | 7625 | 16330 | 2678 | 8032 | 13397 | 16323 | 16387 | 14957 | 7230 | 7798 | 13950 | 12659 | 10147 | 13206 | 21724 | 24372 | 38007 | 30904 |
| 30 | 2110 | 3340 | 2765 | 6195 | 12717 | 2242 | 6138 | 7942 | 11346 | 12127 | 11093 | 5122 | 4910 | 12267 | 9865 | 7475 | 7643 | 18374 | 14245 | 26788 | 35523 |
| 31 | 1960 | 3229 | 1949 | 4553 | 16297 | 3409 | 4994 | 6250 | 7641 | 10199 | 9147 | 5109 | 3755 | 9066 | 7347 | 9531 | 6404 | 11854 | 10895 | 15934 | 17230 |
| 32 | 1314 | 2389 | 1901 | 2709 | 10628 | 2210 | 4035 | 5730 | 6315 | 7165 | 5261 | 4608 | 3523 | 6787 | 5214 | 7469 | 4180 | 6793 | 7953 | 14869 | 11668 |
| 33 | 1212 | 3299 | 1671 | 1603 | 7262 | 1220 | 2107 | 3878 | 5642 | 5026 | 4354 | 3862 | 3360 | 4636 | 4905 | 4870 | 3623 | 6389 | 6675 | 9280 | 4838 |
| 34 | 1117 | 1431 | 1286 | 916 | 3447 | 559 | 1673 | 4512 | 4545 | 3369 | 2776 | 2701 | 2182 | 2959 | 3942 | 2096 | 2183 | 5268 | 3627 | 5875 | 2164 |
| 35 | 1287 | 716 | 1044 | 610 | 1966 | 217 | 653 | 2048 | 3256 | 1303 | 1679 | 1451 | 1175 | 1760 | 2720 | 1118 | 1067 | 2385 | 2538 | 1885 | 1869 |
| 36 | 1184 | 595 | 800 | 297 | 1171 | 118 | 499 | 1080 | 1539 | 1092 | 675 | 560 | 506 | 1259 | 1456 | 537 | 416 | 970 | 2183 | 2310 | 1332 |
| 37 | 1005 | 385 | 460 | 211 | 335 | 64 | 308 | 426 | 339 | 499 | 636 | 325 | 182 | 765 | 1298 | 444 | 847 | 784 | 1772 | 1299 | 817 |
| 38 | 1166 | 401 | 427 | 257 | 398 | 14 | 243 | 247 | 184 | 329 | 282 | 85 | 111 | 392 | 385 | 136 | 275 | 654 | 700 | 1374 | 138 |
| 39 | 787 | 228 | 308 | 274 | 572 | 22 | 176 | 85 | 272 | 227 | 215 | 67 | 115 | 666 | 228 | 55 | 40 | 0 | 300 | 372 | 136 |
| 40 | 662 | 93 | 237 | 119 | 75 | 22 | 164 | 17 | 67 | 151 | 180 | 136 | | 308 | 60 | 116 | 17 | 391 | 250 | 389 | 0 |
| 41 | 221 | 124 | 155 | 0 | 20 | 22 | 191 | 40 | 82 | 67 | 81 | | | 76 | 85 | 61 | 103 | | 129 | 208 | 0 |
| 42 | 135 | 77 | 132 | 15 | 24 | | 45 | | | 67 | | 17 | | 232 | 60 | | | 263 | 505 | 195 | 0 |
| 43 | 102 | 31 | 37 | 32 | 32 | | | 35 | 50 | | 4 | 21 | | 99 | | | | | 92 | | 45 |
| 44 | 128 | 46 | 99 | | | 42 | | 17 | 50 | 4 | | 17 | | | | | | | | | |
| 45 | 46 | 15 | 69 | 15 | 36 | 28 | | 17 | 50 | 76 | | 17 | | | | | 63 | 131 | 46 | 83 | |
| 46 | 24 | 46 | | | 12 | 14 | | | | 18 | 17 | | | | | 16 | | | | | |
| 47 | 15 | 15 | 15 | 8 | | 12 | | | 17 | | | | | | | | | | | | |
| 48 | | | | | | | | | 17 | | | | | | | | | 62 | | | |
| 49 | | 15 | | | | | | | | | | | | | | | | | | | |
| 50 | 15 | | | | | | | | | | | | | | | | | | | | |
| 51 | | | | | | | | | | | | | | | | | | | | | |
| 52 | | | | | | | | | | | | | | | | | | | | 1022 | |
| **abundance (millions)** | 422 | 1130 | 89 | 175 | 432 | 71 | 327 | 593 | 288 | 487 | 882 | 245 | 407 | 195 | 297 | 526 | 755 | 1456 | 1892 | 2797.7 | 4205.1 |
| **mean length (cm)** | 16.9 | 20.2 | 23.9 | 22.7 | 23.2 | 24.0 | 24.1 | 23.6 | 25.8 | 24.4 | 22.8 | 23.8 | 22.3 | 25.4 | 23.0 | 22.8 | 21.9 | 20.8 | 20.6 | 22.7 | 21.8 |
| **length anomalies (cm)** | -5.8 | -2.5 | 1.2 | 0.0 | 0.5 | 1.3 | 1.4 | 0.9 | 3.1 | 1.7 | 0.1 | 1.1 | -0.4 | 2.7 | 0.3 | 0.1 | -0.8 | -1.9 | -2.1 | 0.0 | -0.9 |

Table 6a: A traffic light rating of diagnostics for posible frameworks of ASPICfit 2012 assessment. Compairision with ASPICfit 2010 assessment.

| R squared in CPUE | ASPICfit 2012A | rate | ASPICfit 2012B | rate | ASPICfit 2012C | rate | ASPICfit 2012D | rate |
|---|---|---|---|---|---|---|---|---|
| I1 | -0.298 | -1 | -0.161 | -1 | -0.148 | -1 | 0.019 | 2 |
| I2 | 0.710 | 2 | 0.664 | 1 | 0.653 | 1 | 0.612 | 0 |
| I3 | 0.514 | 1 | 0.474 | 0 | 0.503 | 1 | 0.522 | 2 |
| I4 | 0.157 | 1 | 0.154 | 0 | 0.158 | 1 | 0.201 | 2 |
| I5 | 0.307 | 0 | 0.309 | 1 | 0.313 | 1 | 0.366 | 2 |
| I6 | 0.463 | 1 | 0.457 | 0 | 0.471 | 1 | 0.579 | 2 |
| I7 | 0.310 | 1 | 0.277 | 0 | 0.529 | 2 | 0.462 | 1 |
| N restarts | 248 | 1 | 353 | 0 | 280 | 1 | 124 | 2 |
| contrast index (ideal = 1.0) | 0.3967 | 1 | 0.3975 | 1 | 0.3749 | 0 | 0.6434 | 2 |
| nearness index (ideal = 1.0) | 0.9290 | 1 | 0.9371 | 1 | 0.9135 | 0 | 1.0000 | 2 |
| Total obj. function | 51.3034125 | 0 | 34.0409 | 1 | 44.8540 | 1 | 29.3160 | 2 |
| | | **8** | | **4** | | **8** | | **19** |

| | | |
|---|---|---|
| (green) | best result | 2 |
| (yellow) | intermediate result | 1 |
| (light orange) | worst result | 0 |
| (dark red) | violation of a basic ASPIC assumption | -1 |

ASPIC fit 2012 formulations:

**ASPICfit 2012A with 3N Spain**

I1 (Statlant CPUE)+I2 (3LN spring survey)+I3 (3N autumn survey)+I4 (3LN Power russian survey)+I5 (3L winter survey)+I6 (3L summer survey full series)+I7(3L autumn survey)+I8 (3N spanish survey)

**ASPICfit 2012B without 3N Spain**

I1 (Statlant CPUE)+I2 (3LN spring survey)+I3 (3N autumn survey)+I4 (3LN Power russian survey)+I5 (3L winter survey)+I6 (3L summer survey)+I7(3L autumn survey)

**ASPICfit 2012C with 3N Spain but 2009, 3L autumn but 2010 and 3N autumn but 2011**

I1 (Statlant CPUE)+I2 (3LN spring survey 1991-2005, 2007-2011)+I3 (3N autumn survey 1991, 1993-2010)+I4 (3LN Power russian survey)+I5 (3L winter survey)+I6 (3L summer survey)+
I7(3L autumn survey, 1985-1986, 1990-1994,1996-2009,2011)+I8 (3N spanish survey 1995-2008, 2010-2011)

**ASPICfit 2012D without 3N Spain, 3LN spring but 2007, 3L autumn but 2010 and 3N autumn but 2011**

I1 (Statlant CPUE)+I2 (3LN spring survey 1991-2005, 2008-2011)+I3 (3N autumn survey 1991, 1993-2010)+I4 (3LN Power russian survey)+I5 (3L winter survey)+I6 (3L summer survey)+
I7(3L autumn survey, 1985-1986, 1990-1994,1996-2009,2011)

Table 6b: Key parameters of posible frameworks for ASPICfit 2012 assessment *versus* ASPICfit 2010 assessment.

| | MSY | $F_{msy}$ | $F_{2011}/F_{msy}$ | $Ye_{2012}$ | $B_{msy}$ | $B_{2012}/B_{msy}$ |
|---|---|---|---|---|---|---|
| $ASPIC_{fit}$ 2012A | 49830 | 0.0997 | 0.0997 | 48820 | 500000 | 0.8579 |
| $ASPIC_{fit}$ 2012B | 46370 | 0.0927 | 0.1490 | 45630 | 500000 | 0.8742 |
| $ASPIC_{fit}$ 2012C | 45600 | 0.0912 | 0.1603 | 44230 | 500000 | 0.8270 |
| $ASPIC_{fit}$ 2012D | 23700 | 0.1053 | 0.1683 | 18360 | 225100 | 1.4750 |
| | MSY | $F_{msy}$ | $F_{2009}/F_{msy}$ | $Ye_{2010}$ | $B_{msy}$ | $B_{2010}/B_{msy}$ |
| $ASPIC_{fit}$ 2010 | 22580 | 0.1168 | 0.0140 | 15350 | 193300 | 1.5660 |

Table7a: Different random seed, seeds for key parameters and last year survey biomasses used on ASPIC$_{fit}$ 2012 sensitivity analysis (differences in bold for each input set)

| | Standard | -25%seed | +25%seed | 25% Pessimistic | 25% Optimistic | Last year$_{-25\% survB}$ | Last year$_{-10\% survB}$ | Last year$_{+10\% survB}$ | Last year$_{+25\% survB}$ |
|---|---|---|---|---|---|---|---|---|---|
| B1/K | 0.5d0 | 0.5d0 | 0.5d0 | **0.375** | **0.625** | 0.5d0 | 0.5d0 | 0.5d0 | 0.5d0 |
| MSY | 2.0d4 | 2.0d4 | 2.0d4 | **15000** | **25000** | 2.0d4 | 2.0d4 | 2.0d4 | 2.0d4 |
| K | 500000 | 500000 | 500000 | **375000** | **625000** | 500000 | 500000 | 500000 | 500000 |
| $q_{cpue}$ | 9.01E-06 | 9.01E-06 | 9.01E-06 | **1.13E-05** | **6.76E-06** | 9.01E-06 | 9.01E-06 | 9.01E-06 | 9.01E-06 |
| $q_{3LNspring}$ | 0.658 | 0.658 | 0.658 | **0.823** | **0.494** | 0.658 | 0.658 | 0.658 | 0.658 |
| $q_{3Nautumn}$ | 0.759 | 0.759 | 0.759 | **0.949** | **0.569** | 0.759 | 0.759 | 0.759 | 0.759 |
| $q_{3LNRussia}$ | 0.658 | 0.658 | 0.658 | **0.823** | **0.494** | 0.658 | 0.658 | 0.658 | 0.658 |
| $q_{3Lwinter}$ | 0.322 | 0.322 | 0.322 | **0.403** | **0.242** | 0.322 | 0.322 | 0.322 | 0.322 |
| $q_{3Lsummer}$ | 0.275 | 0.275 | 0.275 | **0.344** | **0.206** | 0.275 | 0.275 | 0.275 | 0.275 |
| $q_{3Lautumn}$ | 0.275 | 0.275 | 0.275 | **0.344** | **0.206** | 0.275 | 0.275 | 0.275 | 0.275 |
| Random seed | 3941285 | **2955964** | **4926606** | 3941285 | 3941285 | 3941285 | 3941285 | 3941285 | 3941285 |
| 3LNspring$_{2011}$ | 173692 | 173692 | 173692 | 173692 | 173692 | **130269** | **156323** | **191061** | **217115** |
| 3Lautumn$_{2011}$ | 71425 | 71425 | 71425 | 71425 | 71425 | **53569** | **64283** | **78568** | **89281** |

Table 7b: Compairision of main results from sensitivity analysis of ASPIC$_{fit}$ 2012

| | **Standard** | -25%seed | +25%seed | 25% Pessimistic | 25% Optimistic | Last year$_{-25\% survB}$ | Last year$_{-10\% survB}$ | Last year$_{+10\% survB}$ | Last year$_{+25\% survB}$ |
|---|---|---|---|---|---|---|---|---|---|
| K | **450300** | 453500 | 452900 | 450000 | 453000 | 421400 | 438500 | 465400 | 486800 |
| B1/K | **0.4434** | 0.4392 | 0.4400 | 0.444 | 0.440 | 0.4915 | 0.4620 | 0.4224 | 0.3957 |
| MSY | **23700** | 23780 | 23770 | 23690 | 23770 | 22920 | 23360 | 24160 | 24880 |
| $B_{msy}$ | **225100** | 226800 | 226500 | 225000 | 226500 | 210700 | 219200 | 232700 | 243400 |
| $F_{msy}$ | **0.1053** | 0.1049 | 0.1050 | 0.1053 | 0.1049 | 0.1088 | 0.1065 | 0.1038 | 0.1022 |
| $B_{2012}/B_{msy}$ | **1.4750** | 1.4680 | 1.4690 | 1.4750 | 1.4690 | 1.5510 | 1.5040 | 1.4400 | 1.3960 |
| $F_{2011}/F_{msy}$ | **0.1683** | 0.1686 | 0.1685 | 0.1683 | 0.1685 | 0.1649 | 0.1672 | 0.1693 | 0.1701 |
| $Ye_{2012}$ | **18360** | 18580 | 18540 | 18340 | 18550 | 15970 | 17420 | 19480 | 20980 |

Table 8: Compairision of key parameters for retrospective ASPIC last year 2011-2009 assessment.

| Last year | MSY | bias between consecutive years | $F_{msy}$ | bias between consecutive years | $F_{2009}/F_{msy}$ | bias between consecutive years | $B_{msy}$ | bias between consecutive years | $B_{2010}/B_{msy}$ | bias between consecutive years |
|---|---|---|---|---|---|---|---|---|---|---|
| 2009 | 22350 | | 0.116 | | 0.030 | | 192000 | | 1.587 | |
| 2010 | 22690 | 2% | 0.111 | -5% | 0.032 | 6% | 205100 | 7% | 1.477 | -7% |
| 2011 | 23700 | 4% | 0.105 | -5% | 0.034 | 6% | 225000 | 10% | 1.344 | -9% |

Table 9a: Compairision of $ASPIC_{2012}$ and $ASPIC_{2010}$ summaries of bootstrapped analysis results.

| Param. name | ASPIC assessment | Point estimate | Bias corrected | Estimated bias in pt estimate | Estimated relative bias | Bias-corrected approximate confidence limits 80% lower | 80% upper | 50% lower | 50% upper | Inter-quartile range | Relative IQ range |
|---|---|---|---|---|---|---|---|---|---|---|---|
| B1/K | 2012 | 0.443 | **0.507** | 0.064 | 14.37% | 0.241 | 0.643 | 0.315 | 0.519 | 0.204 | 0.460 |
| | 2010 | 0.541 | **0.591** | 0.050 | 9.25% | 0.312 | 0.832 | 0.411 | 0.658 | 0.247 | 0.456 |
| K | 2012 | 450300 | **466510** | 16210 | 3.60% | 351100 | 747600 | 398800 | 608400 | 209700 | 0.466 |
| | 2010 | 386700 | **414670** | 27970 | 7.23% | 316300 | 606000 | 345000 | 471600 | 126600 | 0.327 |
| MSY | 2012 | 23700 | **24799** | 1099 | 4.64% | 21360 | 31580 | 22430 | 26430 | 4002 | 0.169 |
| | 2010 | 22580 | **23906** | 1326 | 5.87% | 20400 | 24630 | 21310 | 23180 | 1871 | 0.083 |
| $Ye_{Last\ year+1}$ | 2012 | 18360 | **17642** | -718 | -3.91% | 10640 | 32820 | 14670 | 26200 | 11530 | 0.628 |
| | 2010 | 15350 | **15702** | 352 | 2.29% | 7152 | 25890 | 10590 | 20850 | 10260 | 0.668 |
| Bmsy | 2012 | 225100 | **233203** | 8103 | 3.60% | 175600 | 373800 | 199400 | 304200 | 104800 | 0.466 |
| | 2010 | 193300 | **207290** | 13990 | 7.23% | 158100 | 303000 | 172500 | 235800 | 63310 | 0.327 |
| Fmsy | 2012 | 0.105 | **0.111** | 0.006 | 5.50% | 0.082 | 0.131 | 0.090 | 0.116 | 0.027 | 0.253 |
| | 2010 | 0.117 | **0.121** | 0.004 | 3.27% | 0.090 | 0.149 | 0.100 | 0.132 | 0.032 | 0.273 |
| $B_{Last\ year+1}$/Bmsy | 2012 | 1.475 | **1.470** | -0.005 | -0.35% | 0.950 | 1.761 | 1.164 | 1.637 | 0.473 | 0.321 |
| | 2010 | 1.566 | **1.517** | -0.049 | -3.15% | 1.060 | 1.831 | 1.289 | 1.726 | 0.437 | 0.279 |
| $F_{Last\ year}$/Fmsy | 2012 | 0.168 | **0.170** | 0.00196 | 1.16% | 0.139 | 0.241 | 0.153 | 0.204 | 0.050 | 0.299 |
| | 2010 | 0.014 | **0.014** | 0.00042 | 2.97% | 0.011 | 0.020 | 0.013 | 0.017 | 0.005 | 0.327 |

Table 9b; Bias corrected trajectories from $ASPIC_{bot}$ 2012 assessment.

| Year | B/Bmsy | | | F/Fmsy | | |
|---|---|---|---|---|---|---|
| | Point estimate | Estimated bias | Bias corrected | Point estimate | Estimated bias | Bias corrected |
| 1959 | 0.887 | 0.127 | 1.014 | 2.247 | -0.122 | 2.125 |
| 1960 | 0.791 | 0.110 | 0.901 | 1.433 | -0.073 | 1.360 |
| 1961 | 0.774 | 0.101 | 0.874 | 1.267 | -0.061 | 1.206 |
| 1962 | 0.770 | 0.094 | 0.864 | 1.171 | -0.053 | 1.118 |
| 1963 | 0.775 | 0.089 | 0.864 | 1.512 | -0.065 | 1.447 |
| 1964 | 0.753 | 0.083 | 0.836 | 0.555 | -0.023 | 0.532 |
| 1965 | 0.807 | 0.081 | 0.888 | 1.229 | -0.048 | 1.181 |
| 1966 | 0.804 | 0.076 | 0.880 | 0.876 | -0.033 | 0.843 |
| 1967 | 0.831 | 0.072 | 0.903 | 1.397 | -0.050 | 1.347 |
| 1968 | 0.812 | 0.067 | 0.879 | 0.905 | -0.031 | 0.874 |
| 1969 | 0.836 | 0.064 | 0.899 | 1.256 | -0.041 | 1.215 |
| 1970 | 0.828 | 0.060 | 0.888 | 0.718 | -0.022 | 0.696 |
| 1971 | 0.867 | 0.057 | 0.924 | 1.724 | -0.052 | 1.672 |
| 1972 | 0.817 | 0.052 | 0.869 | 1.521 | -0.043 | 1.478 |
| 1973 | 0.789 | 0.049 | 0.838 | 1.838 | -0.049 | 1.789 |
| 1974 | 0.741 | 0.046 | 0.787 | 1.270 | -0.032 | 1.238 |
| 1975 | 0.740 | 0.045 | 0.785 | 1.006 | -0.025 | 0.981 |
| 1976 | 0.759 | 0.045 | 0.804 | 1.134 | -0.027 | 1.107 |
| 1977 | 0.767 | 0.045 | 0.812 | 0.892 | -0.020 | 0.872 |
| 1978 | 0.794 | 0.044 | 0.838 | 0.621 | -0.014 | 0.607 |
| 1979 | 0.843 | 0.044 | 0.886 | 0.688 | -0.015 | 0.673 |
| 1980 | 0.883 | 0.042 | 0.925 | 0.752 | -0.016 | 0.736 |
| 1981 | 0.916 | 0.039 | 0.956 | 1.120 | -0.022 | 1.098 |
| 1982 | 0.913 | 0.035 | 0.949 | 0.991 | -0.019 | 0.972 |
| 1983 | 0.922 | 0.032 | 0.954 | 0.895 | -0.017 | 0.879 |
| 1984 | 0.939 | 0.029 | 0.968 | 0.650 | -0.012 | 0.638 |
| 1985 | 0.979 | 0.027 | 1.006 | 0.880 | -0.016 | 0.864 |
| 1986 | 0.992 | 0.024 | 1.016 | 1.904 | -0.033 | 1.871 |
| 1987 | 0.907 | 0.018 | 0.925 | 4.315 | -0.071 | 4.244 |
| 1988 | 0.656 | 0.009 | 0.665 | 3.900 | -0.061 | 3.839 |
| 1989 | 0.505 | 0.006 | 0.511 | 3.043 | -0.049 | 2.994 |
| 1990 | 0.431 | 0.005 | 0.436 | 3.080 | -0.052 | 3.028 |
| 1991 | 0.369 | 0.006 | 0.374 | 3.202 | -0.057 | 3.145 |
| 1992 | 0.314 | 0.006 | 0.320 | 4.167 | -0.070 | 4.097 |
| 1993 | 0.242 | 0.006 | 0.248 | 4.203 | -0.039 | 4.164 |
| 1994 | 0.188 | 0.006 | 0.194 | 1.252 | 0.000 | 1.252 |
| 1995 | 0.199 | 0.009 | 0.209 | 0.391 | 0.000 | 0.391 |
| 1996 | 0.231 | 0.014 | 0.245 | 0.075 | 0.000 | 0.075 |
| 1997 | 0.275 | 0.020 | 0.295 | 0.089 | 0.000 | 0.088 |
| 1998 | 0.326 | 0.027 | 0.353 | 0.107 | -0.001 | 0.106 |
| 1999 | 0.383 | 0.035 | 0.418 | 0.237 | -0.001 | 0.236 |
| 2000 | 0.442 | 0.043 | 0.485 | 0.281 | -0.001 | 0.279 |
| 2001 | 0.504 | 0.050 | 0.554 | 0.112 | 0.000 | 0.112 |
| 2002 | 0.581 | 0.057 | 0.637 | 0.082 | 0.000 | 0.082 |
| 2003 | 0.665 | 0.061 | 0.727 | 0.079 | 0.000 | 0.079 |
| 2004 | 0.756 | 0.063 | 0.819 | 0.033 | 0.000 | 0.034 |
| 2005 | 0.854 | 0.062 | 0.916 | 0.031 | 0.000 | 0.031 |
| 2006 | 0.956 | 0.058 | 1.013 | 0.021 | 0.000 | 0.021 |
| 2007 | 1.058 | 0.050 | 1.108 | 0.063 | 0.001 | 0.064 |
| 2008 | 1.155 | 0.040 | 1.195 | 0.021 | 0.000 | 0.021 |
| 2009 | 1.253 | 0.029 | 1.282 | 0.034 | 0.000 | 0.035 |
| 2010 | 1.344 | 0.017 | 1.361 | 0.126 | 0.001 | 0.127 |
| 2011 | 1.416 | 0.005 | 1.421 | 0.168 | 0.002 | 0.170 |
| 2012 | 1.475 | -0.005 | 1.470 | | | |

Table 10a: B/Bmsy short term projections with 80% lower CL's for several fishing mortality options relative to Fmsy. (a status quo level of catch is assumed for 2012)

| | Bias corrected B/Bmsy | | | | Approx 80% lower CL for B/Bmsy | | | |
|---|---|---|---|---|---|---|---|---|
| | $F_{2011}$/Fmsy | Fmsy | | | $F_{2011}$/Fmsy | Fmsy | | |
| Year | | 1/6 | 1/3 | 2/3 | | 1/6 | 1/3 | 2/3 |
| 2012 | 1.470 | 1.470 | 1.470 | 1.470 | 0.950 | 0.950 | 0.950 | 0.950 |
| 2013 | 1.514 | 1.514 | 1.514 | 1.514 | 1.023 | 1.023 | 1.023 | 1.023 |
| 2014 | 1.554 | 1.554 | 1.528 | 1.478 | 1.078 | 1.079 | 1.059 | 1.030 |
| 2015 | 1.588 | 1.589 | 1.541 | 1.450 | 1.151 | 1.151 | 1.120 | 1.037 |

Table 10b: Predicted 2013-2014 yields correponding to the fishing mortality options used in the short term projections.

| | Predicted Yields | | | |
|---|---|---|---|---|
| | $F_{2011}$/Fmsy | Fmsy | | |
| Year | | 1/6 | 1/3 | 2/3 |
| 2012 | 5768 | 5768 | 5768 | 5768 |
| 2013 | 6172 | 6113 | 12126 | 23830 |
| 2014 | 6346 | 6287 | 12277 | 23397 |
| $AV_{2013-2014}$ | 6259 | 6200 | 12202 | 23613 |

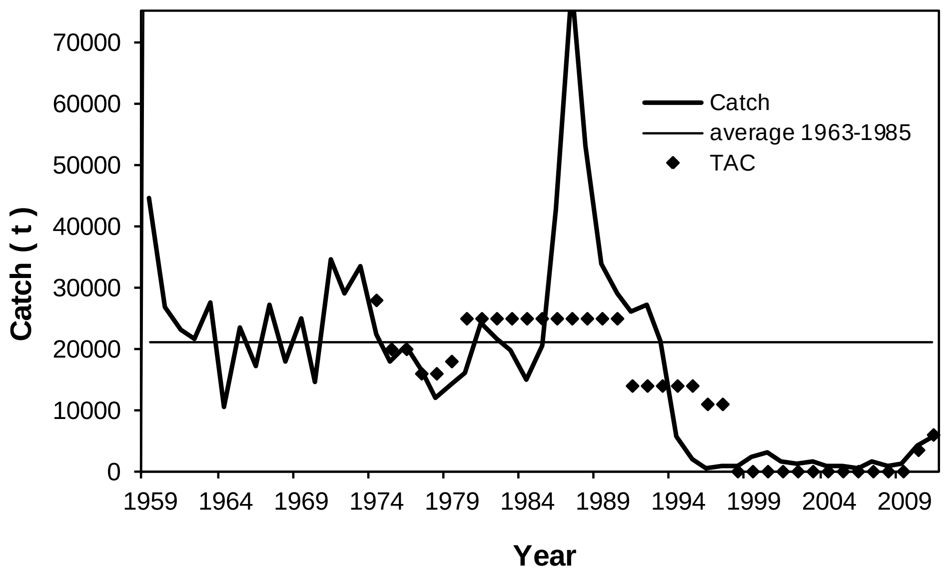


**Fig. 1: Redfish catch and TAC's in Div. 3LN**

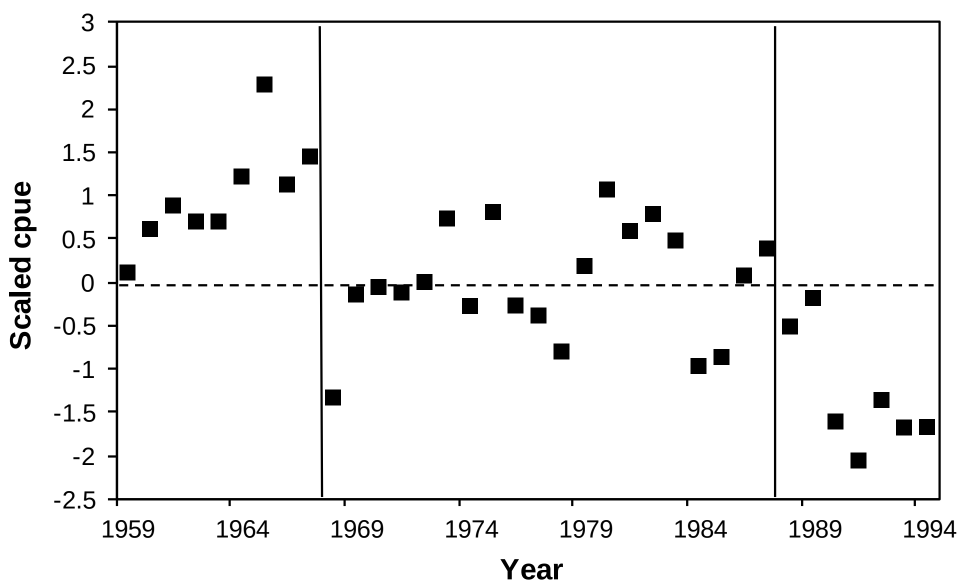


**Fig. 2: Redfish Div. 3LN cpue 1959-1994**

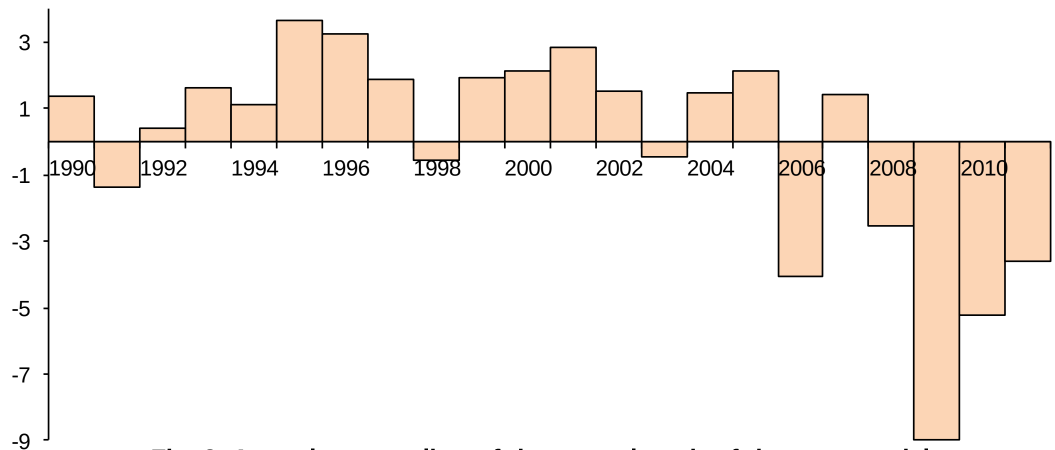


**Fig. 3: Annual annomalies of the mean length of the commercial catch, 1990-2011**

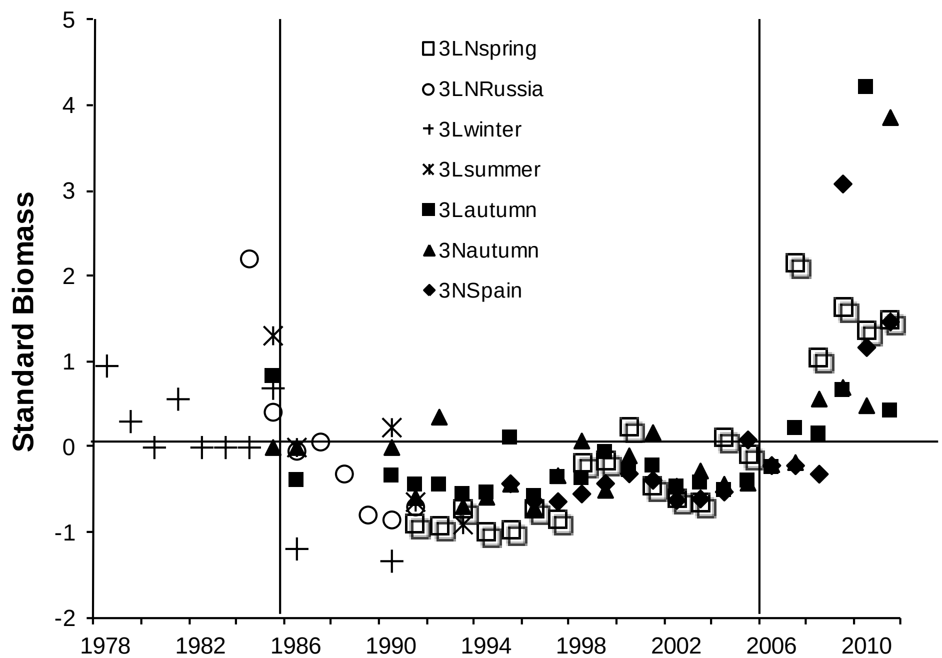


**Fig. 4a: Standardized biomass from bottom trawl surveys included in ASPIC framework, 1978-2011**

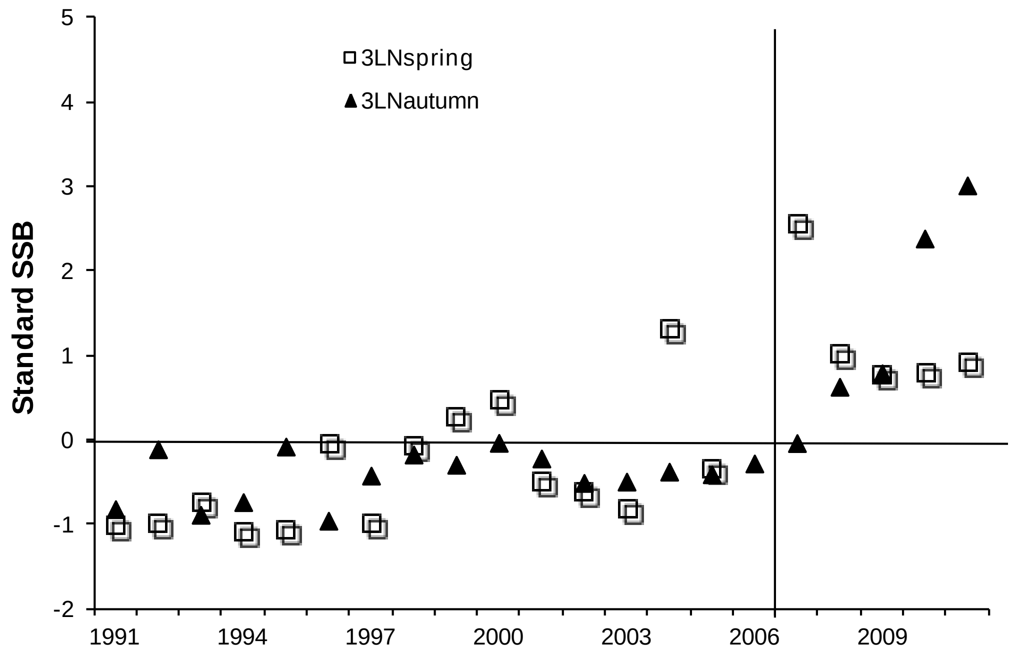


**Fig. 4b: Standardized survey female SSB from spring and autumn Canadian surveys on Div. 3LN, 1991-2011**

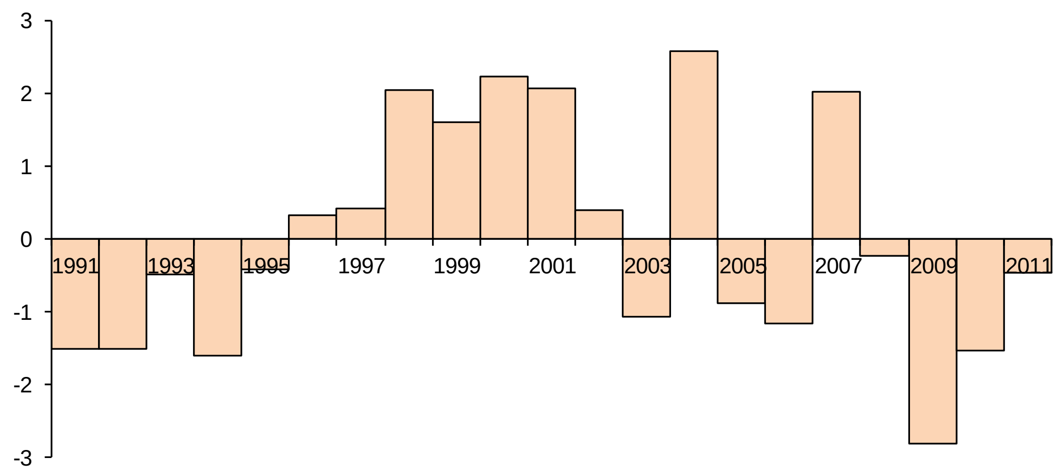


**Fig. 5a: Annual annomalies of the mean length on the spring survey stock, 1991-2011**

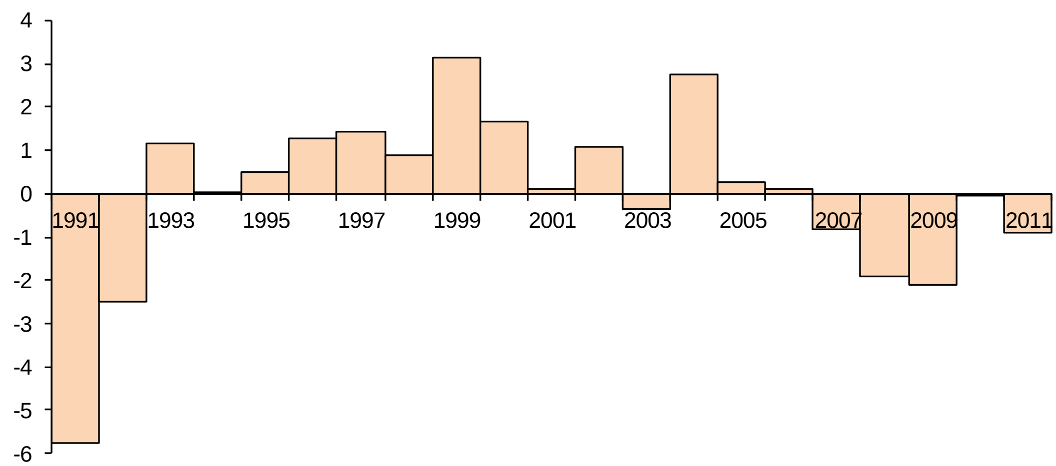


**Fig. 5b: Annual annomalies of the mean length on the atumng survey stock, 1991-2011**

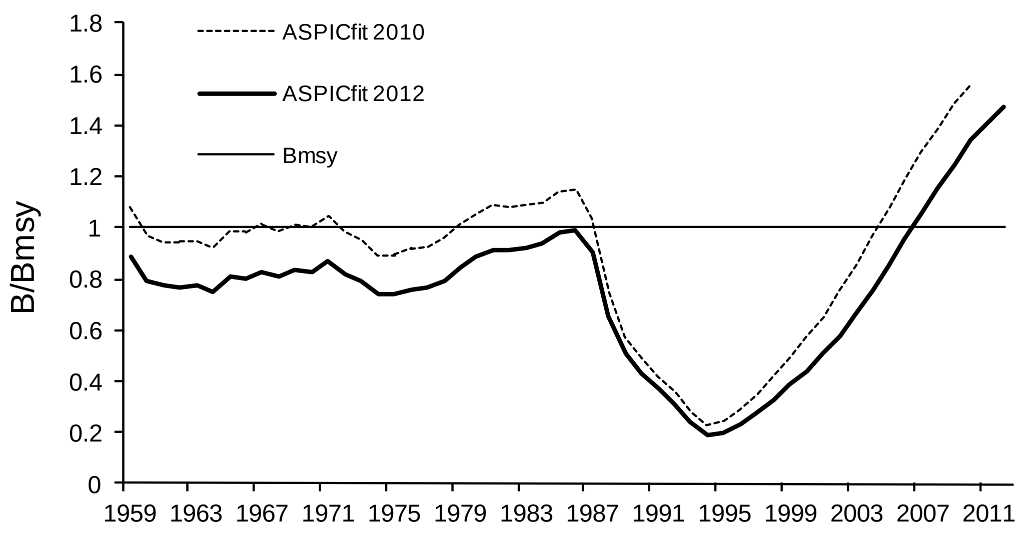


**Fig. 6a: B/Bmsy from 2010 and 2012 ASPIC$_{fit}$**

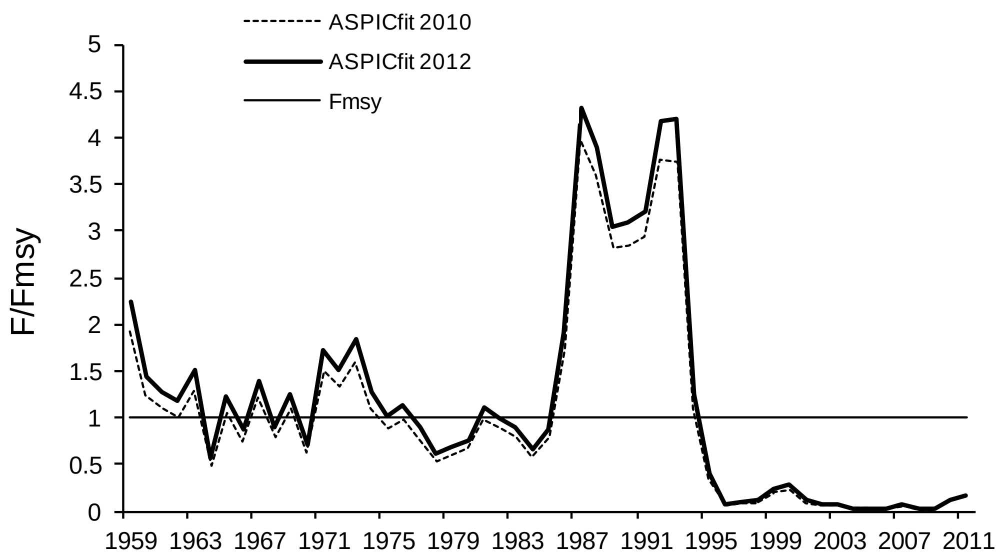


**Fig. 6b: F/Fmsy from 2010 and 2012 $ASPIC_{fit}$**

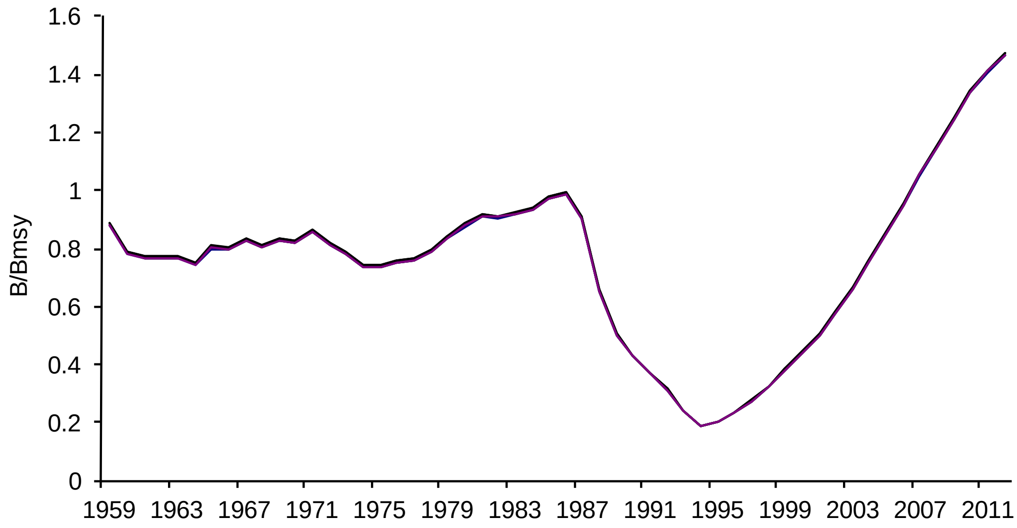


**Fig. 7a: Impact of different sets of initial parameters and random seeds on the B/Bmsy trajectory of ASPIC$_{fit}$ 2012**

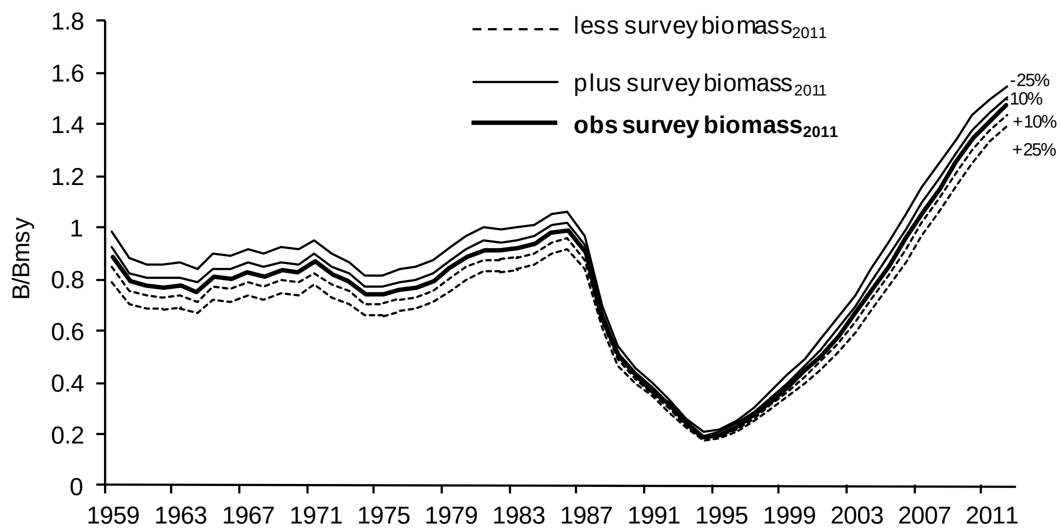


**Fig. 7b: Impact of last year 3LN$_{spring}$ and 3L$_{autumn}$ survey biomass on B/Bmsy trajectory of ASPIC$_{fit}$ 2012**

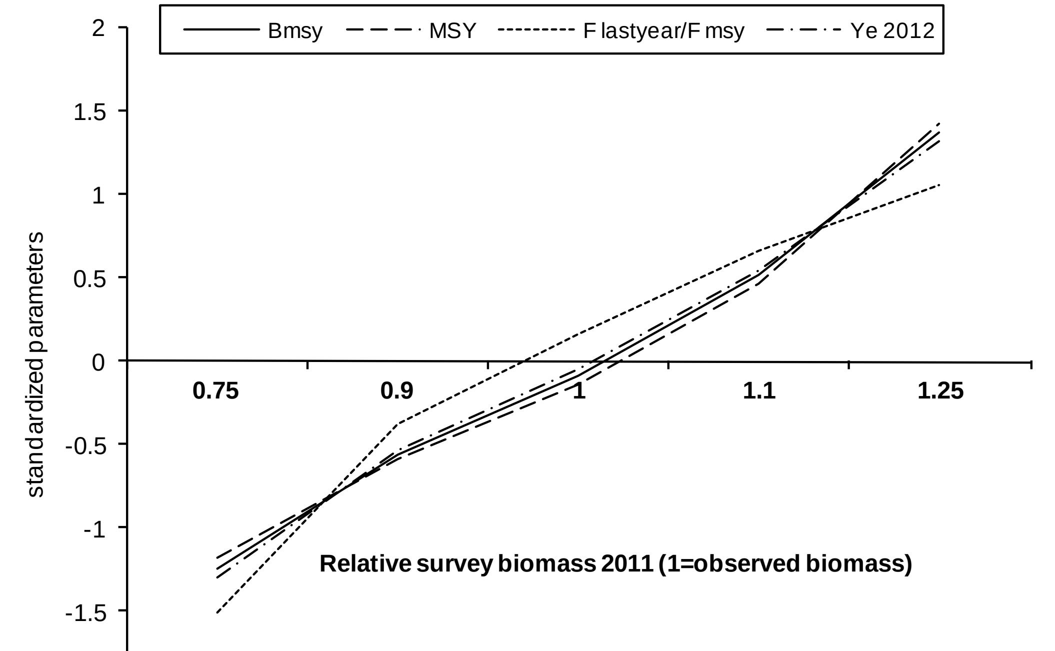


**Fig. 7c: Impact of last year surveys on ASPIC results I (positive dependent parameters)**

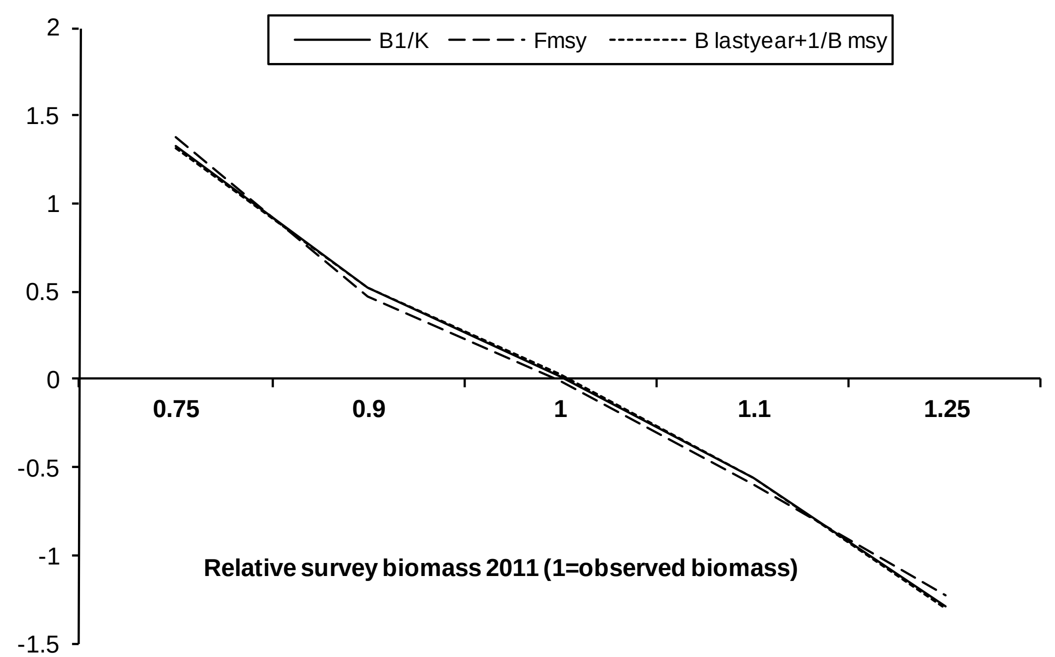


**Fig. 7d: Impact of last year surveys on ASPIC results II (negative dependent parameters)**

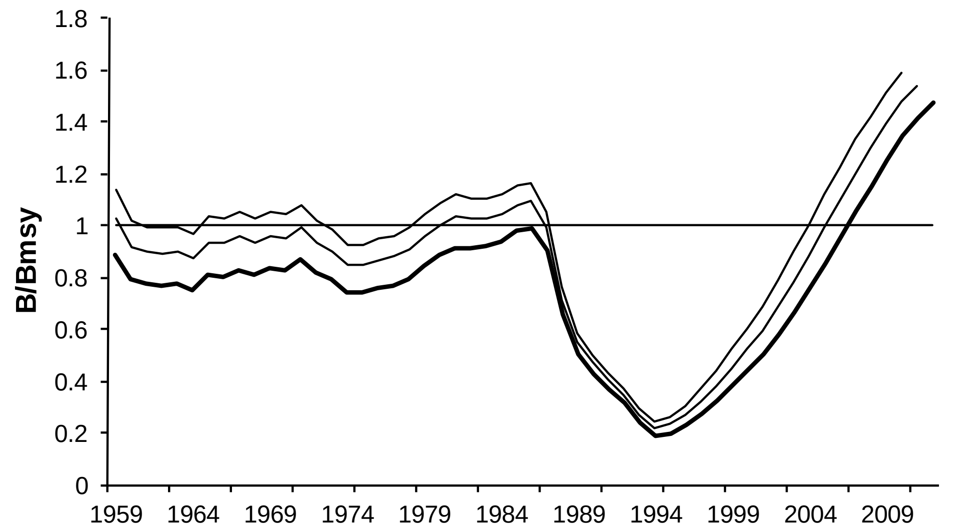


**Fig. 8a: B/Bmsy trajectories from retrospective ASPIC last year 2011-2009**

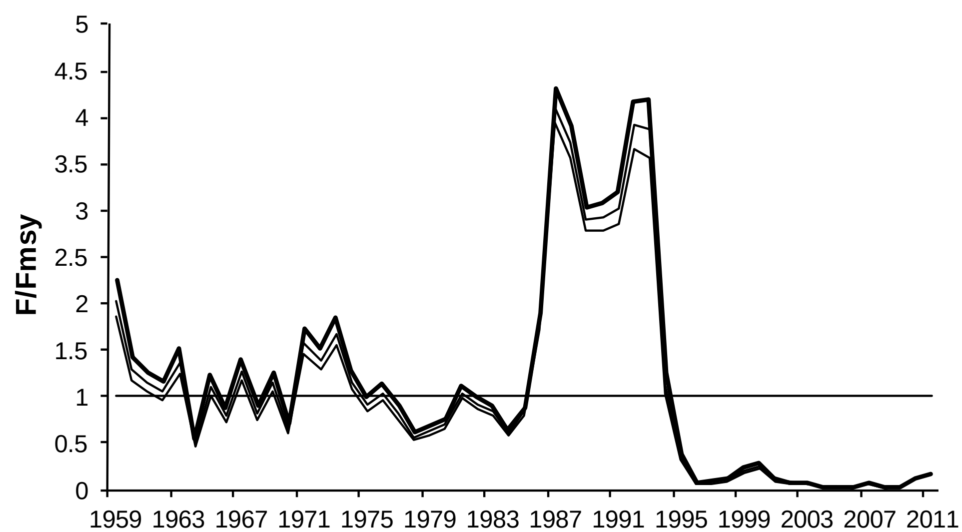


**Fig. 8b : F/Fmsy trajectories from retrospective ASPIC last year 2011-2009**

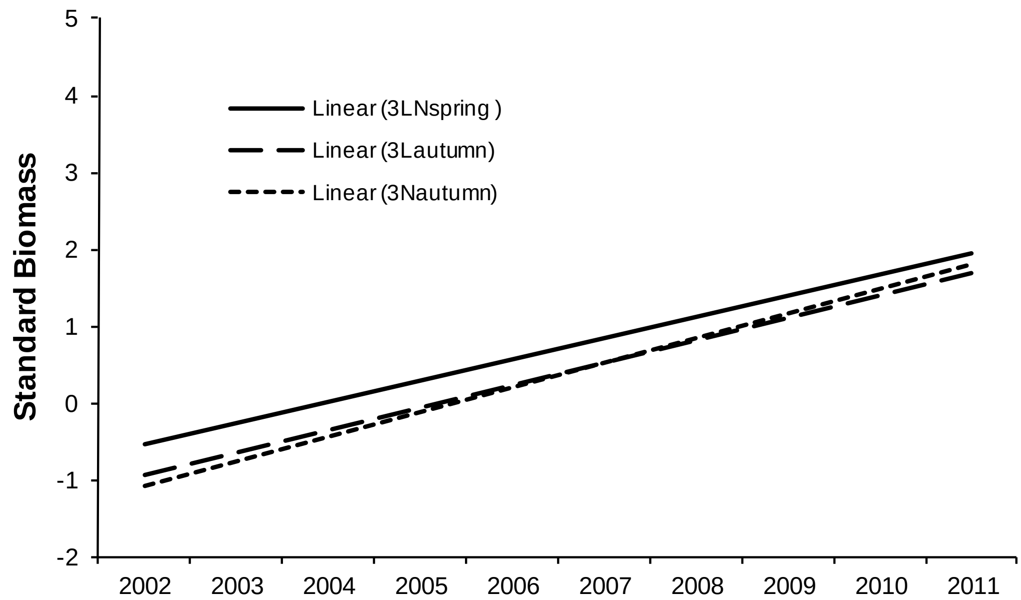


**Fig. 8c: trends of the actual bottom trawl surveys included in ASPIC framework, 2002-2011**

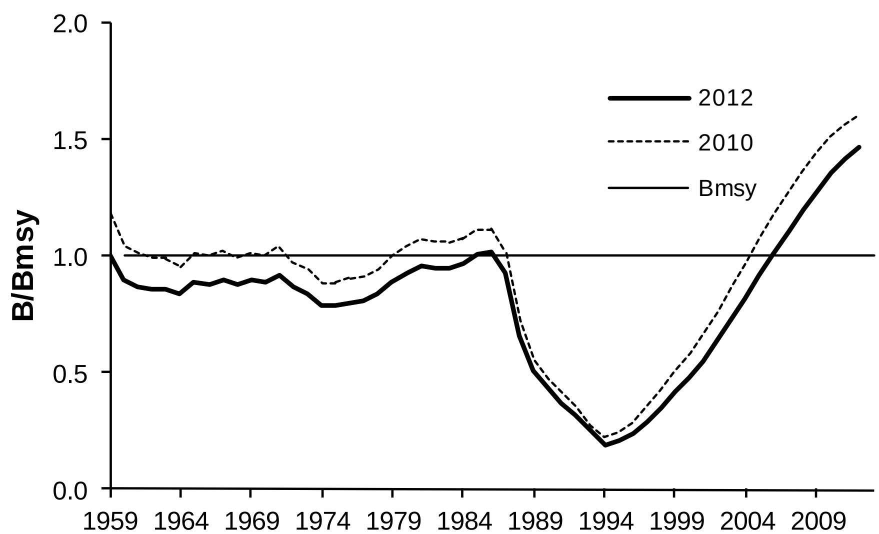


**Fig. 9a: B/Bmsy bias corrected trajectories from $ASPIC_{bot}$ 2010 and 2012 assessments**

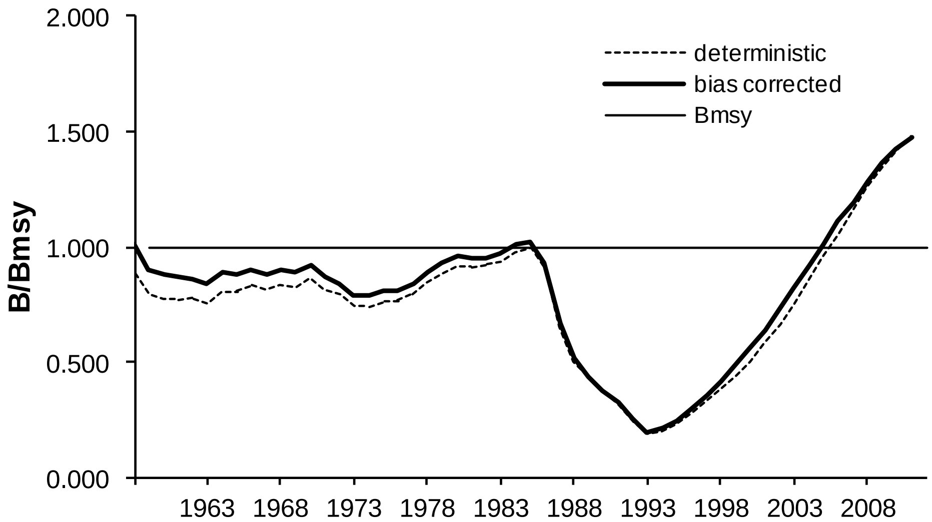


**Fig. 9b: B/Bmsy deterministic and bias corrected trajectories for $ASPIC_{bot}$ 2012**

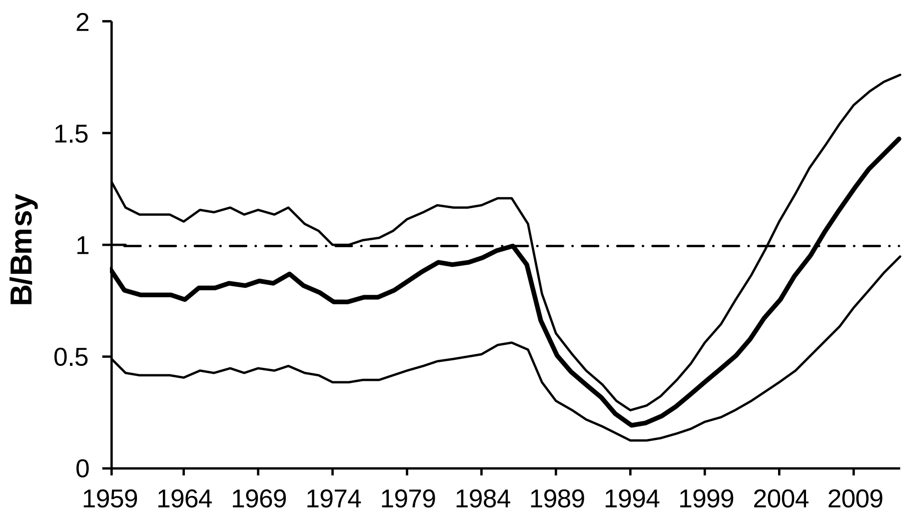


**Fig. 9c: B/Bmsy trajectories for $ASPIC_{bot}$ 2012 (point estimates with approximate 80% CL's)**

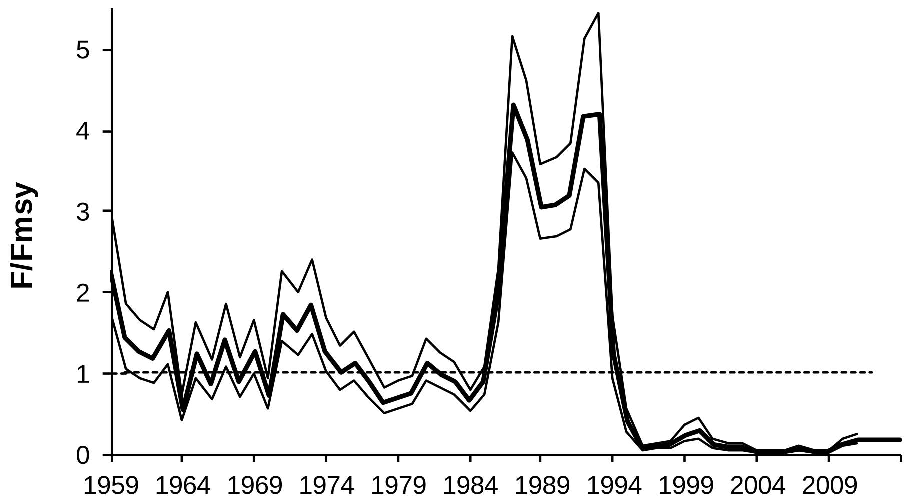


**Fig. 9d: F/Fmsy trajectories for ASPIC$_{bot}$ 2012 (point estimates with approximate 80% CL's)**

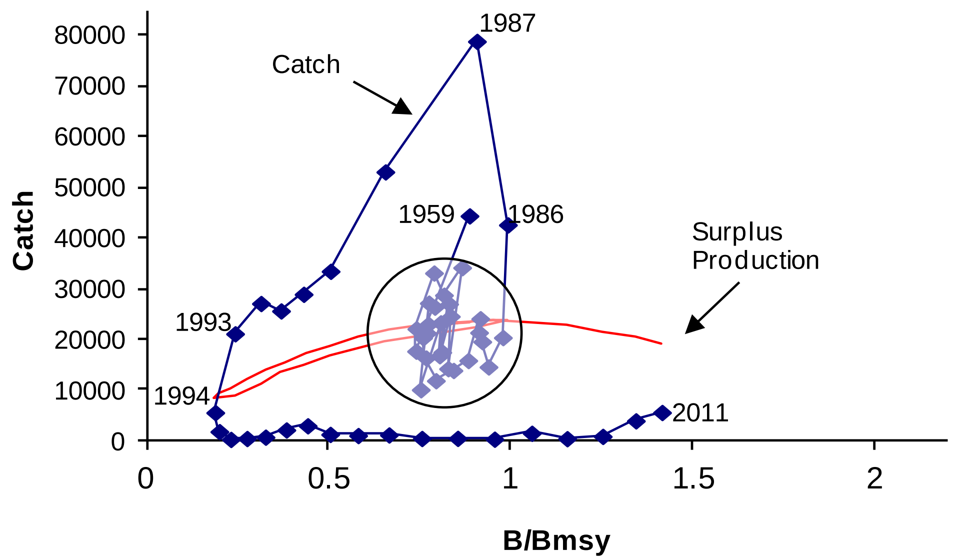


**Fig. 10: Catch versus Surplus Production from ASPIC$_{fit}$ 2012**

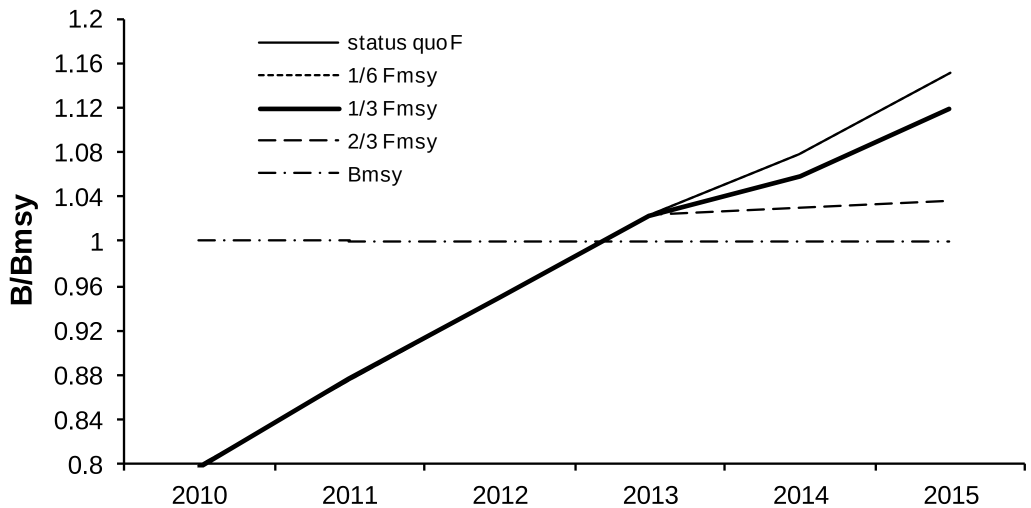


**Fig. 11: 2010-2015 lower 80% CL of B/Bmsy trajectories under several 2013-2014 F options.**

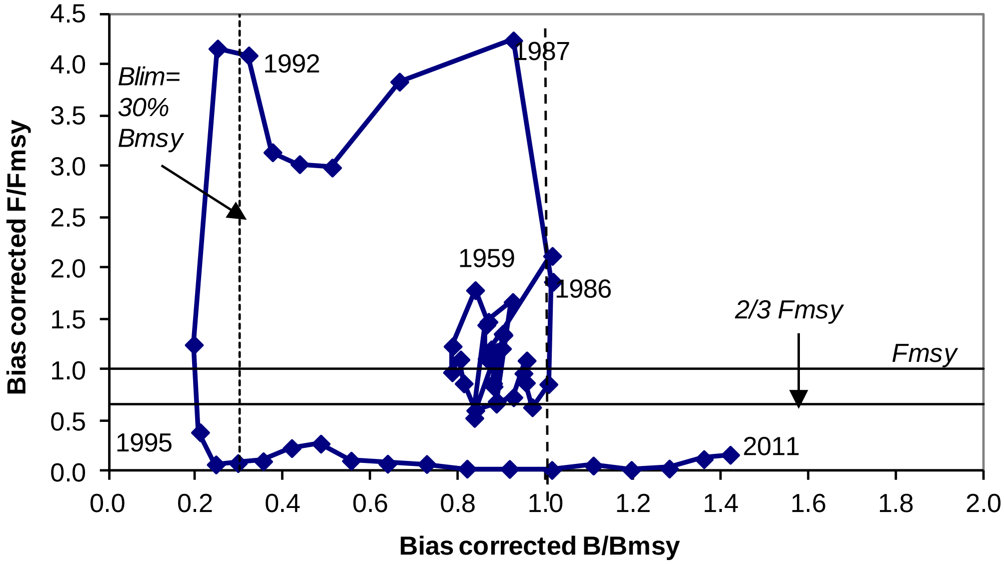


**Fig. 12: Stock trajectory under a precautionary framework for $ASPIC_{bot}$ 2012**

Appendix 1: input file with all survey sets

```
FIT                                                 ## Run type (FIT, BOT, or IRF)
"3LN redfish"
LOGISTIC  YLD    SSE
2                                                   ## Verbosity
1000  50                                            ## Number of bootstrap trials, <= 1000
0  20000                                            ## 0=no MC search, 1=search, 2=repeated srch; N trials
1.0000E-08                                          ## Convergence crit. for simplex
3.0000E-08  6                                       ## Convergence crit. for restarts, N restarts
1.0000E-04  24                                      ## Conv. crit. for F; N steps/yr for gen. model
6.0000                                              ## Maximum F when cond. on yield
0.0                                                 ## Stat weight for B1>K as residual (usually 0 or 1)
8                                                   ## Number of fisheries (data series)
1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00
                                                    ## Statistical weights for data series
0.5000                                              ## B1/K (starting guess, usually 0 to 1)
2.0000E+04                                          ## MSY (starting guess)
5.0000E+05                                          ## K (carrying capacity) (starting guess)
9.0070E-06  6.5800E-01  7.5900E-01  6.5800E-01  3.2200E-01  2.7500E-01  2.7500E-01  7.5900E-01
                                                    ## q (starting guesses -- 1 per data series)
1  1  1  1  1  1  1  1  1  1  1                     ## Estimate flags (0 or 1) (B1/K,MSY,K,q1...qn)
5.0000E+03  5.0000E+04                              ## Min and max constraints -- MSY
1.0000E+05  1.0000E+06                              ## Min and max constraints -- K
3941285                                             ## Random number seed
53                                                  ## Number of years of data in each series
"Statlant CPUE"
CC
   1959     1.426000E+00     4.458500E+04
   1960     1.602000E+00     2.656200E+04
   1961     1.697000E+00     2.317500E+04
   1962     1.631000E+00     2.143900E+04
   1963     1.632000E+00     2.736200E+04
   1964     1.812000E+00     1.026100E+04
   1965     2.185000E+00     2.346600E+04
   1966     1.781000E+00     1.697400E+04
   1967     1.893000E+00     2.718800E+04
   1968     9.220000E-01     1.766000E+04
   1969     1.338000E+00     2.475000E+04
   1970     1.367000E+00     1.441900E+04
   1971     1.346000E+00     3.437000E+04
   1972     1.387000E+00     2.893300E+04
   1973     1.643000E+00     3.329700E+04
   1974     1.290000E+00     2.228600E+04
   1975     1.669000E+00     1.787100E+04
   1976     1.292000E+00     2.051300E+04
   1977     1.251000E+00     1.651600E+04
   1978     1.106000E+00     1.204300E+04
   1979     1.451000E+00     1.406700E+04
   1980     1.761000E+00     1.603000E+04
   1981     1.594000E+00     2.428000E+04
   1982     1.661000E+00     2.154700E+04
   1983     1.556000E+00     1.974700E+04
   1984     1.049000E+00     1.476100E+04
   1985     1.084000E+00     2.055700E+04
   1986     1.413000E+00     4.280500E+04
   1987     1.523000E+00     7.903100E+04
   1988     1.208000E+00     5.326600E+04
   1989     1.322000E+00     3.364900E+04
   1990     8.250000E-01     2.910500E+04
   1991     6.680000E-01     2.581500E+04
   1992     9.120000E-01     2.728300E+04
   1993     8.010000E-01     2.130800E+04
   1994     8.020000E-01     5.741000E+03
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   1997    -1.000000E-03     6.300000E+02
   1998    -1.000000E-03     8.990000E+02
   1999    -1.000000E-03     2.318000E+03
   2000    -1.000000E-03     3.141000E+03
   2001    -1.000000E-03     1.442000E+03
   2002    -1.000000E-03     1.216000E+03
   2003    -1.000000E-03     1.334000E+03
   2004    -1.000000E-03     6.370000E+02
   2005    -1.000000E-03     6.590000E+02
   2006    -1.000000E-03     4.960000E+02
   2007    -1.000000E-03     1.664000E+03
   2008    -1.000000E-03     5.970000E+02
   2009    -1.000000E-03     1.051000E+03
   2010    -1.000000E-03     4.120000E+03
   2011    -1.000000E-03     5.768000E+03
```

"3LN spring survey"
I1

| | |
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| 1992 | 1.006600E+04 |
| 1993 | 2.257300E+04 |
| 1994 | 4.162000E+03 |
| 1995 | 5.856000E+03 |
| 1996 | 2.281200E+04 |
| 1997 | 1.492800E+04 |
| 1998 | 5.940200E+04 |
| 1999 | 6.149600E+04 |
| 2000 | 8.784200E+04 |
| 2001 | 4.157300E+04 |
| 2002 | 3.095900E+04 |
| 2003 | 2.770000E+04 |
| 2004 | 7.963100E+04 |
| 2005 | 6.646200E+04 |
| 2006 | -1.000000E-03 |
| 2007 | 2.188470E+05 |
| 2008 | 1.439780E+05 |
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| 2010 | 1.653460E+05 |
| 2011 | 1.736920E+05 |

"3N autumn survey"
I2

| | |
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| 1991 | 2.422100E+04 |
| 1992 | -1.000000E-03 |
| 1993 | 1.322200E+04 |
| 1994 | 2.458400E+04 |
| 1995 | 4.065000E+04 |
| 1996 | 1.127700E+04 |
| 1997 | 5.111600E+04 |
| 1998 | 9.370300E+04 |
| 1999 | 3.312500E+04 |
| 2000 | 7.554400E+04 |
| 2001 | 1.039970E+05 |
| 2002 | 3.826100E+04 |
| 2003 | 5.688200E+04 |
| 2004 | 4.061400E+04 |
| 2005 | 4.191100E+04 |
| 2006 | 6.466500E+04 |
| 2007 | 6.721200E+04 |
| 2008 | 1.452100E+05 |
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| 2010 | 1.370800E+05 |
| 2011 | 4.908560E+05 |

"3LN Power russian survey"
I1

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| 1987 | 7.029800E+04 |
| 1988 | 4.488400E+04 |
| 1989 | 1.226800E+04 |
| 1990 | 8.365000E+03 |
| 1991 | 1.868000E+04 |
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"3L winter survey"
I0

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| 1985 | 9.024500E+04 |
| 1986 | 3.656800E+04 |
| 1987 | -1.000000E-03 |
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| 2007 | -1.000000E-03 |
| 2008 | -1.000000E-03 |
| 2009 | -1.000000E-03 |
| 2010 | -1.000000E-03 |
| 2011 | -1.000000E-03 |

"3L summer survey"
I1

| | |
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| 1971 | -1.000000E-03 |
| 1972 | -1.000000E-03 |
| 1973 | -1.000000E-03 |
| 1974 | -1.000000E-03 |
| 1975 | -1.000000E-03 |
| 1976 | -1.000000E-03 |
| 1977 | -1.000000E-03 |
| 1978 | 3.111630E+05 |
| 1979 | 2.277880E+05 |
| 1980 | -1.000000E-03 |
| 1981 | 2.613840E+05 |
| 1982 | -1.000000E-03 |
| 1983 | -1.000000E-03 |
| 1984 | 2.777110E+05 |
| 1985 | 1.610380E+05 |
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| 2007 | -1.000000E-03 |
| 2008 | -1.000000E-03 |
| 2009 | -1.000000E-03 |
| 2010 | -1.000000E-03 |
| 2011 | -1.000000E-03 |

"3L autumn survey"
I2

| | |
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| 1960 | -1.000000E-03 |
| 1961 | -1.000000E-03 |
| 1962 | -1.000000E-03 |
| 1963 | -1.000000E-03 |
| 1964 | -1.000000E-03 |
| 1965 | -1.000000E-03 |
| 1966 | -1.000000E-03 |
| 1967 | -1.000000E-03 |
| 1968 | -1.000000E-03 |
| 1969 | -1.000000E-03 |
| 1970 | -1.000000E-03 |
| 1971 | -1.000000E-03 |
| 1972 | -1.000000E-03 |
| 1973 | -1.000000E-03 |
| 1974 | -1.000000E-03 |
| 1975 | -1.000000E-03 |
| 1976 | -1.000000E-03 |
| 1977 | -1.000000E-03 |
| 1978 | -1.000000E-03 |
| 1979 | -1.000000E-03 |
| 1980 | -1.000000E-03 |
| 1981 | -1.000000E-03 |
| 1982 | -1.000000E-03 |
| 1983 | -1.000000E-03 |
| 1984 | -1.000000E-03 |
| 1985 | 9.823300E+04 |
| 1986 | 1.711900E+04 |
| 1987 | -1.000000E-03 |
| 1988 | -1.000000E-03 |
| 1989 | -1.000000E-03 |
| 1990 | 2.074300E+04 |
| 1991 | 1.366500E+04 |
| 1992 | 1.342400E+04 |
| 1993 | 6.011000E+03 |
| 1994 | 7.173000E+03 |
| 1995 | -1.000000E-03 |
| 1996 | 4.691000E+03 |
| 1997 | 1.954400E+04 |
| 1998 | 1.852200E+04 |
| 1999 | 3.886100E+04 |
| 2000 | 2.491700E+04 |
| 2001 | 2.856900E+04 |
| 2002 | 1.188800E+04 |
| 2003 | 1.500700E+04 |
| 2004 | 9.293000E+03 |
| 2005 | 1.665000E+04 |
| 2006 | 2.721800E+04 |
| 2007 | 5.754600E+04 |
| 2008 | 5.327600E+04 |
| 2009 | 8.724500E+04 |
| 2010 | 3.244110E+05 |
| 2011 | 7.142500E+04 |

```
"3N spanish survey"
I1
   1959    -1.000000E-03
   1960    -1.000000E-03
   1961    -1.000000E-03
   1962    -1.000000E-03
   1963    -1.000000E-03
   1964    -1.000000E-03
   1965    -1.000000E-03
   1966    -1.000000E-03
   1967    -1.000000E-03
   1968    -1.000000E-03
   1969    -1.000000E-03
   1970    -1.000000E-03
   1971    -1.000000E-03
   1972    -1.000000E-03
   1973    -1.000000E-03
   1974    -1.000000E-03
   1975    -1.000000E-03
   1976    -1.000000E-03
   1977    -1.000000E-03
   1978    -1.000000E-03
   1979    -1.000000E-03
   1980    -1.000000E-03
   1981    -1.000000E-03
   1982    -1.000000E-03
   1983    -1.000000E-03
   1984    -1.000000E-03
   1985    -1.000000E-03
   1986    -1.000000E-03
   1987    -1.000000E-03
   1988    -1.000000E-03
   1989    -1.000000E-03
   1990    -1.000000E-03
   1991    -1.000000E-03
   1992    -1.000000E-03
   1993    -1.000000E-03
   1994    -1.000000E-03
   1995     4.608400E+04
   1996     6.558000E+03
   1997     4.753000E+03
   1998     2.254000E+04
   1999     4.645900E+04
   2000     6.892800E+04
   2001     5.385500E+04
   2002     7.620000E+03
   2003     1.103100E+04
   2004     2.701600E+04
   2005     1.469180E+05
   2006     8.783000E+04
   2007     8.760200E+04
   2008     6.805900E+04
   2009     7.357430E+05
   2010     3.595360E+05
   2011     4.183050E+05
```

Appendix 2 APIC Fit 2012 results

3LN redfish | Page 1
Sunday, 03 Jun 2012 at 16:16:52

ASPIC -- A Surplus-Production Model Including Covariates (Ver. 5.34)

FIT program mode
LOGISTIC model mode
YLD conditioning
SSE optimization

Author: Michael H. Prager; NOAA Center for Coastal Fisheries and Habitat Research
101 Pivers Island Road; Beaufort, North Carolina 28516 USA
Mike.Prager@noaa.gov

Reference: Prager, M. H. 1994. A suite of extensions to a nonequilibrium surplus-production model. Fishery Bulletin 92: 374-389.

ASPIC User's Manual is available gratis from the author.

CONTROL PARAMETERS (FROM INPUT FILE) Input file: c:\...\aspicfit11\exploratory with aspicnew\expfit\aspic.inp

Operation of ASPIC: Fit logistic (Schaefer) model by direct optimization.

| | | | | |
|---|---|---|---|---|
| Number of years analyzed: | 53 | Number of bootstrap trials: | | 0 |
| Number of data series: | 7 | Bounds on MSY (min, max): | 5.000E+03 | 5.000E+04 |
| Objective function: | Least squares | Bounds on K (min, max): | 1.000E+05 | 1.000E+06 |
| Relative conv. criterion (simplex): | 1.000E-08 | Monte Carlo search mode, trials: | 0 | 20000 |
| Relative conv. criterion (restart): | 3.000E-08 | Random number seed: | | 3941285 |
| Relative conv. criterion (effort): | 1.000E-04 | Identical convergences required in fitting: | | 6 |
| Maximum F allowed in fitting: | 6.000 | | | |

PROGRAM STATUS INFORMATION (NON-BOOTSTRAPPED ANALYSIS) error code 0

Normal convergence

WARNING: Negative correlations detected between some indices. A fundamental assumption of ASPIC is that all indices represent the abundance of the stock. That assumption should be checked.
Number of restarts required for convergence: 124

CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 Statlant CPUE | 1.000 | | | | | | |
| | 36 | | | | | | |
| 2 3LN spring survey | -0.019 | 1.000 | | | | | |
| | 4 | 19 | | | | | |
| 3 3N autumn survey | -0.470 | 0.854 | 1.000 | | | | |
| | 3 | 17 | 19 | | | | |
| 4 3LN Power russian survey | 0.108 | 0.000 | 0.000 | 1.000 | | | |
| | 8 | 1 | 1 | 8 | | | |
| 5 3L winter survey | 0.178 | 0.000 | 0.000 | 0.908 | 1.000 | | |
| | 3 | 0 | 0 | 3 | 3 | | |
| 6 3L summer survey | 0.733 | -1.000 | 1.000 | 0.964 | 1.000 | 1.000 | |
| | 8 | 2 | 2 | 4 | 2 | 8 | |
| 7 3L autumn survey | 0.326 | 0.902 | 0.798 | 0.794 | 0.959 | 0.930 | 1.000 |
| | 7 | 17 | 17 | 4 | 3 | 4 | 22 |

GOODNESS-OF-FIT AND WEIGHTING (NON-BOOTSTRAPPED ANALYSIS)

| Loss component number and title | Weighted SSE | N | Weighted MSE | Current weight | Inv. var. weight | R-squared in CPUE |
|---|---|---|---|---|---|---|
| Loss(-1) SSE in yield | 0.000E+00 | | | | | |
| Loss(0) Penalty for B1 > K | 0.000E+00 | 1 | N/A | 0.000E+00 | N/A | |
| Loss(1) Statlant CPUE | 3.113E+00 | 36 | 9.155E-02 | 1.000E+00 | 2.070E+00 | 0.019 |
| Loss(2) 3LN spring survey | 7.866E+00 | 19 | 4.627E-01 | 1.000E+00 | 4.095E-01 | 0.612 |
| Loss(3) 3N autumn survey | 4.968E+00 | 19 | 2.922E-01 | 1.000E+00 | 6.484E-01 | 0.522 |
| Loss(4) 3LN Power russian survey | 3.963E+00 | 8 | 6.605E-01 | 1.000E+00 | 2.869E-01 | 0.201 |
| Loss(5) 3L winter survey | 4.900E-01 | 3 | 4.900E-01 | 1.000E+00 | 3.867E-01 | 0.366 |
| Loss(6) 3L summer survey | 1.678E+00 | 8 | 2.796E-01 | 1.000E+00 | 6.777E-01 | 0.579 |
| Loss(7) 3L autumn survey | 7.239E+00 | 22 | 3.619E-01 | 1.000E+00 | 5.235E-01 | 0.462 |

| | | | |
|---|---|---|---|
| TOTAL OBJECTIVE FUNCTION, MSE, RMSE: | 2.93160376E+01 | 2.792E-01 | 5.284E-01 |
| Estimated contrast index (ideal = 1.0): | 0.6434 | C* = (Bmax-Bmin)/K | |
| Estimated nearness index (ideal = 1.0): | 1.0000 | N* = 1 - \|min(B-Bmsy)\|/K | |

MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

| Parameter | | Estimate | User/pgm guess | 2nd guess | Estimated | User guess |
|---|---|---|---|---|---|---|
| B1/K | Starting relative biomass (in 1959) | 4.434E-01 | 5.000E-01 | 6.568E-01 | 1 | 1 |
| MSY | Maximum sustainable yield | 2.370E+04 | 2.000E+04 | 1.509E+04 | 1 | 1 |
| K | Maximum population size | 4.503E+05 | 5.000E+05 | 2.800E+05 | 1 | 1 |
| phi | Shape of production curve (Bmsy/K) | 0.5000 | 0.5000 | ---- | 0 | 1 |
| --------- | Catchability Coefficients by Data Series --------------- | | | | | |
| q(1) | Statlant CPUE | 8.588E-06 | 9.007E-06 | 8.557E-04 | 1 | 1 |
| q(2) | 3LN spring survey | 3.317E-01 | 6.580E-01 | 7.095E-01 | 1 | 1 |
| q(3) | 3N autumn survey | 4.033E-01 | 7.590E-01 | 7.036E-01 | 1 | 1 |
| q(4) | 3LN Power russian survey | 2.872E-01 | 6.580E-01 | 6.869E-01 | 1 | 1 |
| q(5) | 3L winter survey | 2.325E-01 | 3.220E-01 | 9.367E-01 | 1 | 1 |
| q(6) | 3L summer survey | 9.207E-01 | 2.750E-01 | 2.605E-01 | 1 | 1 |
| q(7) | 3L autumn survey | 1.652E-01 | 2.750E-01 | 1.140E+00 | 1 | 1 |

MANAGEMENT and DERIVED PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

| Parameter | | Estimate | Logistic formula | General formula |
|---|---|---|---|---|
| MSY | Maximum sustainable yield | 2.370E+04 | ---- | ---- |
| Bmsy | Stock biomass giving MSY | 2.251E+05 | K/2 | K*n**(1/(1-n)) |
| Fmsy | Fishing mortality rate at MSY | 1.053E-01 | MSY/Bmsy | MSY/Bmsy |
| n | Exponent in production function | 2.0000 | ---- | ---- |
| g | Fletcher's gamma | 4.000E+00 | ---- | [n**(n/(n-1))]/[n-1] |
| B./Bmsy | Ratio: B(2012)/Bmsy | 1.475E+00 | ---- | ---- |
| F./Fmsy | Ratio: F(2011)/Fmsy | 1.683E-01 | ---- | ---- |
| Fmsy/F. | Ratio: Fmsy/F(2011) | 5.941E+00 | ---- | ---- |
| Y.(Fmsy) | Approx. yield available at Fmsy in 2012 | 3.413E+04 | MSY*B./Bmsy | MSY*B./Bmsy |
| | ...as proportion of MSY | 1.440E+00 | ---- | ---- |
| Ye. | Equilibrium yield available in 2012 | 1.836E+04 | 4*MSY*(B/K-(B/K)**2) | g*MSY*(B/K-(B/K)**n) |
| | ...as proportion of MSY | 7.747E-01 | ---- | ---- |
| --------- | Fishing effort rate at MSY in units of each CE or CC series --------- | | | |
| fmsy(1) | Statlant CPUE | 1.226E+04 | Fmsy/q( 1) | Fmsy/q( 1) |

ESTIMATED POPULATION TRAJECTORY (NON-BOOTSTRAPPED)

| Obs | Year or ID | Estimated total F mort | Estimated starting biomass | Estimated average biomass | Observed total yield | Model total yield | Estimated surplus production | Ratio of F mort to Fmsy | Ratio of biomass to Bmsy |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1959 | 0.237 | 1.996E+05 | 1.885E+05 | 4.458E+04 | 4.458E+04 | 2.306E+04 | 2.247E+00 | 8.868E-01 |
| 2 | 1960 | 0.151 | 1.781E+05 | 1.761E+05 | 2.656E+04 | 2.656E+04 | 2.258E+04 | 1.433E+00 | 7.912E-01 |
| 3 | 1961 | 0.133 | 1.741E+05 | 1.738E+05 | 2.318E+04 | 2.318E+04 | 2.247E+04 | 1.267E+00 | 7.735E-01 |
| 4 | 1962 | 0.123 | 1.734E+05 | 1.739E+05 | 2.144E+04 | 2.144E+04 | 2.248E+04 | 1.171E+00 | 7.703E-01 |
| 5 | 1963 | 0.159 | 1.745E+05 | 1.719E+05 | 2.736E+04 | 2.736E+04 | 2.238E+04 | 1.512E+00 | 7.749E-01 |
| 6 | 1964 | 0.058 | 1.695E+05 | 1.756E+05 | 1.026E+04 | 1.026E+04 | 2.255E+04 | 5.550E-01 | 7.528E-01 |
| 7 | 1965 | 0.129 | 1.818E+05 | 1.814E+05 | 2.347E+04 | 2.347E+04 | 2.281E+04 | 1.229E+00 | 8.074E-01 |
| 8 | 1966 | 0.092 | 1.811E+05 | 1.841E+05 | 1.697E+04 | 1.697E+04 | 2.291E+04 | 8.758E-01 | 8.044E-01 |
| 9 | 1967 | 0.147 | 1.870E+05 | 1.849E+05 | 2.719E+04 | 2.719E+04 | 2.294E+04 | 1.397E+00 | 8.308E-01 |
| 10 | 1968 | 0.095 | 1.828E+05 | 1.855E+05 | 1.766E+04 | 1.766E+04 | 2.296E+04 | 9.045E-01 | 8.120E-01 |
| 11 | 1969 | 0.132 | 1.881E+05 | 1.872E+05 | 2.475E+04 | 2.475E+04 | 2.303E+04 | 1.256E+00 | 8.355E-01 |
| 12 | 1970 | 0.076 | 1.864E+05 | 1.908E+05 | 1.442E+04 | 1.442E+04 | 2.315E+04 | 7.180E-01 | 8.279E-01 |
| 13 | 1971 | 0.182 | 1.951E+05 | 1.893E+05 | 3.437E+04 | 3.437E+04 | 2.310E+04 | 1.724E+00 | 8.666E-01 |
| 14 | 1972 | 0.160 | 1.838E+05 | 1.807E+05 | 2.893E+04 | 2.893E+04 | 2.278E+04 | 1.521E+00 | 8.166E-01 |
| 15 | 1973 | 0.193 | 1.777E+05 | 1.721E+05 | 3.330E+04 | 3.330E+04 | 2.238E+04 | 1.838E+00 | 7.892E-01 |
| 16 | 1974 | 0.134 | 1.668E+05 | 1.667E+05 | 2.229E+04 | 2.229E+04 | 2.210E+04 | 1.270E+00 | 7.407E-01 |
| 17 | 1975 | 0.106 | 1.666E+05 | 1.688E+05 | 1.787E+04 | 1.787E+04 | 2.221E+04 | 1.006E+00 | 7.399E-01 |
| 18 | 1976 | 0.119 | 1.709E+05 | 1.719E+05 | 2.051E+04 | 2.051E+04 | 2.237E+04 | 1.134E+00 | 7.592E-01 |
| 19 | 1977 | 0.094 | 1.728E+05 | 1.758E+05 | 1.652E+04 | 1.652E+04 | 2.256E+04 | 8.923E-01 | 7.674E-01 |
| 20 | 1978 | 0.065 | 1.788E+05 | 1.843E+05 | 1.204E+04 | 1.204E+04 | 2.292E+04 | 6.208E-01 | 7.943E-01 |
| 21 | 1979 | 0.072 | 1.897E+05 | 1.943E+05 | 1.407E+04 | 1.407E+04 | 2.325E+04 | 6.876E-01 | 8.426E-01 |
| 22 | 1980 | 0.079 | 1.989E+05 | 2.026E+05 | 1.603E+04 | 1.603E+04 | 2.346E+04 | 7.515E-01 | 8.834E-01 |
| 23 | 1981 | 0.118 | 2.063E+05 | 2.059E+05 | 2.428E+04 | 2.428E+04 | 2.353E+04 | 1.120E+00 | 9.164E-01 |
| 24 | 1982 | 0.104 | 2.056E+05 | 2.066E+05 | 2.155E+04 | 2.155E+04 | 2.354E+04 | 9.908E-01 | 9.131E-01 |
| 25 | 1983 | 0.094 | 2.075E+05 | 2.095E+05 | 1.975E+04 | 1.975E+04 | 2.359E+04 | 8.954E-01 | 9.219E-01 |
| 26 | 1984 | 0.068 | 2.114E+05 | 2.159E+05 | 1.476E+04 | 1.476E+04 | 2.366E+04 | 6.495E-01 | 9.390E-01 |
| 27 | 1985 | 0.093 | 2.203E+05 | 2.219E+05 | 2.056E+04 | 2.056E+04 | 2.370E+04 | 8.801E-01 | 9.785E-01 |
| 28 | 1986 | 0.200 | 2.234E+05 | 2.135E+05 | 4.280E+04 | 4.280E+04 | 2.362E+04 | 1.904E+00 | 9.924E-01 |
| 29 | 1987 | 0.454 | 2.042E+05 | 1.740E+05 | 7.903E+04 | 7.903E+04 | 2.235E+04 | 4.315E+00 | 9.072E-01 |
| 30 | 1988 | 0.411 | 1.476E+05 | 1.297E+05 | 5.327E+04 | 5.327E+04 | 1.940E+04 | 3.900E+00 | 6.555E-01 |
| 31 | 1989 | 0.320 | 1.137E+05 | 1.051E+05 | 3.365E+04 | 3.365E+04 | 1.695E+04 | 3.043E+00 | 5.050E-01 |
| 32 | 1990 | 0.324 | 9.699E+04 | 8.977E+04 | 2.910E+04 | 2.910E+04 | 1.512E+04 | 3.080E+00 | 4.308E-01 |
| 33 | 1991 | 0.337 | 8.301E+04 | 7.659E+04 | 2.582E+04 | 2.582E+04 | 1.338E+04 | 3.202E+00 | 3.687E-01 |
| 34 | 1992 | 0.439 | 7.057E+04 | 6.219E+04 | 2.728E+04 | 2.728E+04 | 1.127E+04 | 4.167E+00 | 3.135E-01 |
| 35 | 1993 | 0.443 | 5.456E+04 | 4.815E+04 | 2.131E+04 | 2.131E+04 | 9.048E+03 | 4.203E+00 | 2.424E-01 |
| 36 | 1994 | 0.132 | 4.230E+04 | 4.357E+04 | 5.741E+03 | 5.741E+03 | 8.286E+03 | 1.252E+00 | 1.879E-01 |
| 37 | 1995 | 0.041 | 4.485E+04 | 4.832E+04 | 1.989E+03 | 1.989E+03 | 9.080E+03 | 3.910E-01 | 1.992E-01 |
| 38 | 1996 | 0.008 | 5.194E+04 | 5.681E+04 | 4.510E+02 | 4.510E+02 | 1.045E+04 | 7.540E-02 | 2.307E-01 |
| 39 | 1997 | 0.009 | 6.194E+04 | 6.753E+04 | 6.300E+02 | 6.300E+02 | 1.208E+04 | 8.861E-02 | 2.751E-01 |
| 40 | 1998 | 0.011 | 7.339E+04 | 7.971E+04 | 8.990E+02 | 8.990E+02 | 1.381E+04 | 1.071E-01 | 3.260E-01 |
| 41 | 1999 | 0.025 | 8.630E+04 | 9.278E+04 | 2.318E+03 | 2.318E+03 | 1.550E+04 | 2.373E-01 | 3.833E-01 |
| 42 | 2000 | 0.030 | 9.948E+04 | 1.064E+05 | 3.141E+03 | 3.141E+03 | 1.710E+04 | 2.805E-01 | 4.419E-01 |
| 43 | 2001 | 0.012 | 1.134E+05 | 1.219E+05 | 1.442E+03 | 1.442E+03 | 1.871E+04 | 1.123E-01 | 5.039E-01 |
| 44 | 2002 | 0.009 | 1.307E+05 | 1.401E+05 | 1.216E+03 | 1.216E+03 | 2.031E+04 | 8.242E-02 | 5.806E-01 |
| 45 | 2003 | 0.008 | 1.498E+05 | 1.599E+05 | 1.334E+03 | 1.334E+03 | 2.169E+04 | 7.925E-02 | 6.654E-01 |
| 46 | 2004 | 0.004 | 1.702E+05 | 1.812E+05 | 6.370E+02 | 6.370E+02 | 2.278E+04 | 3.340E-02 | 7.558E-01 |
| 47 | 2005 | 0.003 | 1.923E+05 | 2.037E+05 | 6.590E+02 | 6.590E+02 | 2.346E+04 | 3.073E-02 | 8.542E-01 |
| 48 | 2006 | 0.002 | 2.151E+05 | 2.267E+05 | 4.960E+02 | 4.960E+02 | 2.368E+04 | 2.078E-02 | 9.555E-01 |
| 49 | 2007 | 0.007 | 2.383E+05 | 2.492E+05 | 1.664E+03 | 1.664E+03 | 2.341E+04 | 6.342E-02 | 1.058E+00 |
| 50 | 2008 | 0.002 | 2.600E+05 | 2.712E+05 | 5.970E+02 | 5.970E+02 | 2.269E+04 | 2.091E-02 | 1.155E+00 |
| 51 | 2009 | 0.004 | 2.821E+05 | 2.925E+05 | 1.051E+03 | 1.051E+03 | 2.156E+04 | 3.413E-02 | 1.253E+00 |
| 52 | 2010 | 0.013 | 3.026E+05 | 3.108E+05 | 4.120E+03 | 4.120E+03 | 2.026E+04 | 1.259E-01 | 1.344E+00 |
| 53 | 2011 | 0.018 | 3.188E+05 | 3.255E+05 | 5.768E+03 | 5.768E+03 | 1.898E+04 | 1.683E-01 | 1.416E+00 |
| 54 | 2012 | | 3.320E+05 | | | | | | 1.475E+00 |

RESULTS FOR DATA SERIES # 1 (NON-BOOTSTRAPPED) Statlant CPUE

Data type CC: CPUE-catch series Series weight: 1.000

| Obs | Year | Observed CPUE | Estimated CPUE | Estim F | Observed yield | Model yield | Resid in log scale | Statist weight |
|---|---|---|---|---|---|---|---|---|
| 1 | 1959 | 1.426E+00 | 1.619E+00 | 0.2365 | 4.458E+04 | 4.458E+04 | 0.12695 | 1.000E+00 |
| 2 | 1960 | 1.602E+00 | 1.512E+00 | 0.1508 | 2.656E+04 | 2.656E+04 | -0.05764 | 1.000E+00 |
| 3 | 1961 | 1.697E+00 | 1.492E+00 | 0.1334 | 2.318E+04 | 2.318E+04 | -0.12850 | 1.000E+00 |
| 4 | 1962 | 1.631E+00 | 1.494E+00 | 0.1233 | 2.144E+04 | 2.144E+04 | -0.08782 | 1.000E+00 |
| 5 | 1963 | 1.632E+00 | 1.476E+00 | 0.1592 | 2.736E+04 | 2.736E+04 | -0.10015 | 1.000E+00 |
| 6 | 1964 | 1.812E+00 | 1.508E+00 | 0.0584 | 1.026E+04 | 1.026E+04 | -0.18344 | 1.000E+00 |
| 7 | 1965 | 2.185E+00 | 1.558E+00 | 0.1293 | 2.347E+04 | 2.347E+04 | -0.33814 | 1.000E+00 |
| 8 | 1966 | 1.781E+00 | 1.581E+00 | 0.0922 | 1.697E+04 | 1.697E+04 | -0.11909 | 1.000E+00 |
| 9 | 1967 | 1.893E+00 | 1.588E+00 | 0.1471 | 2.719E+04 | 2.719E+04 | -0.17584 | 1.000E+00 |
| 10 | 1968 | 9.220E-01 | 1.593E+00 | 0.0952 | 1.766E+04 | 1.766E+04 | 0.54673 | 1.000E+00 |
| 11 | 1969 | 1.338E+00 | 1.608E+00 | 0.1322 | 2.475E+04 | 2.475E+04 | 0.18374 | 1.000E+00 |
| 12 | 1970 | 1.367E+00 | 1.638E+00 | 0.0756 | 1.442E+04 | 1.442E+04 | 0.18108 | 1.000E+00 |
| 13 | 1971 | 1.346E+00 | 1.626E+00 | 0.1815 | 3.437E+04 | 3.437E+04 | 0.18896 | 1.000E+00 |
| 14 | 1972 | 1.387E+00 | 1.552E+00 | 0.1601 | 2.893E+04 | 2.893E+04 | 0.11225 | 1.000E+00 |
| 15 | 1973 | 1.643E+00 | 1.478E+00 | 0.1935 | 3.330E+04 | 3.330E+04 | -0.10593 | 1.000E+00 |
| 16 | 1974 | 1.290E+00 | 1.431E+00 | 0.1337 | 2.229E+04 | 2.229E+04 | 0.10394 | 1.000E+00 |
| 17 | 1975 | 1.669E+00 | 1.449E+00 | 0.1059 | 1.787E+04 | 1.787E+04 | -0.14112 | 1.000E+00 |
| 18 | 1976 | 1.292E+00 | 1.476E+00 | 0.1194 | 2.051E+04 | 2.051E+04 | 0.13307 | 1.000E+00 |
| 19 | 1977 | 1.251E+00 | 1.510E+00 | 0.0939 | 1.652E+04 | 1.652E+04 | 0.18814 | 1.000E+00 |
| 20 | 1978 | 1.106E+00 | 1.583E+00 | 0.0654 | 1.204E+04 | 1.204E+04 | 0.35833 | 1.000E+00 |
| 21 | 1979 | 1.451E+00 | 1.669E+00 | 0.0724 | 1.407E+04 | 1.407E+04 | 0.13986 | 1.000E+00 |
| 22 | 1980 | 1.761E+00 | 1.740E+00 | 0.0791 | 1.603E+04 | 1.603E+04 | -0.01188 | 1.000E+00 |
| 23 | 1981 | 1.594E+00 | 1.769E+00 | 0.1179 | 2.428E+04 | 2.428E+04 | 0.10389 | 1.000E+00 |
| 24 | 1982 | 1.661E+00 | 1.774E+00 | 0.1043 | 2.155E+04 | 2.155E+04 | 0.06583 | 1.000E+00 |
| 25 | 1983 | 1.556E+00 | 1.799E+00 | 0.0943 | 1.975E+04 | 1.975E+04 | 0.14520 | 1.000E+00 |
| 26 | 1984 | 1.049E+00 | 1.854E+00 | 0.0684 | 1.476E+04 | 1.476E+04 | 0.56951 | 1.000E+00 |
| 27 | 1985 | 1.084E+00 | 1.905E+00 | 0.0927 | 2.056E+04 | 2.056E+04 | 0.56408 | 1.000E+00 |
| 28 | 1986 | 1.413E+00 | 1.834E+00 | 0.2005 | 4.280E+04 | 4.280E+04 | 0.26067 | 1.000E+00 |
| 29 | 1987 | 1.523E+00 | 1.494E+00 | 0.4542 | 7.903E+04 | 7.903E+04 | -0.01910 | 1.000E+00 |
| 30 | 1988 | 1.208E+00 | 1.114E+00 | 0.4106 | 5.327E+04 | 5.327E+04 | -0.08096 | 1.000E+00 |
| 31 | 1989 | 1.322E+00 | 9.022E-01 | 0.3203 | 3.365E+04 | 3.365E+04 | -0.38206 | 1.000E+00 |
| 32 | 1990 | 8.250E-01 | 7.710E-01 | 0.3242 | 2.910E+04 | 2.910E+04 | -0.06775 | 1.000E+00 |
| 33 | 1991 | 6.680E-01 | 6.577E-01 | 0.3371 | 2.582E+04 | 2.582E+04 | -0.01549 | 1.000E+00 |
| 34 | 1992 | 9.120E-01 | 5.341E-01 | 0.4387 | 2.728E+04 | 2.728E+04 | -0.53512 | 1.000E+00 |
| 35 | 1993 | 8.010E-01 | 4.135E-01 | 0.4425 | 2.131E+04 | 2.131E+04 | -0.66113 | 1.000E+00 |
| 36 | 1994 | 8.020E-01 | 3.742E-01 | 0.1318 | 5.741E+03 | 5.741E+03 | -0.76239 | 1.000E+00 |
| 37 | 1995 | * | 4.150E-01 | 0.0412 | 1.989E+03 | 1.989E+03 | 0.00000 | 1.000E+00 |
| 38 | 1996 | * | 4.879E-01 | 0.0079 | 4.510E+02 | 4.510E+02 | 0.00000 | 1.000E+00 |
| 39 | 1997 | * | 5.800E-01 | 0.0093 | 6.300E+02 | 6.300E+02 | 0.00000 | 1.000E+00 |
| 40 | 1998 | * | 6.846E-01 | 0.0113 | 8.990E+02 | 8.990E+02 | 0.00000 | 1.000E+00 |
| 41 | 1999 | * | 7.968E-01 | 0.0250 | 2.318E+03 | 2.318E+03 | 0.00000 | 1.000E+00 |
| 42 | 2000 | * | 9.135E-01 | 0.0295 | 3.141E+03 | 3.141E+03 | 0.00000 | 1.000E+00 |
| 43 | 2001 | * | 1.047E+00 | 0.0118 | 1.442E+03 | 1.442E+03 | 0.00000 | 1.000E+00 |
| 44 | 2002 | * | 1.204E+00 | 0.0087 | 1.216E+03 | 1.216E+03 | 0.00000 | 1.000E+00 |
| 45 | 2003 | * | 1.373E+00 | 0.0083 | 1.334E+03 | 1.334E+03 | 0.00000 | 1.000E+00 |
| 46 | 2004 | * | 1.556E+00 | 0.0035 | 6.370E+02 | 6.370E+02 | 0.00000 | 1.000E+00 |
| 47 | 2005 | * | 1.749E+00 | 0.0032 | 6.590E+02 | 6.590E+02 | 0.00000 | 1.000E+00 |
| 48 | 2006 | * | 1.947E+00 | 0.0022 | 4.960E+02 | 4.960E+02 | 0.00000 | 1.000E+00 |
| 49 | 2007 | * | 2.140E+00 | 0.0067 | 1.664E+03 | 1.664E+03 | 0.00000 | 1.000E+00 |
| 50 | 2008 | * | 2.329E+00 | 0.0022 | 5.970E+02 | 5.970E+02 | 0.00000 | 1.000E+00 |
| 51 | 2009 | * | 2.512E+00 | 0.0036 | 1.051E+03 | 1.051E+03 | 0.00000 | 1.000E+00 |
| 52 | 2010 | * | 2.669E+00 | 0.0133 | 4.120E+03 | 4.120E+03 | 0.00000 | 1.000E+00 |
| 53 | 2011 | * | 2.795E+00 | 0.0177 | 5.768E+03 | 5.768E+03 | 0.00000 | 1.000E+00 |

* Asterisk indicates missing value(s).

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3LN redfish                                                                                                        Page 5

UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 1
                   -1       -0.75     -0.5      -0.25       0        0.25      0.5       0.75       1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    ------------------------------------------------------------------------------------
1959     0.1269                                             |=====
1960    -0.0576                                           ==|
1961    -0.1285                                        =====|
1962    -0.0878                                         ====|
1963    -0.1002                                         ====|
1964    -0.1834                                      =======|
1965    -0.3381                               ==============|
1966    -0.1191                                        =====|
1967    -0.1758                                      =======|
1968     0.5467                                             |======================
1969     0.1837                                             |=======
1970     0.1811                                             |=======
1971     0.1890                                             |========
1972     0.1123                                             |====
1973    -0.1059                                         ====|
1974     0.1039                                             |====
1975    -0.1411                                       ======|
1976     0.1331                                             |=====
1977     0.1881                                             |========
1978     0.3583                                             |==============
1979     0.1399                                             |======
1980    -0.0119                                             |
1981     0.1039                                             |====
1982     0.0658                                             |===
1983     0.1452                                             |======
1984     0.5695                                             |=======================
1985     0.5641                                             |=======================
1986     0.2607                                             |==========
1987    -0.0191                                            =|
1988    -0.0810                                          ===|
1989    -0.3821                              ===============|
1990    -0.0678                                          ===|
1991    -0.0155                                            =|
1992    -0.5351                        =====================|
1993    -0.6611                   ==========================|
1994    -0.7624               ==============================|
1995     0.0000                                             |
1996     0.0000                                             |
1997     0.0000                                             |
1998     0.0000                                             |
1999     0.0000                                             |
2000     0.0000                                             |
2001     0.0000                                             |
2002     0.0000                                             |
2003     0.0000                                             |
2004     0.0000                                             |
2005     0.0000                                             |
2006     0.0000                                             |
2007     0.0000                                             |
2008     0.0000                                             |
2009     0.0000                                             |
2010     0.0000                                             |
2011     0.0000                                             |
                   ------------------------------------------------------------------------------------
```

RESULTS FOR DATA SERIES # 2 (NON-BOOTSTRAPPED) 3LN spring survey

Data type I1: Abundance index (annual average) Series weight: 1.000

| Obs | Year | Observed effort | Estimated effort | Estim F | Observed index | Model index | Resid in log index | Statist weight |
|---|---|---|---|---|---|---|---|---|
| 1 | 1959 | 0.000E+00 | 0.000E+00 | -- | * | 6.253E+04 | 0.00000 | 1.000E+00 |
| 2 | 1960 | 0.000E+00 | 0.000E+00 | -- | * | 5.841E+04 | 0.00000 | 1.000E+00 |
| 3 | 1961 | 0.000E+00 | 0.000E+00 | -- | * | 5.764E+04 | 0.00000 | 1.000E+00 |
| 4 | 1962 | 0.000E+00 | 0.000E+00 | -- | * | 5.770E+04 | 0.00000 | 1.000E+00 |
| 5 | 1963 | 0.000E+00 | 0.000E+00 | -- | * | 5.702E+04 | 0.00000 | 1.000E+00 |
| 6 | 1964 | 0.000E+00 | 0.000E+00 | -- | * | 5.825E+04 | 0.00000 | 1.000E+00 |
| 7 | 1965 | 0.000E+00 | 0.000E+00 | -- | * | 6.018E+04 | 0.00000 | 1.000E+00 |
| 8 | 1966 | 0.000E+00 | 0.000E+00 | -- | * | 6.106E+04 | 0.00000 | 1.000E+00 |
| 9 | 1967 | 0.000E+00 | 0.000E+00 | -- | * | 6.132E+04 | 0.00000 | 1.000E+00 |
| 10 | 1968 | 0.000E+00 | 0.000E+00 | -- | * | 6.152E+04 | 0.00000 | 1.000E+00 |
| 11 | 1969 | 0.000E+00 | 0.000E+00 | -- | * | 6.210E+04 | 0.00000 | 1.000E+00 |
| 12 | 1970 | 0.000E+00 | 0.000E+00 | -- | * | 6.328E+04 | 0.00000 | 1.000E+00 |
| 13 | 1971 | 0.000E+00 | 0.000E+00 | -- | * | 6.280E+04 | 0.00000 | 1.000E+00 |
| 14 | 1972 | 0.000E+00 | 0.000E+00 | -- | * | 5.993E+04 | 0.00000 | 1.000E+00 |
| 15 | 1973 | 0.000E+00 | 0.000E+00 | -- | * | 5.708E+04 | 0.00000 | 1.000E+00 |
| 16 | 1974 | 0.000E+00 | 0.000E+00 | -- | * | 5.528E+04 | 0.00000 | 1.000E+00 |
| 17 | 1975 | 0.000E+00 | 0.000E+00 | -- | * | 5.598E+04 | 0.00000 | 1.000E+00 |
| 18 | 1976 | 0.000E+00 | 0.000E+00 | -- | * | 5.700E+04 | 0.00000 | 1.000E+00 |
| 19 | 1977 | 0.000E+00 | 0.000E+00 | -- | * | 5.832E+04 | 0.00000 | 1.000E+00 |
| 20 | 1978 | 0.000E+00 | 0.000E+00 | -- | * | 6.112E+04 | 0.00000 | 1.000E+00 |
| 21 | 1979 | 0.000E+00 | 0.000E+00 | -- | * | 6.445E+04 | 0.00000 | 1.000E+00 |
| 22 | 1980 | 0.000E+00 | 0.000E+00 | -- | * | 6.721E+04 | 0.00000 | 1.000E+00 |
| 23 | 1981 | 0.000E+00 | 0.000E+00 | -- | * | 6.830E+04 | 0.00000 | 1.000E+00 |
| 24 | 1982 | 0.000E+00 | 0.000E+00 | -- | * | 6.852E+04 | 0.00000 | 1.000E+00 |
| 25 | 1983 | 0.000E+00 | 0.000E+00 | -- | * | 6.949E+04 | 0.00000 | 1.000E+00 |
| 26 | 1984 | 0.000E+00 | 0.000E+00 | -- | * | 7.160E+04 | 0.00000 | 1.000E+00 |
| 27 | 1985 | 0.000E+00 | 0.000E+00 | -- | * | 7.359E+04 | 0.00000 | 1.000E+00 |
| 28 | 1986 | 0.000E+00 | 0.000E+00 | -- | * | 7.082E+04 | 0.00000 | 1.000E+00 |
| 29 | 1987 | 0.000E+00 | 0.000E+00 | -- | * | 5.771E+04 | 0.00000 | 1.000E+00 |
| 30 | 1988 | 0.000E+00 | 0.000E+00 | -- | * | 4.303E+04 | 0.00000 | 1.000E+00 |
| 31 | 1989 | 0.000E+00 | 0.000E+00 | -- | * | 3.484E+04 | 0.00000 | 1.000E+00 |
| 32 | 1990 | 0.000E+00 | 0.000E+00 | -- | * | 2.978E+04 | 0.00000 | 1.000E+00 |
| 33 | 1991 | 1.000E+00 | 1.000E+00 | -- | 1.064E+04 | 2.540E+04 | -0.87006 | 1.000E+00 |
| 34 | 1992 | 1.000E+00 | 1.000E+00 | -- | 1.007E+04 | 2.063E+04 | -0.71742 | 1.000E+00 |
| 35 | 1993 | 1.000E+00 | 1.000E+00 | -- | 2.257E+04 | 1.597E+04 | 0.34596 | 1.000E+00 |
| 36 | 1994 | 1.000E+00 | 1.000E+00 | -- | 4.162E+03 | 1.445E+04 | -1.24479 | 1.000E+00 |
| 37 | 1995 | 1.000E+00 | 1.000E+00 | -- | 5.856E+03 | 1.603E+04 | -1.00685 | 1.000E+00 |
| 38 | 1996 | 1.000E+00 | 1.000E+00 | -- | 2.281E+04 | 1.884E+04 | 0.19104 | 1.000E+00 |
| 39 | 1997 | 1.000E+00 | 1.000E+00 | -- | 1.493E+04 | 2.240E+04 | -0.40582 | 1.000E+00 |
| 40 | 1998 | 1.000E+00 | 1.000E+00 | -- | 5.940E+04 | 2.644E+04 | 0.80950 | 1.000E+00 |
| 41 | 1999 | 1.000E+00 | 1.000E+00 | -- | 6.150E+04 | 3.077E+04 | 0.69230 | 1.000E+00 |
| 42 | 2000 | 1.000E+00 | 1.000E+00 | -- | 8.784E+04 | 3.528E+04 | 0.91223 | 1.000E+00 |
| 43 | 2001 | 1.000E+00 | 1.000E+00 | -- | 4.157E+04 | 4.045E+04 | 0.02740 | 1.000E+00 |
| 44 | 2002 | 1.000E+00 | 1.000E+00 | -- | 3.096E+04 | 4.648E+04 | -0.40642 | 1.000E+00 |
| 45 | 2003 | 1.000E+00 | 1.000E+00 | -- | 2.770E+04 | 5.303E+04 | -0.64949 | 1.000E+00 |
| 46 | 2004 | 1.000E+00 | 1.000E+00 | -- | 7.963E+04 | 6.009E+04 | 0.28158 | 1.000E+00 |
| 47 | 2005 | 1.000E+00 | 1.000E+00 | -- | 6.646E+04 | 6.756E+04 | -0.01631 | 1.000E+00 |
| 48 | 2006 | 0.000E+00 | 0.000E+00 | -- | * | 7.520E+04 | 0.00000 | 1.000E+00 |
| 49 | 2007 | 0.000E+00 | 0.000E+00 | -- | * | 8.266E+04 | 0.00000 | 1.000E+00 |
| 50 | 2008 | 1.000E+00 | 1.000E+00 | -- | 1.440E+05 | 8.994E+04 | 0.47049 | 1.000E+00 |
| 51 | 2009 | 1.000E+00 | 1.000E+00 | -- | 1.834E+05 | 9.702E+04 | 0.63665 | 1.000E+00 |
| 52 | 2010 | 1.000E+00 | 1.000E+00 | -- | 1.653E+05 | 1.031E+05 | 0.47235 | 1.000E+00 |
| 53 | 2011 | 1.000E+00 | 1.000E+00 | -- | 1.737E+05 | 1.080E+05 | 0.47547 | 1.000E+00 |

* Asterisk indicates missing value(s).

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3LN redfish                                                                                                Page 7

UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 2
                   -2      -1.5       -1      -0.5        0        0.5        1        1.5        2
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    -------------------------------------------------------------------------------------
1959     0.0000                                             |
1960     0.0000                                             |
1961     0.0000                                             |
1962     0.0000                                             |
1963     0.0000                                             |
1964     0.0000                                             |
1965     0.0000                                             |
1966     0.0000                                             |
1967     0.0000                                             |
1968     0.0000                                             |
1969     0.0000                                             |
1970     0.0000                                             |
1971     0.0000                                             |
1972     0.0000                                             |
1973     0.0000                                             |
1974     0.0000                                             |
1975     0.0000                                             |
1976     0.0000                                             |
1977     0.0000                                             |
1978     0.0000                                             |
1979     0.0000                                             |
1980     0.0000                                             |
1981     0.0000                                             |
1982     0.0000                                             |
1983     0.0000                                             |
1984     0.0000                                             |
1985     0.0000                                             |
1986     0.0000                                             |
1987     0.0000                                             |
1988     0.0000                                             |
1989     0.0000                                             |
1990     0.0000                                             |
1991    -0.8701                            =================|
1992    -0.7174                               ==============|
1993     0.3460                                             |=======
1994    -1.2448                    =========================|
1995    -1.0069                         ====================|
1996     0.1910                                             |====
1997    -0.4058                                     ========|
1998     0.8095                                             |================
1999     0.6923                                             |==============
2000     0.9122                                             |==================
2001     0.0274                                             |=
2002    -0.4064                                     ========|
2003    -0.6495                                ==============|
2004     0.2816                                             |======
2005    -0.0163                                             |
2006     0.0000                                             |
2007     0.0000                                             |
2008     0.4705                                             |=========
2009     0.6367                                             |=============
2010     0.4723                                             |=========
2011     0.4755                                             |==========
                   -------------------------------------------------------------------------------------
```

RESULTS FOR DATA SERIES # 3 (NON-BOOTSTRAPPED) 3N autumn survey

Data type I2: Abundance index (end of year) Series weight: 1.000

| Obs | Year | Observed effort | Estimated effort | Estim F | Observed index | Model index | Resid in log index | Statist weight |
|---|---|---|---|---|---|---|---|---|
| 1 | 1959 | 0.000E+00 | 0.000E+00 | -- | * | 7.184E+04 | 0.00000 | 1.000E+00 |
| 2 | 1960 | 0.000E+00 | 0.000E+00 | -- | * | 7.023E+04 | 0.00000 | 1.000E+00 |
| 3 | 1961 | 0.000E+00 | 0.000E+00 | -- | * | 6.994E+04 | 0.00000 | 1.000E+00 |
| 4 | 1962 | 0.000E+00 | 0.000E+00 | -- | * | 7.036E+04 | 0.00000 | 1.000E+00 |
| 5 | 1963 | 0.000E+00 | 0.000E+00 | -- | * | 6.835E+04 | 0.00000 | 1.000E+00 |
| 6 | 1964 | 0.000E+00 | 0.000E+00 | -- | * | 7.331E+04 | 0.00000 | 1.000E+00 |
| 7 | 1965 | 0.000E+00 | 0.000E+00 | -- | * | 7.304E+04 | 0.00000 | 1.000E+00 |
| 8 | 1966 | 0.000E+00 | 0.000E+00 | -- | * | 7.543E+04 | 0.00000 | 1.000E+00 |
| 9 | 1967 | 0.000E+00 | 0.000E+00 | -- | * | 7.372E+04 | 0.00000 | 1.000E+00 |
| 10 | 1968 | 0.000E+00 | 0.000E+00 | -- | * | 7.586E+04 | 0.00000 | 1.000E+00 |
| 11 | 1969 | 0.000E+00 | 0.000E+00 | -- | * | 7.517E+04 | 0.00000 | 1.000E+00 |
| 12 | 1970 | 0.000E+00 | 0.000E+00 | -- | * | 7.869E+04 | 0.00000 | 1.000E+00 |
| 13 | 1971 | 0.000E+00 | 0.000E+00 | -- | * | 7.414E+04 | 0.00000 | 1.000E+00 |
| 14 | 1972 | 0.000E+00 | 0.000E+00 | -- | * | 7.166E+04 | 0.00000 | 1.000E+00 |
| 15 | 1973 | 0.000E+00 | 0.000E+00 | -- | * | 6.725E+04 | 0.00000 | 1.000E+00 |
| 16 | 1974 | 0.000E+00 | 0.000E+00 | -- | * | 6.718E+04 | 0.00000 | 1.000E+00 |
| 17 | 1975 | 0.000E+00 | 0.000E+00 | -- | * | 6.893E+04 | 0.00000 | 1.000E+00 |
| 18 | 1976 | 0.000E+00 | 0.000E+00 | -- | * | 6.968E+04 | 0.00000 | 1.000E+00 |
| 19 | 1977 | 0.000E+00 | 0.000E+00 | -- | * | 7.212E+04 | 0.00000 | 1.000E+00 |
| 20 | 1978 | 0.000E+00 | 0.000E+00 | -- | * | 7.650E+04 | 0.00000 | 1.000E+00 |
| 21 | 1979 | 0.000E+00 | 0.000E+00 | -- | * | 8.021E+04 | 0.00000 | 1.000E+00 |
| 22 | 1980 | 0.000E+00 | 0.000E+00 | -- | * | 8.321E+04 | 0.00000 | 1.000E+00 |
| 23 | 1981 | 0.000E+00 | 0.000E+00 | -- | * | 8.290E+04 | 0.00000 | 1.000E+00 |
| 24 | 1982 | 0.000E+00 | 0.000E+00 | -- | * | 8.371E+04 | 0.00000 | 1.000E+00 |
| 25 | 1983 | 0.000E+00 | 0.000E+00 | -- | * | 8.525E+04 | 0.00000 | 1.000E+00 |
| 26 | 1984 | 0.000E+00 | 0.000E+00 | -- | * | 8.884E+04 | 0.00000 | 1.000E+00 |
| 27 | 1985 | 0.000E+00 | 0.000E+00 | -- | * | 9.011E+04 | 0.00000 | 1.000E+00 |
| 28 | 1986 | 0.000E+00 | 0.000E+00 | -- | * | 8.237E+04 | 0.00000 | 1.000E+00 |
| 29 | 1987 | 0.000E+00 | 0.000E+00 | -- | * | 5.951E+04 | 0.00000 | 1.000E+00 |
| 30 | 1988 | 0.000E+00 | 0.000E+00 | -- | * | 4.585E+04 | 0.00000 | 1.000E+00 |
| 31 | 1989 | 0.000E+00 | 0.000E+00 | -- | * | 3.912E+04 | 0.00000 | 1.000E+00 |
| 32 | 1990 | 0.000E+00 | 0.000E+00 | -- | * | 3.348E+04 | 0.00000 | 1.000E+00 |
| 33 | 1991 | 1.000E+00 | 1.000E+00 | -- | 2.422E+04 | 2.846E+04 | -0.16137 | 1.000E+00 |
| 34 | 1992 | 0.000E+00 | 0.000E+00 | -- | * | 2.201E+04 | 0.00000 | 1.000E+00 |
| 35 | 1993 | 1.000E+00 | 1.000E+00 | -- | 1.322E+04 | 1.706E+04 | -0.25496 | 1.000E+00 |
| 36 | 1994 | 1.000E+00 | 1.000E+00 | -- | 2.458E+04 | 1.809E+04 | 0.30684 | 1.000E+00 |
| 37 | 1995 | 1.000E+00 | 1.000E+00 | -- | 4.065E+04 | 2.095E+04 | 0.66295 | 1.000E+00 |
| 38 | 1996 | 1.000E+00 | 1.000E+00 | -- | 1.128E+04 | 2.498E+04 | -0.79533 | 1.000E+00 |
| 39 | 1997 | 1.000E+00 | 1.000E+00 | -- | 5.112E+04 | 2.960E+04 | 0.54636 | 1.000E+00 |
| 40 | 1998 | 1.000E+00 | 1.000E+00 | -- | 9.370E+04 | 3.480E+04 | 0.99040 | 1.000E+00 |
| 41 | 1999 | 1.000E+00 | 1.000E+00 | -- | 3.312E+04 | 4.012E+04 | -0.19163 | 1.000E+00 |
| 42 | 2000 | 1.000E+00 | 1.000E+00 | -- | 7.554E+04 | 4.575E+04 | 0.50152 | 1.000E+00 |
| 43 | 2001 | 1.000E+00 | 1.000E+00 | -- | 1.040E+05 | 5.271E+04 | 0.67946 | 1.000E+00 |
| 44 | 2002 | 1.000E+00 | 1.000E+00 | -- | 3.826E+04 | 6.042E+04 | -0.45681 | 1.000E+00 |
| 45 | 2003 | 1.000E+00 | 1.000E+00 | -- | 5.688E+04 | 6.863E+04 | -0.18770 | 1.000E+00 |
| 46 | 2004 | 1.000E+00 | 1.000E+00 | -- | 4.061E+04 | 7.756E+04 | -0.64689 | 1.000E+00 |
| 47 | 2005 | 1.000E+00 | 1.000E+00 | -- | 4.191E+04 | 8.675E+04 | -0.72753 | 1.000E+00 |
| 48 | 2006 | 1.000E+00 | 1.000E+00 | -- | 6.466E+04 | 9.610E+04 | -0.39620 | 1.000E+00 |
| 49 | 2007 | 1.000E+00 | 1.000E+00 | -- | 6.721E+04 | 1.049E+05 | -0.44491 | 1.000E+00 |
| 50 | 2008 | 1.000E+00 | 1.000E+00 | -- | 1.452E+05 | 1.138E+05 | 0.24387 | 1.000E+00 |
| 51 | 2009 | 1.000E+00 | 1.000E+00 | -- | 1.595E+05 | 1.221E+05 | 0.26732 | 1.000E+00 |
| 52 | 2010 | 1.000E+00 | 1.000E+00 | -- | 1.371E+05 | 1.286E+05 | 0.06414 | 1.000E+00 |
| 53 | 2011 | 0.000E+00 | 0.000E+00 | -- | * | 1.339E+05 | 0.00000 | 1.000E+00 |

* Asterisk indicates missing value(s).

```
UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 3
                   -1       -0.75     -0.5      -0.25       0        0.25      0.5       0.75       1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    ------------------------------------------------------------------------------------
1959     0.0000                                             |
1960     0.0000                                             |
1961     0.0000                                             |
1962     0.0000                                             |
1963     0.0000                                             |
1964     0.0000                                             |
1965     0.0000                                             |
1966     0.0000                                             |
1967     0.0000                                             |
1968     0.0000                                             |
1969     0.0000                                             |
1970     0.0000                                             |
1971     0.0000                                             |
1972     0.0000                                             |
1973     0.0000                                             |
1974     0.0000                                             |
1975     0.0000                                             |
1976     0.0000                                             |
1977     0.0000                                             |
1978     0.0000                                             |
1979     0.0000                                             |
1980     0.0000                                             |
1981     0.0000                                             |
1982     0.0000                                             |
1983     0.0000                                             |
1984     0.0000                                             |
1985     0.0000                                             |
1986     0.0000                                             |
1987     0.0000                                             |
1988     0.0000                                             |
1989     0.0000                                             |
1990     0.0000                                             |
1991    -0.1614                                       ======|
1992     0.0000                                             |
1993    -0.2550                                   ==========|
1994     0.3068                                             |============
1995     0.6630                                             |===========================
1996    -0.7953             ================================|
1997     0.5464                                             |======================
1998     0.9904                                             |========================================
1999    -0.1916                                     ========|
2000     0.5015                                             |====================
2001     0.6795                                             |===========================
2002    -0.4568                           ==================|
2003    -0.1877                                     ========|
2004    -0.6469                   ==========================|
2005    -0.7275                =============================|
2006    -0.3962                             ================|
2007    -0.4449                           ==================|
2008     0.2439                                             |==========
2009     0.2673                                             |===========
2010     0.0641                                             |===
2011     0.0000                                             |
                   ------------------------------------------------------------------------------------
```

RESULTS FOR DATA SERIES # 4 (NON-BOOTSTRAPPED) 3LN Power russian survey

Data type I1: Abundance index (annual average) Series weight: 1.000

| Obs | Year | Observed effort | Estimated effort | Estim F | Observed index | Model index | Resid in log index | Statist weight |
|---|---|---|---|---|---|---|---|---|
| 1 | 1959 | 0.000E+00 | 0.000E+00 | -- | * | 5.415E+04 | 0.00000 | 1.000E+00 |
| 2 | 1960 | 0.000E+00 | 0.000E+00 | -- | * | 5.058E+04 | 0.00000 | 1.000E+00 |
| 3 | 1961 | 0.000E+00 | 0.000E+00 | -- | * | 4.992E+04 | 0.00000 | 1.000E+00 |
| 4 | 1962 | 0.000E+00 | 0.000E+00 | -- | * | 4.997E+04 | 0.00000 | 1.000E+00 |
| 5 | 1963 | 0.000E+00 | 0.000E+00 | -- | * | 4.938E+04 | 0.00000 | 1.000E+00 |
| 6 | 1964 | 0.000E+00 | 0.000E+00 | -- | * | 5.045E+04 | 0.00000 | 1.000E+00 |
| 7 | 1965 | 0.000E+00 | 0.000E+00 | -- | * | 5.211E+04 | 0.00000 | 1.000E+00 |
| 8 | 1966 | 0.000E+00 | 0.000E+00 | -- | * | 5.288E+04 | 0.00000 | 1.000E+00 |
| 9 | 1967 | 0.000E+00 | 0.000E+00 | -- | * | 5.311E+04 | 0.00000 | 1.000E+00 |
| 10 | 1968 | 0.000E+00 | 0.000E+00 | -- | * | 5.328E+04 | 0.00000 | 1.000E+00 |
| 11 | 1969 | 0.000E+00 | 0.000E+00 | -- | * | 5.378E+04 | 0.00000 | 1.000E+00 |
| 12 | 1970 | 0.000E+00 | 0.000E+00 | -- | * | 5.480E+04 | 0.00000 | 1.000E+00 |
| 13 | 1971 | 0.000E+00 | 0.000E+00 | -- | * | 5.438E+04 | 0.00000 | 1.000E+00 |
| 14 | 1972 | 0.000E+00 | 0.000E+00 | -- | * | 5.190E+04 | 0.00000 | 1.000E+00 |
| 15 | 1973 | 0.000E+00 | 0.000E+00 | -- | * | 4.943E+04 | 0.00000 | 1.000E+00 |
| 16 | 1974 | 0.000E+00 | 0.000E+00 | -- | * | 4.787E+04 | 0.00000 | 1.000E+00 |
| 17 | 1975 | 0.000E+00 | 0.000E+00 | -- | * | 4.848E+04 | 0.00000 | 1.000E+00 |
| 18 | 1976 | 0.000E+00 | 0.000E+00 | -- | * | 4.936E+04 | 0.00000 | 1.000E+00 |
| 19 | 1977 | 0.000E+00 | 0.000E+00 | -- | * | 5.050E+04 | 0.00000 | 1.000E+00 |
| 20 | 1978 | 0.000E+00 | 0.000E+00 | -- | * | 5.293E+04 | 0.00000 | 1.000E+00 |
| 21 | 1979 | 0.000E+00 | 0.000E+00 | -- | * | 5.582E+04 | 0.00000 | 1.000E+00 |
| 22 | 1980 | 0.000E+00 | 0.000E+00 | -- | * | 5.820E+04 | 0.00000 | 1.000E+00 |
| 23 | 1981 | 0.000E+00 | 0.000E+00 | -- | * | 5.915E+04 | 0.00000 | 1.000E+00 |
| 24 | 1982 | 0.000E+00 | 0.000E+00 | -- | * | 5.934E+04 | 0.00000 | 1.000E+00 |
| 25 | 1983 | 0.000E+00 | 0.000E+00 | -- | * | 6.018E+04 | 0.00000 | 1.000E+00 |
| 26 | 1984 | 1.000E+00 | 1.000E+00 | -- | 2.159E+05 | 6.201E+04 | 1.24742 | 1.000E+00 |
| 27 | 1985 | 1.000E+00 | 1.000E+00 | -- | 9.400E+04 | 6.373E+04 | 0.38854 | 1.000E+00 |
| 28 | 1986 | 1.000E+00 | 1.000E+00 | -- | 6.298E+04 | 6.134E+04 | 0.02638 | 1.000E+00 |
| 29 | 1987 | 1.000E+00 | 1.000E+00 | -- | 7.030E+04 | 4.998E+04 | 0.34120 | 1.000E+00 |
| 30 | 1988 | 1.000E+00 | 1.000E+00 | -- | 4.488E+04 | 3.726E+04 | 0.18611 | 1.000E+00 |
| 31 | 1989 | 1.000E+00 | 1.000E+00 | -- | 1.227E+04 | 3.018E+04 | -0.90006 | 1.000E+00 |
| 32 | 1990 | 1.000E+00 | 1.000E+00 | -- | 8.365E+03 | 2.579E+04 | -1.12579 | 1.000E+00 |
| 33 | 1991 | 1.000E+00 | 1.000E+00 | -- | 1.868E+04 | 2.200E+04 | -0.16356 | 1.000E+00 |
| 34 | 1992 | 0.000E+00 | 0.000E+00 | -- | * | 1.786E+04 | 0.00000 | 1.000E+00 |
| 35 | 1993 | 0.000E+00 | 0.000E+00 | -- | * | 1.383E+04 | 0.00000 | 1.000E+00 |
| 36 | 1994 | 0.000E+00 | 0.000E+00 | -- | * | 1.252E+04 | 0.00000 | 1.000E+00 |
| 37 | 1995 | 0.000E+00 | 0.000E+00 | -- | * | 1.388E+04 | 0.00000 | 1.000E+00 |
| 38 | 1996 | 0.000E+00 | 0.000E+00 | -- | * | 1.632E+04 | 0.00000 | 1.000E+00 |
| 39 | 1997 | 0.000E+00 | 0.000E+00 | -- | * | 1.940E+04 | 0.00000 | 1.000E+00 |
| 40 | 1998 | 0.000E+00 | 0.000E+00 | -- | * | 2.290E+04 | 0.00000 | 1.000E+00 |
| 41 | 1999 | 0.000E+00 | 0.000E+00 | -- | * | 2.665E+04 | 0.00000 | 1.000E+00 |
| 42 | 2000 | 0.000E+00 | 0.000E+00 | -- | * | 3.055E+04 | 0.00000 | 1.000E+00 |
| 43 | 2001 | 0.000E+00 | 0.000E+00 | -- | * | 3.503E+04 | 0.00000 | 1.000E+00 |
| 44 | 2002 | 0.000E+00 | 0.000E+00 | -- | * | 4.025E+04 | 0.00000 | 1.000E+00 |
| 45 | 2003 | 0.000E+00 | 0.000E+00 | -- | * | 4.593E+04 | 0.00000 | 1.000E+00 |
| 46 | 2004 | 0.000E+00 | 0.000E+00 | -- | * | 5.204E+04 | 0.00000 | 1.000E+00 |
| 47 | 2005 | 0.000E+00 | 0.000E+00 | -- | * | 5.850E+04 | 0.00000 | 1.000E+00 |
| 48 | 2006 | 0.000E+00 | 0.000E+00 | -- | * | 6.512E+04 | 0.00000 | 1.000E+00 |
| 49 | 2007 | 0.000E+00 | 0.000E+00 | -- | * | 7.159E+04 | 0.00000 | 1.000E+00 |
| 50 | 2008 | 0.000E+00 | 0.000E+00 | -- | * | 7.789E+04 | 0.00000 | 1.000E+00 |
| 51 | 2009 | 0.000E+00 | 0.000E+00 | -- | * | 8.402E+04 | 0.00000 | 1.000E+00 |
| 52 | 2010 | 0.000E+00 | 0.000E+00 | -- | * | 8.929E+04 | 0.00000 | 1.000E+00 |
| 53 | 2011 | 0.000E+00 | 0.000E+00 | -- | * | 9.350E+04 | 0.00000 | 1.000E+00 |

* Asterisk indicates missing value(s).

```
UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 4
                   -2       -1.5       -1       -0.5        0        0.5        1        1.5        2
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    ----------------------------------------------------------------------------------
1959     0.0000                                             |
1960     0.0000                                             |
1961     0.0000                                             |
1962     0.0000                                             |
1963     0.0000                                             |
1964     0.0000                                             |
1965     0.0000                                             |
1966     0.0000                                             |
1967     0.0000                                             |
1968     0.0000                                             |
1969     0.0000                                             |
1970     0.0000                                             |
1971     0.0000                                             |
1972     0.0000                                             |
1973     0.0000                                             |
1974     0.0000                                             |
1975     0.0000                                             |
1976     0.0000                                             |
1977     0.0000                                             |
1978     0.0000                                             |
1979     0.0000                                             |
1980     0.0000                                             |
1981     0.0000                                             |
1982     0.0000                                             |
1983     0.0000                                             |
1984     1.2474                                             |=========================
1985     0.3885                                             |========
1986     0.0264                                             |=
1987     0.3412                                             |=======
1988     0.1861                                             |====
1989    -0.9001                           ==================|
1990    -1.1258                      =======================|
1991    -0.1636                                          ===|
1992     0.0000                                             |
1993     0.0000                                             |
1994     0.0000                                             |
1995     0.0000                                             |
1996     0.0000                                             |
1997     0.0000                                             |
1998     0.0000                                             |
1999     0.0000                                             |
2000     0.0000                                             |
2001     0.0000                                             |
2002     0.0000                                             |
2003     0.0000                                             |
2004     0.0000                                             |
2005     0.0000                                             |
2006     0.0000                                             |
2007     0.0000                                             |
2008     0.0000                                             |
2009     0.0000                                             |
2010     0.0000                                             |
2011     0.0000                                             |
                   ----------------------------------------------------------------------------------
```

RESULTS FOR DATA SERIES # 5 (NON-BOOTSTRAPPED) 3L winter survey

Data type I0: Abundance index (start of year) Series weight: 1.000

| Obs | Year | Observed effort | Estimated effort | Estim F | Observed index | Model index | Resid in log index | Statist weight |
|---|---|---|---|---|---|---|---|---|
| 1 | 1959 | 0.000E+00 | 0.000E+00 | -- | * | 4.642E+04 | 0.00000 | 1.000E+00 |
| 2 | 1960 | 0.000E+00 | 0.000E+00 | -- | * | 4.142E+04 | 0.00000 | 1.000E+00 |
| 3 | 1961 | 0.000E+00 | 0.000E+00 | -- | * | 4.049E+04 | 0.00000 | 1.000E+00 |
| 4 | 1962 | 0.000E+00 | 0.000E+00 | -- | * | 4.032E+04 | 0.00000 | 1.000E+00 |
| 5 | 1963 | 0.000E+00 | 0.000E+00 | -- | * | 4.057E+04 | 0.00000 | 1.000E+00 |
| 6 | 1964 | 0.000E+00 | 0.000E+00 | -- | * | 3.941E+04 | 0.00000 | 1.000E+00 |
| 7 | 1965 | 0.000E+00 | 0.000E+00 | -- | * | 4.226E+04 | 0.00000 | 1.000E+00 |
| 8 | 1966 | 0.000E+00 | 0.000E+00 | -- | * | 4.211E+04 | 0.00000 | 1.000E+00 |
| 9 | 1967 | 0.000E+00 | 0.000E+00 | -- | * | 4.349E+04 | 0.00000 | 1.000E+00 |
| 10 | 1968 | 0.000E+00 | 0.000E+00 | -- | * | 4.250E+04 | 0.00000 | 1.000E+00 |
| 11 | 1969 | 0.000E+00 | 0.000E+00 | -- | * | 4.374E+04 | 0.00000 | 1.000E+00 |
| 12 | 1970 | 0.000E+00 | 0.000E+00 | -- | * | 4.334E+04 | 0.00000 | 1.000E+00 |
| 13 | 1971 | 0.000E+00 | 0.000E+00 | -- | * | 4.537E+04 | 0.00000 | 1.000E+00 |
| 14 | 1972 | 0.000E+00 | 0.000E+00 | -- | * | 4.274E+04 | 0.00000 | 1.000E+00 |
| 15 | 1973 | 0.000E+00 | 0.000E+00 | -- | * | 4.131E+04 | 0.00000 | 1.000E+00 |
| 16 | 1974 | 0.000E+00 | 0.000E+00 | -- | * | 3.877E+04 | 0.00000 | 1.000E+00 |
| 17 | 1975 | 0.000E+00 | 0.000E+00 | -- | * | 3.873E+04 | 0.00000 | 1.000E+00 |
| 18 | 1976 | 0.000E+00 | 0.000E+00 | -- | * | 3.974E+04 | 0.00000 | 1.000E+00 |
| 19 | 1977 | 0.000E+00 | 0.000E+00 | -- | * | 4.017E+04 | 0.00000 | 1.000E+00 |
| 20 | 1978 | 0.000E+00 | 0.000E+00 | -- | * | 4.158E+04 | 0.00000 | 1.000E+00 |
| 21 | 1979 | 0.000E+00 | 0.000E+00 | -- | * | 4.411E+04 | 0.00000 | 1.000E+00 |
| 22 | 1980 | 0.000E+00 | 0.000E+00 | -- | * | 4.624E+04 | 0.00000 | 1.000E+00 |
| 23 | 1981 | 0.000E+00 | 0.000E+00 | -- | * | 4.797E+04 | 0.00000 | 1.000E+00 |
| 24 | 1982 | 0.000E+00 | 0.000E+00 | -- | * | 4.780E+04 | 0.00000 | 1.000E+00 |
| 25 | 1983 | 0.000E+00 | 0.000E+00 | -- | * | 4.826E+04 | 0.00000 | 1.000E+00 |
| 26 | 1984 | 0.000E+00 | 0.000E+00 | -- | * | 4.915E+04 | 0.00000 | 1.000E+00 |
| 27 | 1985 | 1.000E+00 | 1.000E+00 | -- | 9.024E+04 | 5.122E+04 | 0.56637 | 1.000E+00 |
| 28 | 1986 | 1.000E+00 | 1.000E+00 | -- | 3.657E+04 | 5.195E+04 | -0.35113 | 1.000E+00 |
| 29 | 1987 | 0.000E+00 | 0.000E+00 | -- | * | 4.749E+04 | 0.00000 | 1.000E+00 |
| 30 | 1988 | 0.000E+00 | 0.000E+00 | -- | * | 3.431E+04 | 0.00000 | 1.000E+00 |
| 31 | 1989 | 0.000E+00 | 0.000E+00 | -- | * | 2.644E+04 | 0.00000 | 1.000E+00 |
| 32 | 1990 | 1.000E+00 | 1.000E+00 | -- | 1.820E+04 | 2.255E+04 | -0.21433 | 1.000E+00 |
| 33 | 1991 | 0.000E+00 | 0.000E+00 | -- | * | 1.930E+04 | 0.00000 | 1.000E+00 |
| 34 | 1992 | 0.000E+00 | 0.000E+00 | -- | * | 1.641E+04 | 0.00000 | 1.000E+00 |
| 35 | 1993 | 0.000E+00 | 0.000E+00 | -- | * | 1.269E+04 | 0.00000 | 1.000E+00 |
| 36 | 1994 | 0.000E+00 | 0.000E+00 | -- | * | 9.837E+03 | 0.00000 | 1.000E+00 |
| 37 | 1995 | 0.000E+00 | 0.000E+00 | -- | * | 1.043E+04 | 0.00000 | 1.000E+00 |
| 38 | 1996 | 0.000E+00 | 0.000E+00 | -- | * | 1.208E+04 | 0.00000 | 1.000E+00 |
| 39 | 1997 | 0.000E+00 | 0.000E+00 | -- | * | 1.440E+04 | 0.00000 | 1.000E+00 |
| 40 | 1998 | 0.000E+00 | 0.000E+00 | -- | * | 1.707E+04 | 0.00000 | 1.000E+00 |
| 41 | 1999 | 0.000E+00 | 0.000E+00 | -- | * | 2.007E+04 | 0.00000 | 1.000E+00 |
| 42 | 2000 | 0.000E+00 | 0.000E+00 | -- | * | 2.313E+04 | 0.00000 | 1.000E+00 |
| 43 | 2001 | 0.000E+00 | 0.000E+00 | -- | * | 2.638E+04 | 0.00000 | 1.000E+00 |
| 44 | 2002 | 0.000E+00 | 0.000E+00 | -- | * | 3.039E+04 | 0.00000 | 1.000E+00 |
| 45 | 2003 | 0.000E+00 | 0.000E+00 | -- | * | 3.483E+04 | 0.00000 | 1.000E+00 |
| 46 | 2004 | 0.000E+00 | 0.000E+00 | -- | * | 3.957E+04 | 0.00000 | 1.000E+00 |
| 47 | 2005 | 0.000E+00 | 0.000E+00 | -- | * | 4.471E+04 | 0.00000 | 1.000E+00 |
| 48 | 2006 | 0.000E+00 | 0.000E+00 | -- | * | 5.002E+04 | 0.00000 | 1.000E+00 |
| 49 | 2007 | 0.000E+00 | 0.000E+00 | -- | * | 5.541E+04 | 0.00000 | 1.000E+00 |
| 50 | 2008 | 0.000E+00 | 0.000E+00 | -- | * | 6.046E+04 | 0.00000 | 1.000E+00 |
| 51 | 2009 | 0.000E+00 | 0.000E+00 | -- | * | 6.560E+04 | 0.00000 | 1.000E+00 |
| 52 | 2010 | 0.000E+00 | 0.000E+00 | -- | * | 7.037E+04 | 0.00000 | 1.000E+00 |
| 53 | 2011 | 0.000E+00 | 0.000E+00 | -- | * | 7.412E+04 | 0.00000 | 1.000E+00 |

* Asterisk indicates missing value(s).

```
UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 5
                   -1       -0.75     -0.5      -0.25       0        0.25      0.5       0.75      1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    ------------------------------------------------------------------------------------
1959     0.0000                                             |
1960     0.0000                                             |
1961     0.0000                                             |
1962     0.0000                                             |
1963     0.0000                                             |
1964     0.0000                                             |
1965     0.0000                                             |
1966     0.0000                                             |
1967     0.0000                                             |
1968     0.0000                                             |
1969     0.0000                                             |
1970     0.0000                                             |
1971     0.0000                                             |
1972     0.0000                                             |
1973     0.0000                                             |
1974     0.0000                                             |
1975     0.0000                                             |
1976     0.0000                                             |
1977     0.0000                                             |
1978     0.0000                                             |
1979     0.0000                                             |
1980     0.0000                                             |
1981     0.0000                                             |
1982     0.0000                                             |
1983     0.0000                                             |
1984     0.0000                                             |
1985     0.5664                                             |=======================
1986    -0.3511                               ==============|
1987     0.0000                                             |
1988     0.0000                                             |
1989     0.0000                                             |
1990    -0.2143                                    =========|
1991     0.0000                                             |
1992     0.0000                                             |
1993     0.0000                                             |
1994     0.0000                                             |
1995     0.0000                                             |
1996     0.0000                                             |
1997     0.0000                                             |
1998     0.0000                                             |
1999     0.0000                                             |
2000     0.0000                                             |
2001     0.0000                                             |
2002     0.0000                                             |
2003     0.0000                                             |
2004     0.0000                                             |
2005     0.0000                                             |
2006     0.0000                                             |
2007     0.0000                                             |
2008     0.0000                                             |
2009     0.0000                                             |
2010     0.0000                                             |
2011     0.0000                                             |
                   ------------------------------------------------------------------------------------
```

RESULTS FOR DATA SERIES # 6 (NON-BOOTSTRAPPED) 3L summer survey

Data type I1: Abundance index (annual average) Series weight: 1.000

| Obs | Year | Observed effort | Estimated effort | Estim F | Observed index | Model index | Resid in log index | Statist weight |
|---|---|---|---|---|---|---|---|---|
| 1 | 1959 | 0.000E+00 | 0.000E+00 | -- | * | 1.736E+05 | 0.00000 | 1.000E+00 |
| 2 | 1960 | 0.000E+00 | 0.000E+00 | -- | * | 1.621E+05 | 0.00000 | 1.000E+00 |
| 3 | 1961 | 0.000E+00 | 0.000E+00 | -- | * | 1.600E+05 | 0.00000 | 1.000E+00 |
| 4 | 1962 | 0.000E+00 | 0.000E+00 | -- | * | 1.602E+05 | 0.00000 | 1.000E+00 |
| 5 | 1963 | 0.000E+00 | 0.000E+00 | -- | * | 1.583E+05 | 0.00000 | 1.000E+00 |
| 6 | 1964 | 0.000E+00 | 0.000E+00 | -- | * | 1.617E+05 | 0.00000 | 1.000E+00 |
| 7 | 1965 | 0.000E+00 | 0.000E+00 | -- | * | 1.670E+05 | 0.00000 | 1.000E+00 |
| 8 | 1966 | 0.000E+00 | 0.000E+00 | -- | * | 1.695E+05 | 0.00000 | 1.000E+00 |
| 9 | 1967 | 0.000E+00 | 0.000E+00 | -- | * | 1.702E+05 | 0.00000 | 1.000E+00 |
| 10 | 1968 | 0.000E+00 | 0.000E+00 | -- | * | 1.708E+05 | 0.00000 | 1.000E+00 |
| 11 | 1969 | 0.000E+00 | 0.000E+00 | -- | * | 1.724E+05 | 0.00000 | 1.000E+00 |
| 12 | 1970 | 0.000E+00 | 0.000E+00 | -- | * | 1.756E+05 | 0.00000 | 1.000E+00 |
| 13 | 1971 | 0.000E+00 | 0.000E+00 | -- | * | 1.743E+05 | 0.00000 | 1.000E+00 |
| 14 | 1972 | 0.000E+00 | 0.000E+00 | -- | * | 1.664E+05 | 0.00000 | 1.000E+00 |
| 15 | 1973 | 0.000E+00 | 0.000E+00 | -- | * | 1.584E+05 | 0.00000 | 1.000E+00 |
| 16 | 1974 | 0.000E+00 | 0.000E+00 | -- | * | 1.534E+05 | 0.00000 | 1.000E+00 |
| 17 | 1975 | 0.000E+00 | 0.000E+00 | -- | * | 1.554E+05 | 0.00000 | 1.000E+00 |
| 18 | 1976 | 0.000E+00 | 0.000E+00 | -- | * | 1.582E+05 | 0.00000 | 1.000E+00 |
| 19 | 1977 | 0.000E+00 | 0.000E+00 | -- | * | 1.619E+05 | 0.00000 | 1.000E+00 |
| 20 | 1978 | 1.000E+00 | 1.000E+00 | -- | 3.112E+05 | 1.697E+05 | 0.60645 | 1.000E+00 |
| 21 | 1979 | 1.000E+00 | 1.000E+00 | -- | 2.278E+05 | 1.789E+05 | 0.24151 | 1.000E+00 |
| 22 | 1980 | 0.000E+00 | 0.000E+00 | -- | * | 1.866E+05 | 0.00000 | 1.000E+00 |
| 23 | 1981 | 1.000E+00 | 1.000E+00 | -- | 2.614E+05 | 1.896E+05 | 0.32106 | 1.000E+00 |
| 24 | 1982 | 0.000E+00 | 0.000E+00 | -- | * | 1.902E+05 | 0.00000 | 1.000E+00 |
| 25 | 1983 | 0.000E+00 | 0.000E+00 | -- | * | 1.929E+05 | 0.00000 | 1.000E+00 |
| 26 | 1984 | 1.000E+00 | 1.000E+00 | -- | 2.777E+05 | 1.988E+05 | 0.33445 | 1.000E+00 |
| 27 | 1985 | 1.000E+00 | 1.000E+00 | -- | 1.610E+05 | 2.043E+05 | -0.23789 | 1.000E+00 |
| 28 | 1986 | 0.000E+00 | 0.000E+00 | -- | * | 1.966E+05 | 0.00000 | 1.000E+00 |
| 29 | 1987 | 0.000E+00 | 0.000E+00 | -- | * | 1.602E+05 | 0.00000 | 1.000E+00 |
| 30 | 1988 | 0.000E+00 | 0.000E+00 | -- | * | 1.194E+05 | 0.00000 | 1.000E+00 |
| 31 | 1989 | 0.000E+00 | 0.000E+00 | -- | * | 9.673E+04 | 0.00000 | 1.000E+00 |
| 32 | 1990 | 1.000E+00 | 1.000E+00 | -- | 9.284E+04 | 8.265E+04 | 0.11621 | 1.000E+00 |
| 33 | 1991 | 1.000E+00 | 1.000E+00 | -- | 3.757E+04 | 7.052E+04 | -0.62958 | 1.000E+00 |
| 34 | 1992 | 0.000E+00 | 0.000E+00 | -- | * | 5.726E+04 | 0.00000 | 1.000E+00 |
| 35 | 1993 | 1.000E+00 | 1.000E+00 | -- | 2.084E+04 | 4.433E+04 | -0.75498 | 1.000E+00 |
| 36 | 1994 | 0.000E+00 | 0.000E+00 | -- | * | 4.012E+04 | 0.00000 | 1.000E+00 |
| 37 | 1995 | 0.000E+00 | 0.000E+00 | -- | * | 4.449E+04 | 0.00000 | 1.000E+00 |
| 38 | 1996 | 0.000E+00 | 0.000E+00 | -- | * | 5.231E+04 | 0.00000 | 1.000E+00 |
| 39 | 1997 | 0.000E+00 | 0.000E+00 | -- | * | 6.218E+04 | 0.00000 | 1.000E+00 |
| 40 | 1998 | 0.000E+00 | 0.000E+00 | -- | * | 7.339E+04 | 0.00000 | 1.000E+00 |
| 41 | 1999 | 0.000E+00 | 0.000E+00 | -- | * | 8.543E+04 | 0.00000 | 1.000E+00 |
| 42 | 2000 | 0.000E+00 | 0.000E+00 | -- | * | 9.793E+04 | 0.00000 | 1.000E+00 |
| 43 | 2001 | 0.000E+00 | 0.000E+00 | -- | * | 1.123E+05 | 0.00000 | 1.000E+00 |
| 44 | 2002 | 0.000E+00 | 0.000E+00 | -- | * | 1.290E+05 | 0.00000 | 1.000E+00 |
| 45 | 2003 | 0.000E+00 | 0.000E+00 | -- | * | 1.472E+05 | 0.00000 | 1.000E+00 |
| 46 | 2004 | 0.000E+00 | 0.000E+00 | -- | * | 1.668E+05 | 0.00000 | 1.000E+00 |
| 47 | 2005 | 0.000E+00 | 0.000E+00 | -- | * | 1.875E+05 | 0.00000 | 1.000E+00 |
| 48 | 2006 | 0.000E+00 | 0.000E+00 | -- | * | 2.087E+05 | 0.00000 | 1.000E+00 |
| 49 | 2007 | 0.000E+00 | 0.000E+00 | -- | * | 2.295E+05 | 0.00000 | 1.000E+00 |
| 50 | 2008 | 0.000E+00 | 0.000E+00 | -- | * | 2.497E+05 | 0.00000 | 1.000E+00 |
| 51 | 2009 | 0.000E+00 | 0.000E+00 | -- | * | 2.693E+05 | 0.00000 | 1.000E+00 |
| 52 | 2010 | 0.000E+00 | 0.000E+00 | -- | * | 2.862E+05 | 0.00000 | 1.000E+00 |
| 53 | 2011 | 0.000E+00 | 0.000E+00 | -- | * | 2.997E+05 | 0.00000 | 1.000E+00 |

* Asterisk indicates missing value(s).

UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 6

```
                   -1       -0.75     -0.5      -0.25       0        0.25      0.5       0.75       1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    ------------------------------------------------------------------------------------
1959     0.0000                                             |
1960     0.0000                                             |
1961     0.0000                                             |
1962     0.0000                                             |
1963     0.0000                                             |
1964     0.0000                                             |
1965     0.0000                                             |
1966     0.0000                                             |
1967     0.0000                                             |
1968     0.0000                                             |
1969     0.0000                                             |
1970     0.0000                                             |
1971     0.0000                                             |
1972     0.0000                                             |
1973     0.0000                                             |
1974     0.0000                                             |
1975     0.0000                                             |
1976     0.0000                                             |
1977     0.0000                                             |
1978     0.6065                                             |========================
1979     0.2415                                             |==========
1980     0.0000                                             |
1981     0.3211                                             |=============
1982     0.0000                                             |
1983     0.0000                                             |
1984     0.3344                                             |=============
1985    -0.2379                                   ==========|
1986     0.0000                                             |
1987     0.0000                                             |
1988     0.0000                                             |
1989     0.0000                                             |
1990     0.1162                                             |=====
1991    -0.6296                    =========================|
1992     0.0000                                             |
1993    -0.7550               ==============================|
1994     0.0000                                             |
1995     0.0000                                             |
1996     0.0000                                             |
1997     0.0000                                             |
1998     0.0000                                             |
1999     0.0000                                             |
2000     0.0000                                             |
2001     0.0000                                             |
2002     0.0000                                             |
2003     0.0000                                             |
2004     0.0000                                             |
2005     0.0000                                             |
2006     0.0000                                             |
2007     0.0000                                             |
2008     0.0000                                             |
2009     0.0000                                             |
2010     0.0000                                             |
2011     0.0000                                             |
                   ------------------------------------------------------------------------------------
```

RESULTS FOR DATA SERIES # 7 (NON-BOOTSTRAPPED) 3L autumn survey

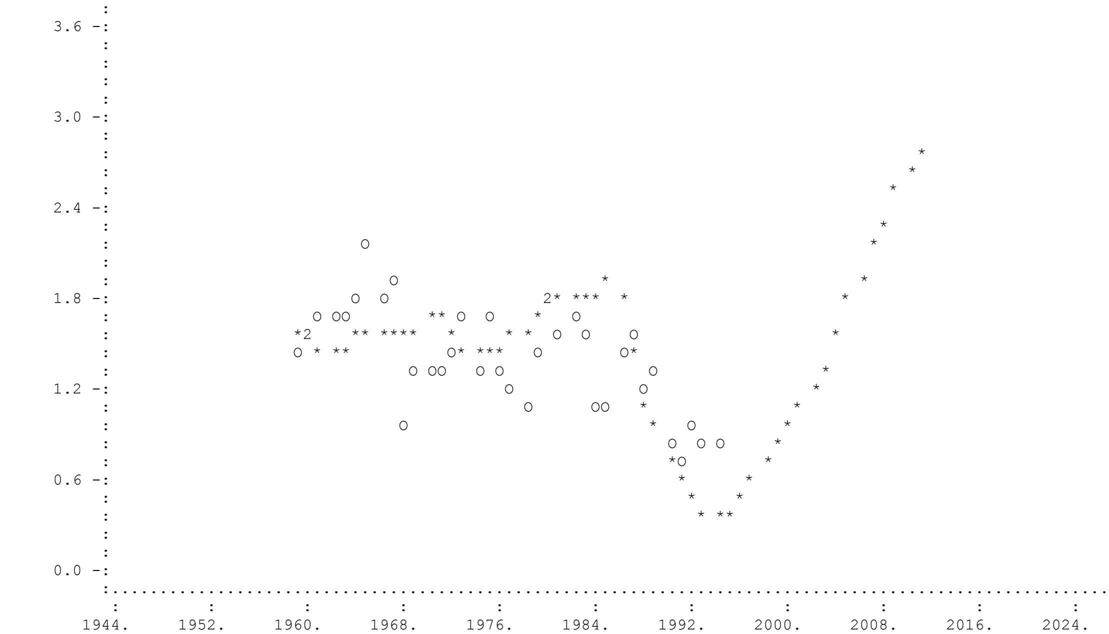
Data type I2: Abundance index (end of year) Series weight: 1.000

| Obs | Year | Observed effort | Estimated effort | Estim F | Observed index | Model index | Resid in log index | Statist weight |
|---|---|---|---|---|---|---|---|---|
| 1 | 1959 | 0.000E+00 | 0.000E+00 | -- | * | 2.943E+04 | 0.00000 | 1.000E+00 |
| 2 | 1960 | 0.000E+00 | 0.000E+00 | -- | * | 2.877E+04 | 0.00000 | 1.000E+00 |
| 3 | 1961 | 0.000E+00 | 0.000E+00 | -- | * | 2.865E+04 | 0.00000 | 1.000E+00 |
| 4 | 1962 | 0.000E+00 | 0.000E+00 | -- | * | 2.883E+04 | 0.00000 | 1.000E+00 |
| 5 | 1963 | 0.000E+00 | 0.000E+00 | -- | * | 2.800E+04 | 0.00000 | 1.000E+00 |
| 6 | 1964 | 0.000E+00 | 0.000E+00 | -- | * | 3.003E+04 | 0.00000 | 1.000E+00 |
| 7 | 1965 | 0.000E+00 | 0.000E+00 | -- | * | 2.992E+04 | 0.00000 | 1.000E+00 |
| 8 | 1966 | 0.000E+00 | 0.000E+00 | -- | * | 3.090E+04 | 0.00000 | 1.000E+00 |
| 9 | 1967 | 0.000E+00 | 0.000E+00 | -- | * | 3.020E+04 | 0.00000 | 1.000E+00 |
| 10 | 1968 | 0.000E+00 | 0.000E+00 | -- | * | 3.108E+04 | 0.00000 | 1.000E+00 |
| 11 | 1969 | 0.000E+00 | 0.000E+00 | -- | * | 3.079E+04 | 0.00000 | 1.000E+00 |
| 12 | 1970 | 0.000E+00 | 0.000E+00 | -- | * | 3.224E+04 | 0.00000 | 1.000E+00 |
| 13 | 1971 | 0.000E+00 | 0.000E+00 | -- | * | 3.037E+04 | 0.00000 | 1.000E+00 |
| 14 | 1972 | 0.000E+00 | 0.000E+00 | -- | * | 2.936E+04 | 0.00000 | 1.000E+00 |
| 15 | 1973 | 0.000E+00 | 0.000E+00 | -- | * | 2.755E+04 | 0.00000 | 1.000E+00 |
| 16 | 1974 | 0.000E+00 | 0.000E+00 | -- | * | 2.752E+04 | 0.00000 | 1.000E+00 |
| 17 | 1975 | 0.000E+00 | 0.000E+00 | -- | * | 2.824E+04 | 0.00000 | 1.000E+00 |
| 18 | 1976 | 0.000E+00 | 0.000E+00 | -- | * | 2.855E+04 | 0.00000 | 1.000E+00 |
| 19 | 1977 | 0.000E+00 | 0.000E+00 | -- | * | 2.955E+04 | 0.00000 | 1.000E+00 |
| 20 | 1978 | 0.000E+00 | 0.000E+00 | -- | * | 3.134E+04 | 0.00000 | 1.000E+00 |
| 21 | 1979 | 0.000E+00 | 0.000E+00 | -- | * | 3.286E+04 | 0.00000 | 1.000E+00 |
| 22 | 1980 | 0.000E+00 | 0.000E+00 | -- | * | 3.409E+04 | 0.00000 | 1.000E+00 |
| 23 | 1981 | 0.000E+00 | 0.000E+00 | -- | * | 3.396E+04 | 0.00000 | 1.000E+00 |
| 24 | 1982 | 0.000E+00 | 0.000E+00 | -- | * | 3.429E+04 | 0.00000 | 1.000E+00 |
| 25 | 1983 | 0.000E+00 | 0.000E+00 | -- | * | 3.493E+04 | 0.00000 | 1.000E+00 |
| 26 | 1984 | 0.000E+00 | 0.000E+00 | -- | * | 3.640E+04 | 0.00000 | 1.000E+00 |
| 27 | 1985 | 1.000E+00 | 1.000E+00 | -- | 9.823E+04 | 3.692E+04 | 0.97870 | 1.000E+00 |
| 28 | 1986 | 1.000E+00 | 1.000E+00 | -- | 1.712E+04 | 3.375E+04 | -0.67869 | 1.000E+00 |
| 29 | 1987 | 0.000E+00 | 0.000E+00 | -- | * | 2.438E+04 | 0.00000 | 1.000E+00 |
| 30 | 1988 | 0.000E+00 | 0.000E+00 | -- | * | 1.879E+04 | 0.00000 | 1.000E+00 |
| 31 | 1989 | 0.000E+00 | 0.000E+00 | -- | * | 1.603E+04 | 0.00000 | 1.000E+00 |
| 32 | 1990 | 1.000E+00 | 1.000E+00 | -- | 2.074E+04 | 1.372E+04 | 0.41365 | 1.000E+00 |
| 33 | 1991 | 1.000E+00 | 1.000E+00 | -- | 1.366E+04 | 1.166E+04 | 0.15861 | 1.000E+00 |
| 34 | 1992 | 1.000E+00 | 1.000E+00 | -- | 1.342E+04 | 9.016E+03 | 0.39808 | 1.000E+00 |
| 35 | 1993 | 1.000E+00 | 1.000E+00 | -- | 6.011E+03 | 6.990E+03 | -0.15089 | 1.000E+00 |
| 36 | 1994 | 1.000E+00 | 1.000E+00 | -- | 7.173E+03 | 7.410E+03 | -0.03256 | 1.000E+00 |
| 37 | 1995 | 0.000E+00 | 0.000E+00 | -- | * | 8.582E+03 | 0.00000 | 1.000E+00 |
| 38 | 1996 | 1.000E+00 | 1.000E+00 | -- | 4.691E+03 | 1.023E+04 | -0.78008 | 1.000E+00 |
| 39 | 1997 | 1.000E+00 | 1.000E+00 | -- | 1.954E+04 | 1.213E+04 | 0.47730 | 1.000E+00 |
| 40 | 1998 | 1.000E+00 | 1.000E+00 | -- | 1.852E+04 | 1.426E+04 | 0.26159 | 1.000E+00 |
| 41 | 1999 | 1.000E+00 | 1.000E+00 | -- | 3.886E+04 | 1.644E+04 | 0.86044 | 1.000E+00 |
| 42 | 2000 | 1.000E+00 | 1.000E+00 | -- | 2.492E+04 | 1.874E+04 | 0.28472 | 1.000E+00 |
| 43 | 2001 | 1.000E+00 | 1.000E+00 | -- | 2.857E+04 | 2.160E+04 | 0.27979 | 1.000E+00 |
| 44 | 2002 | 1.000E+00 | 1.000E+00 | -- | 1.189E+04 | 2.475E+04 | -0.73334 | 1.000E+00 |
| 45 | 2003 | 1.000E+00 | 1.000E+00 | -- | 1.501E+04 | 2.812E+04 | -0.62779 | 1.000E+00 |
| 46 | 2004 | 1.000E+00 | 1.000E+00 | -- | 9.293E+03 | 3.177E+04 | -1.22937 | 1.000E+00 |
| 47 | 2005 | 1.000E+00 | 1.000E+00 | -- | 1.665E+04 | 3.554E+04 | -0.75830 | 1.000E+00 |
| 48 | 2006 | 1.000E+00 | 1.000E+00 | -- | 2.722E+04 | 3.937E+04 | -0.36918 | 1.000E+00 |
| 49 | 2007 | 1.000E+00 | 1.000E+00 | -- | 5.755E+04 | 4.297E+04 | 0.29219 | 1.000E+00 |
| 50 | 2008 | 1.000E+00 | 1.000E+00 | -- | 5.328E+04 | 4.662E+04 | 0.13355 | 1.000E+00 |
| 51 | 2009 | 1.000E+00 | 1.000E+00 | -- | 8.724E+04 | 5.000E+04 | 0.55660 | 1.000E+00 |
| 52 | 2010 | 0.000E+00 | 0.000E+00 | -- | * | 5.267E+04 | 0.00000 | 1.000E+00 |
| 53 | 2011 | 1.000E+00 | 1.000E+00 | -- | 7.142E+04 | 5.485E+04 | 0.26397 | 1.000E+00 |

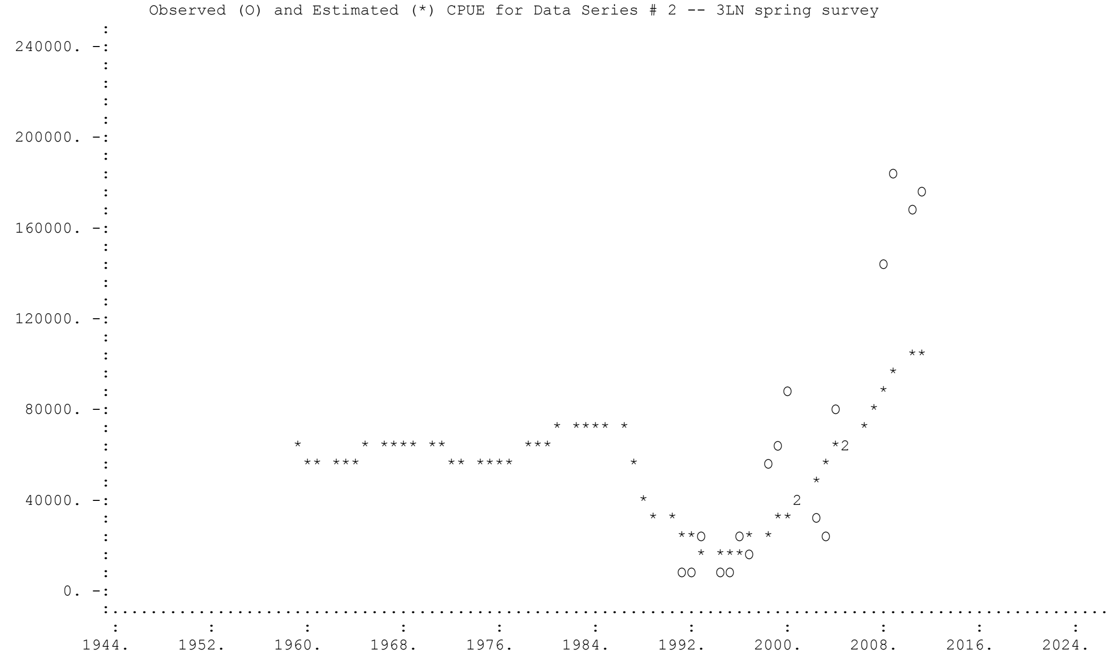
* Asterisk indicates missing value(s).

```
UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 7
                   -2       -1.5       -1       -0.5        0        0.5        1        1.5        2
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    ------------------------------------------------------------------------------------
1959     0.0000                                             |
1960     0.0000                                             |
1961     0.0000                                             |
1962     0.0000                                             |
1963     0.0000                                             |
1964     0.0000                                             |
1965     0.0000                                             |
1966     0.0000                                             |
1967     0.0000                                             |
1968     0.0000                                             |
1969     0.0000                                             |
1970     0.0000                                             |
1971     0.0000                                             |
1972     0.0000                                             |
1973     0.0000                                             |
1974     0.0000                                             |
1975     0.0000                                             |
1976     0.0000                                             |
1977     0.0000                                             |
1978     0.0000                                             |
1979     0.0000                                             |
1980     0.0000                                             |
1981     0.0000                                             |
1982     0.0000                                             |
1983     0.0000                                             |
1984     0.0000                                             |
1985     0.9787                                             |====================
1986    -0.6787                               ==============|
1987     0.0000                                             |
1988     0.0000                                             |
1989     0.0000                                             |
1990     0.4137                                             |========
1991     0.1586                                             |===
1992     0.3981                                             |========
1993    -0.1509                                          ===|
1994    -0.0326                                            =|
1995     0.0000                                             |
1996    -0.7801                             ================|
1997     0.4773                                             |==========
1998     0.2616                                             |=====
1999     0.8604                                             |=================
2000     0.2847                                             |======
2001     0.2798                                             |======
2002    -0.7333                              ===============|
2003    -0.6278                                =============|
2004    -1.2294                    =========================|
2005    -0.7583                              ===============|
2006    -0.3692                                      =======|
2007     0.2922                                             |======
2008     0.1335                                             |===
2009     0.5566                                             |===========
2010     0.0000                                             |
2011     0.2640                                             |=====
                   ------------------------------------------------------------------------------------
```

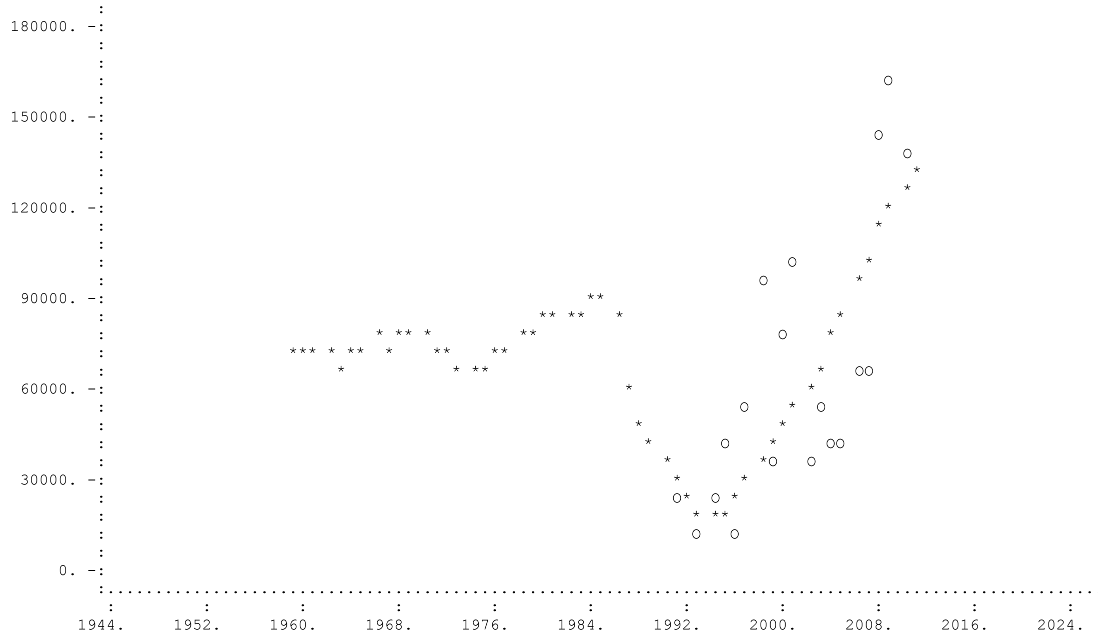
Observed (O) and Estimated (*) CPUE for Data Series # 1 -- Statlant CPUE



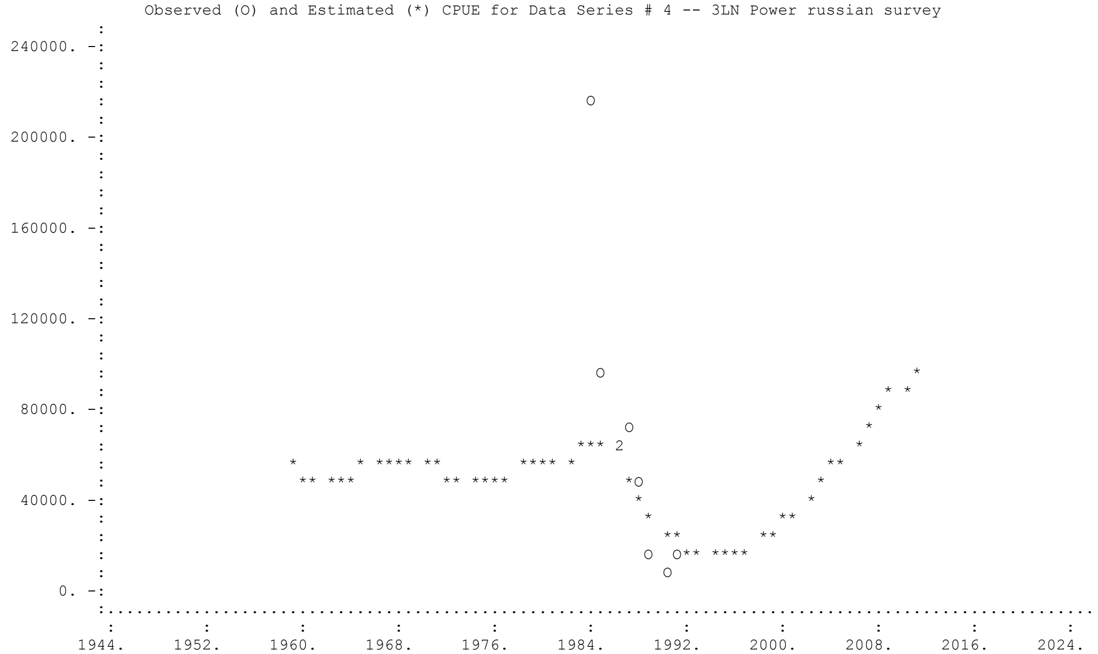

Observed (O) and Estimated (*) CPUE for Data Series # 2 -- 3LN spring survey



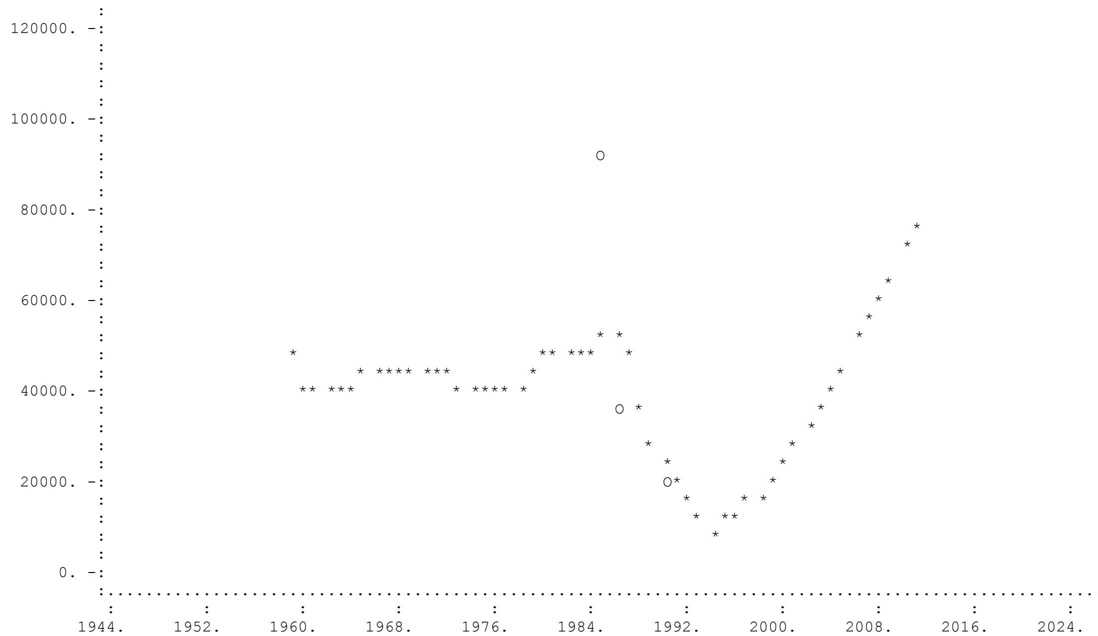
Observed (O) and Estimated (*) CPUE for Data Series # 3 -- 3N autumn survey



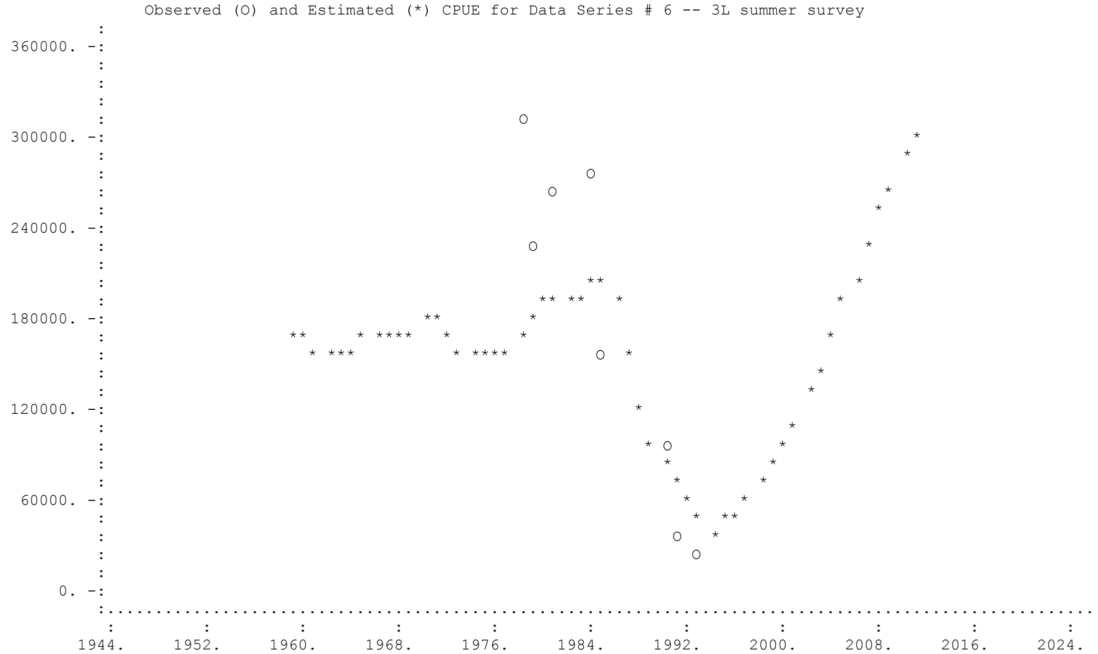

Observed (O) and Estimated (*) CPUE for Data Series # 4 -- 3LN Power russian survey



Observed (O) and Estimated (*) CPUE for Data Series # 5 -- 3L winter survey




Observed (O) and Estimated (*) CPUE for Data Series # 6 -- 3L summer survey



```
3LN redfish                                                                                                     Page 21

                Observed (O) and Estimated (*) CPUE for Data Series # 7 -- 3L autumn survey
           :
  120000. -:
           :
           :
           :
           :
  100000. -:                                                   O
           :
           :
           :                                                                                 O
           :
   80000. -:
           :
           :                                                                                    O
           :
           :
   60000. -:
           :                                                                               O    *
           :                                                                                O* *
           :                                                                                *
           :                                                                               *
   40000. -:                                                                     O        *
           :                                             *  ****                        *
           :                         *  **** **        ** *      *                     *
           :                   *** ** *        ** ****                             O  *   O
           :                                                      *               O  *
   20000. -:                                                       *  O       O O  **
           :                                                     O  *           **    O O
           :                                                          *2O    **      O
           :                                                            *2 2*          O
           :                                                                 O
       0. -:
           :........................................................................................................
            :         :         :         :         :         :         :         :         :         :         :
         1944.     1952.     1960.     1968.     1976.     1984.     1992.     2000.     2008.     2016.     2024.
```

```
                                   Time Plot of Estimated F/Fmsy and B/Bmsy (dashed line = 1.0)
           :
      4.8 -:
           :
           :
           :                                                      F
           :                                                            FF
      4.0 -:
           :                                                       F
           :
           :
           :
      3.2 -:                                                           F
           :                                                        F F
           :
           :
           :
      2.4 -:
           :                   F
           :
           :                                                     F
           :                                  F F
      1.6 -:                                   F
           :                    F   F    F                                                      BB
           :                     F    F    F      F                        F                 B B
           :                       F                F     F                                BB
           :        ---- ---- -2-- ---- --2- ---- -2-2 --22 3323 22-- ---- ---- ---- ---- 2--- ---- ---- ---
      0.8 -:                    BB BBBB 2BBB BBBB BBBB BBF                             BB
           :                                 F         FF     F    B                 BB
           :                         F                              B B           BB
           :                                                           BBB  F B BBF
           :                                                               BBBF FF F F         FF
      0.0 -:                                                                 F        FFF FFFF
           :........................................................................................................
            :         :         :         :         :         :         :         :         :         :         :
         1944.     1952.     1960.     1968.     1976.     1984.     1992.     2000.     2008.     2016.     2024.

Elapsed time: 0 hours, 0 minutes, 13 seconds.
```