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An ASPIC Based Assessment of Redfish in NAFO Divisions 3LN

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 assessment is based on the results of a non-equilibrium surplus production model (ASPIC Prager, 1994, 2004 and 2007), adjusted to a standardized catch rate series (Power, 1997) and two series of stratified bottom trawl surveys, covering from 1991 onwards almost the entire area of redfish distribution in north and south east Grand Bank. The assessment was preceded by an exploratory analysis of different data formulations derived from the available data series, using a traffic light framework to evaluate the diagnostics of each ASPIC run. The chosen input formulation run afterwards with different starting guesses for key parameters (or different random number seeds) in order to check if ASPIC solutions were sensitive to changes in the inputs given by the user (or the program) to initialize the model. The assessment was then carried out with ASPIC on bootstrap mode (1000 trials based on the random re-sampling of *cpue* and survey log residuals) giving bias corrected estimates of model parameters, relative biomass (B/B_{msy}) and relative fishing mortality (F/F_{msy}) trajectories, with associated 50% and 80% confidence intervals. Biomass and fishing mortality rates were finally medium term projected (2007-2016/2017) under a low constant catch regime (5000 ton). The stock trajectory estimated in the surplus production analysis shows a biomass rapidly declining to bellow B_{msy} when fishing mortality rate rises from just above to well above F_{msy} (1986-1987), and a biomass rapidly returning to above B_{msy} after fishing mortality drops to well bellow F_{msy} (1993-1994). A constant catch level of 5000 ton will keep the redfish in Div. 3LN in its present safe zone, with the lower 80% CL of relative biomass well above the B_{msy} level and the upper 80% CL of relative fishing mortality rate well bellow the F_{msy} level.

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 extrusion 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, and as a consequence they are reported collectively as “redfish” in the commercial fishery statistics. For the same reason *S. mentella* and *S. fasciatus* are treated as a single species in the Grand Bank surveys carried out by Canada, Russia and more recently by EU-Spain.

This redfish assessment regards the beaked redfish in Div. 3LN 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.

Nominal catches and TAC’s

Reported catches from Div. 3LN declined from 45 000 to 10 000 ton on the first years of catch records (1959-1964) and oscillated over 21 years afterwards (1965-1985) around 21 000 tons average level. Catches increased sharply to a 79,000 tons high in 1987 and fall steadily afterwards to 450 tons in 1996. From 1986 till 1993 reported catches exceeded TAC’s, but in the rest of the years prior to the close of the fishery catches fell well bellow annual TAC’s. The NAFO Fisheries Commission implemented a moratorium on directed fishing for this stock since in 1998.

Catch increased to 900 tons in 1998, the first year under a moratorium on directed fishing, with a further increase to 3 100 tons in 2000. Catches declined again in 2001-2003 and were stable in 2004-2005 at 650 tons level. From NAFO Circular Letters catch recorded an historic low of 207 tons in 2006 (Table 1, Fig. 1).

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 southeast 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-Spain and EU-Portugal bottom trawl fleets became the main fleets responsible for the 3LN redfish by-catch during the moratorium years.

Commercial Fishery Data

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. The 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 present 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) (Table 2). In order to reduce the inter annual noise and get clearer picture of short/medium term trends within the time series catch rates were transformed to 3 year moving averages (Table 2). Both original and moving average catch rates for Div. 3LN were finally standardized to their respective mean and presented on Fig. 2. Catch rate for Div. 3LN increased on the first years of the time series, 1959 till 1965-1966, oscillate around the average on the intermediate years and start declining from 1986 onwards. On the final years, 1991-1994 catch rates stabilize at a minimum level.

Commercial fishery sampling

Most of the commercial length sampling data available for the 3LN beaked redfish stocks 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.*, 2007). 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 2003-2005 and 2003-2006 respectively (González *et al*., 2006; Vaskov *et al*., 2007). The 1990-2006 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 compute each absolute length frequency vector of the 3LN redfish commercial catch (Table 3b) were derived from individual length /weight observations collected annually through the sampling on board of the Portuguese by-catches from both Divisions 3L and 3N (Alpoim and Vargas, 2004; Vargas *et al.*, 2007). The 1998 length weight relationship was applied to the previous years, back to 1990.

The annual mean length of the catch was calculated as a weighted mean of catch numbers at length for each year (Table 3a). The overall mean length of the 1990-2006 catch (arithmetic mean of the annual mean lengths of the commercial catch) was used to derive the anomalies in the mean length on the 3LN beaked redfish commercial catch over this period (Table 3a, Fig. 3). The proportion of small redfish (less than 20cm) in the catch is presented as well, in Table 3a. The purpose of the first exercise (length anomalies) was to detect eventual shifts in the length structure of the commercial catch or by-catch that could reflect changes in the exploitable stock structure. As for the second exercise (proportion of small redfish), a sudden and important increase on the proportion of small redfish in the catch could be regarded as signal of the income of a good recruitment.

Stability in the length structure of the catch/by-catch is observed through the 1990-2006 interval, with no clear pattern on length anomalies detected over time (Fig. 3). Higher negative anomalies are coupled with higher proportions of small redfish in 1991, 1992, 2003 and 2006 suggesting the income in those years of above average recruitments to the exploitable stock, from year classes 4-5 years back in time.

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, in which strata up to a maximum of 732 m (400 fathoms) were sampled. However only since 1991 two Canadian series of annual 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). No survey was carried out in spring 2006 on Div. 3N. The design of the Canadian surveys was based on a stratification scheme down to 732 m for Div. 3LN. From 1996 onwards the stratification scheme has been updated to include depths down to 1 464 m (800 fathoms) but only the autumn surveys have swept strata bellow 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 utilizing SCANMAR. 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). The survey indices time series from the two Canadians surveys have Engel data converted into Campelen equivalents from 1991 till 1994 (autumn) or 1995 (spring survey) coupled with original Campelen data since then.

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 obtained since 1995, comparative fishing trials were conducted in spring 2001 to develop conversion factors between the two fishing vessel and gear combinations. Former American plaice and Greenland halibut survey indices from C/V *Playa de Menduíña* were transformed to R/V *Vizconde de Eza* units (*González et al.*, 2004), but so far this exercise has not been carried out for beaked redfish. That is the main reason why the Spanish survey data are not yet included in the 3LN redfish assessment.

Russia also conducted a spring bottom trawl survey in Div. 3L (1984-1994) and Div. 3N (1984-1993). Comparison of the winter/spring Canadian and spring Russian bottom trawl surveys in Div. 3L indicate a similar trend of decline in density estimates from 1984 to 1990 and stability at a low level till 1994. The situation is unclear for Div. 3N with both 1991-1993 summer/autumn Canadian and spring Russian surveys showing dramatic year to year changes of their indices but of opposite sign (Power, 2003). Russian survey series on Div. 3L and Div. 3N ended more than a decade ago.

The 1991-2006 bottom trawl Canadian spring and autumn surveys are the only source of survey data incorporated in the present assessment of Div.3LN beaked redfish population.

Abundance at length

Spring and autumn survey abundance at length, for Div. 3LN combined, are presented in Table 4a and b. Survey abundance at length for each division, year and survey is derived from the correspondent mean number per tow at length, expanded to the survey abundance estimated by the swept area method. The overall 1991-2006 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 4a and b, Fig. 4a and b). On both survey series all/most of the anomalies during the first half of the 1990's were negative while all were positive between 1996 and 2000. This shift on the survey catch length structure to larger individuals could reflect a relatively high survival of the year classes through the second half of the 1990's. From 2001 onwards most of the length anomalies from either survey are close to the respective overall means. The relative small magnitudes of length residuals together with the lack of a clear pattern over time suggest stability on the length structure of the population on recent years. With the exception of 1991 and 1992 on the autumn survey, when a couple of large negative residuals are observed probably as a consequence of a pulse on recruitment from the late 1980's, no further signs of other pulses on recruitment are detected.

Female spawning biomass

In order to estimate spring and autumn female spawning stock survey biomass by division, Div. 3L and Div. 3N female proportion and maturity at length vectors (Table 5a) (Power 2001; Ávila de Melo et al., 2005) were applied to the respective 1991-2006 spring and autumn survey abundances at length. Female spawners and stock abundance at length by division were used to calculate female spawning and stock biomass for Div. 3L and Div. 3N as sum of products (SOP), using the 3M *Sebastes sp.* annual length weight relationships (Table 5b) (Casas *pers. comm.*, 2006). The SOP ratios (SSB/stock biomass) by division were then applied to the respective swept area survey biomasses to give estimates of the 1991-2006 spring and autumn female SSB in Div. 3L and Div. 3N. Finally the spring and autumn female spawning biomass for Div. 3LN combined was given by the sum of these two indices for each survey series.

Survey trends of biomass and female spawning biomass

Original 1991-2006 survey indices (biomass and female SSB; abundance and female spawners; mean weight per tow and associated standard error) for Div. 3L, Div. 3N and Div. 3LN combined are presented on Tables 6a and b. Spring and autumn mean weights per tow with upper 95% confidence limits, original biomass and female SSB for Div. 3LN are also represented on Fig. 5a and b and Fig. 6a and b respectively. Either spring or autumn mean weights per tow look flat at a low level when associated with their high confidence intervals. Their trend suggests that no changes occurred on the status of this stock over the past seventeen years. However, when mean weights per tow are converted to

Div. 3L and Div. 3N biomass and finally summed up to give a picture of the relative size of this redfish management unit as a whole, both surveys suggest an increase in the size of the stock from 1996 onwards despite the wide inter annual fluctuations of the indices.

The 1992 autumn indices for Div. 3N have an anomalously high magnitude (the highest for the two surveys and divisions) while staying between relatively low indices from the neighbouring years of 1991 and 1993. The 1992 mean weight per tow for Div. 3N has also associated an anomalously high error, the highest for the two series and divisions (Table 6b). The original 1992 autumn survey indices for Div. 3N were considered outliers of the respective time series. The 1992 autumn survey indices for Div. 3L were used to generate new 1992 indices for Div. 3N, assuming that the relative size of the survey indices for Div. 3N compared to Div. 3L were kept constant between 1991 and 1992. The same assumption was used to generate 2006 spring survey indices for Div. 3N from the 2006 spring survey indices for Div 3L, since no survey data are available for Div. 3N on the terminal year of the assessment.

In order to reduce the wide inter annual variability of both surveys and detect trends within stock dynamics, the original biomass and female SSB annual values were replaced by 3-year moving averages (Table 6a and b, Fig. 6c and d). Each of the two moving average survey biomass series was finally standardized to the mean so that spring and autumn trends of the stock size could be easily compared (Fig. 7).

Redfish survey biomass in Div. 3LN survey biomass remained well bellow the average level until 1993 (autumn)-1996 (spring), raised to well above average level on 1999 (spring)-2000 (autumn), declined to just bellow average on 2002 (spring)-2003 (autumn) and is increasing again over the most recent years, being in 2006 above (autumn) or well above (spring) their 1991-2006 mean size.

ASPIC assessment suite

A non-equilibrium surplus production model (ASPIC; Prager, 1994, 2004 and 2007) was used to assess the status of the stock. The model was adjusted to the STATLANT *cpue*'s (1959-1994), spring and autumn survey biomass (1991-2006) and catches (1959-2006, conditioned on *cpue* series). All input series of biomass indices were given equal weight in the analysis. 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 ASPIC version 5.16 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 $Bmsy$ 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. $$MSY = rK/4 \quad (3)$$

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

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

Starting with user guesses for the key parameters, Initial Biomass (as a ratio to *Bmsy*), *K*, *MSY* and catchability coefficients for each biomass index, ASPIC generate iteratively estimates of 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 Canadian spring and autumn survey biomass.

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

The ASPIC Ver. 5.16 (Prager, 2005) requires from the user a set of initial definitions/starting guess /constraints that have been 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 bootsrap 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: `3` data series are to be analyzed as biomass index of the stock (STATLANT *cpue*, spring and autumn Canadian surveys).
Line 13: `1d0 1d0 1d0` When computing the objective function the squared residuals of each one of the 3 data series have equal weight.
Line 14: `0.5d0` Starting guess for $B1/K = 0.5$, the biomass on the 1st year of the assessment is at B_{msy} level.
Line 15: `2.0d4` Starting guess for $MSY = 20000$ ton. Between 1965 and 1985 catches oscillated with no trend around 21000, catch rates declined when catches were raised above that level.
Line 16: `2.000E+05` Starting guess for carrying capacity $K = 200000$ ton, twice the highest observed level of survey biomass (autumn survey average 1998, 2000-2001).
Line 17: `9.007E-06   0.658d0   1.0d0` Starting guess of catchability for STATLANT cpue (derived from *q* of STATLANT *cpue* for Div. 3M redfish, Ávila de Melo *et al.* 2003), for spring survey (average size of spring survey biomass relative to autumn survey biomass, 1991-2005) and for autumn survey (a conservative guess, assuming that autumn survey biomass is a proxy of absolute stock biomass).
Line 18: `1 1 1 1 1 1` All key parameters of the model ($B1/K$, MSY, K, $q_{cpue,}$ q_{spring} and q_{autumn}) 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* (5000-50000 ton) and *K* (100000-500000 ton) respectively. All ASPIC runs on FIT mode gave final estimates of these parameters far from either constraint. The number of bootstrap trials discarded due to parameter estimates falling outside their bounds is minimal.
Line 22: `48` Total number of years in the data sets included in the input file, from 1959 to 2006. This number is shorter in some of the ASPIC formulations tested on the exploratory analysis.

The rest of the settings of the input file were kept with the default options of the ASPIC Ver.5.16. The input file including the complete series of each biomass index is presented on Appendix 1.

Exploratory analysis

Different arrangements of each biomass index were used to explore the goodness of fit of the model under different data formulations. Due to the short time overlap between *cpue* and surveys (4 years on 48 years of data) the assessment assumes that *cpue* time series basically represent the abundance of the stock during the former period of the 1960's, 1970's and 1980's while surveys time series basically represent the abundance of the stock during the more recent period of the 1990's and 2000's. With such a short time overlap, the two pair-wise negative correlations found among STATLANT cpue and the survey series, each based on just four pairs of observations, 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 the two surveys, were considered a violation of the fundamental assumption of ASPIC that all indices represent the abundance of the stock.

Biomass indices for redfish, derived either from commercial or survey catch rates, typically show large inter-annual variability, too drastic to be only explained by changes in stock abundance from one year to the next. These fluctuations are caused not only by the schooling behaviour of redfish, but also by a wide and "non-uniform" distribution within their geographical and depth limits (all redfish species present both demersal and pelagic concentrations). That is why it is generally accepted that a redfish biomass index represents better a stock trajectory on the long term than the stock size on an annual basis. In order to reduce non explained variability and improve the fit of the ASPIC model to the available biomass indices two different categories of the data set formulations were considered: one based on the original annual values of each biomass index and the other where the annual values were smoothed by 3-year moving averages.

Eleven ASPIC formulations were run on FIT mode corresponding to eleven possible arrangements of the three data series (Table 7a). Those arrangements were assembled in two categories: original or 3-year moving averages as observed annual biomass indices. Each category includes a formulation where the autumn series incorporates the 1992 unmodified survey biomass for Div. 3N (ASPIC 01 and ASPIC 03 formulations). The moving average category includes an option where the STATLANT *cpue* series stop at 1991 in order to have just one year overlap with the surveys data series and so avoid negative correlations among the series (ASPIC 2). This category also includes a sequence of seven formulations were the first year of the assessment is cut by one year at the time: ASPIC 3 formulation starts on 1959 whereas the last formulation of this group, ASPIC 9, starts on 1965. A drastic decline of the catch is observed between 1959 and 1964 (45000 to 10000 ton, Fig. 1) that is not followed by the catch rates, on the contrary, STATLANT *cpue*'s increased (Fig. 2). From 1965 onwards catch oscillate with no clear trend. The objective to include these formulations in the exploratory analysis was to check if this anomalous behaviour of catch versus catch rates over the former years would have some negative impact on the fit of the model.

Besides the correlation among input series and between ASPIC estimated and observed annual values from each data series (`R squared in CPUE`) other parameters were used as diagnostics of the FIT outputs from the several formulations 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, 2005). The shorter the number of restarts the quicker is the convergence 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}.
- `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.

A traffic light classification was used in the exploratory analysis, each diagnostic being good (green), average (yellow), bad (red) or very bad (black) when falling within good, average, bad or very bad intervals, whose bounds are presented on Table 7b. In order to rank the ASPIC formulations each colour has an associated numerical weight as well. The eleven sets of diagnostics are presented, qualified and quantified under these criteria on Table 7c. A black diagnostic or a negative punctuation prevented the respective formulation of further use.

An overview of the exploratory analysis (Table 7c) lead to four main conclusions (1) The use of original autumn 1992 survey biomass jeopardize the ASPIC run with either option of data arrangement (observed annual data or moving averages) (2) Moving average formulations allow a better ASPIC FIT than the one with the original annual data series (3) Moving average formulations with the STATLANT *cpue* series ending in 1994 allow a better ASPIC fit than the one with the STATLANT *cpue* series ending in 1991 to avoid overlap (and negative correlations) among *cpue* and survey series (4) No significant improvement on ASPIC FIT is obtained by shortening the length of the STATLANT *cpue* series at its beginning.

From the initial set of eleven ASPIC formulations a selection of four was chosen for comparison of deterministic results between annual versus moving average data series (ASPIC 1 *vs* ASPIC 3), no overlap versus overlap among STATLANT *cpue* and survey series (ASPIC 2 *vs* ASPIC 3) and the longest moving average formulation versus the one given the best set of diagnostics (ASPIC 3 *vs* ASPIC 6). A summary of the FIT outputs is presented on Table 8, as regards ASPIC parameters, and Fig. 8a and b, as regards B/B_{msy} and F/F_{msy} trajectories. All runs are giving a similar picture of the stock:

- Carrying capacity (*K*) at 257000-271000 ton
- High level of biomass on the 1st year of the assessment corresponding to 81-89% of *K*
- Relatively low rate of stock biomass increase (*r*), 0.38-0.42
- *MSY* at 26000-26900 ton
- Relatively low F_{msy} , 0.19-0.21
- Fishing mortality on the last year of the assessment (2006) near zero and biomass at the beginning of next year near *K*
- Very close B/B_{msy} and F/F_{msy} trajectories

Having better diagnostics than the formulation with non-modified annual values (ASPIC 1) or the one with the STATLANT *cpue* series ending in 1991 (ASPIC 2), the ASPIC 3 formulation has its diagnostics slightly bellow ASPIC 6 but incorporates both *cpue* and spring and autumn survey series in their full extension. The consistency on the outputs between the two formulations (Table 8, Fig 8a and b) leads to the adoption of the longest ASPIC 3 formulation to pursue with the assessment framework.

Sensitivity analysis

Different starting guesses for key parameters or different random number seeds were used to run the ASPIC 3 formulation. The purpose was to check if the model was sensitive to changes in the starting "region" of key parameters (or number seed) used to initialize the search of a solution that minimizes the *cpue* and survey log squared residuals. Four starting options were tested against the standard starting option specified on ASPIC 3 input file (Appendix 1):

- 25% above and bellow the default random number seed (Input file, line 21)
- 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.*

The FIT parameter solutions from each of these four options are compared with the standard FIT solution on Table 9. The four different starting options arrived to the same solutions, showing that the ASPIC results given by the ASPIC 3 formulation are robust and independent of the values chosen for the input parameters used to initialize the model.

Assessment results

The input file for ASPIC 3 formulation (Appendix 1) runs on both deterministic (FIT) and bootstrap (BOT) mode using 1000 trials. Results are presented on Appendix 2. Despite the negative correlations among STATLANT *cpue* and each survey biomass indices, conditioned by the very small number of pair-wise observations and not regarded as an assessment constraint, correlation among surveys is high ($r^2 > 0.7$). The model fit the data relatively well, taking into account the very low level of fishing mortality and the sequence of downward/ upward trends of spring and autumn survey biomass on recent years, probably justified by temporary shifts in survey catchability and certainly not related with exploitation rate (Fig. 7). The majority of variance in spring survey is explained by the model while in autumn survey and STATLANT *cpue* series the variance explained by the model is close to 50%. Residuals seem to be randomly distributed in STATLANT *cpue* but show negative/positive patterns on spring and autumn surveys. Nevertheless these patterns seem to have little impact on the assessment taking into account the bootstrap outputs: generally very small bias of the point estimates (<2.5%) for all parameters except the absolute and relative (to MSY) equilibrium yield for 2007. The reason for this high level of bias is a status quo fishing mortality close to zero, leading to a very small equilibrium catch for last year+1. The impact of spring and autumn residuals on biomass and fishing mortality is minimal as well, with B/B_{msy} and F/F_{msy} bias corrected trajectories practically undistinguishable from their deterministic ones (Fig. 9a and b).

The model results suggest a maximum sustainable yield (*MSY*) of 27000 ton (80% CL = 24500, 29500 ton) that can be produced when stock biomass (B_{msy}) is 136000 ton (80%CL = 110500, 160600 ton) and fishing mortality rate (F_{msy}) is 0.20 (80% CL = 0.15, 0.27). Deterministic and bias corrected trajectories of relative biomass and fishing mortality rates are presented on Fig. 9a and b. Relative biomass oscillated 35-55% above B_{msy} for most of the former years up to 1987. Apart the 1971-1973 interval, when fishing mortality approaches F_{msy}, fishing mortality oscillated within bounds well bellow F_{msy} (30-60%) until 1985. Between 1986 and 1990 catches were higher than *MSY* (29000-79000 ton), pushing fishing mortality to well above F_{msy} from 1987 till 1992. Those six years of heavy over-fishing determine the fall of biomass from 50% above B_{msy} in 1986 to 40% bellow in 1993, when a minimum 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 late 1980's – early 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} (80% CL = 1.88, 1.98 B_{msy}).

Catch versus surplus production (Appendix 2, ESTIMATED POPULATION TRAJECTORY (NON BOOTSTRAPPED, 8th column from the left) trajectories are presented on Fig. 10. From 1960 till 1985 catches form a scattered cloud of points up and down surplus production curve but always within its vicinity. On 1986-1987 catches rise well above the surplus production and though declining continuously since then were still above equilibrium yield in 1992. Estimated catch has been well bellow surplus production levels since 1994.

ASPIC medium term projection

Regardless the input formulations, the starting guess scenario or the mode of the model runs, the main conclusion of this ASPIC assessment is that at present the biomass of redfish in Div. 3LN is well above B_{msy} ,while fishing mortality is well bellow F_{msy} . From the assessment results the status of the stock allows its exploitation, but this is a first attempt to assess quantitatively this stock. Therefore results should be treated with caution despite the apparent good performance of the ASPIC model with the available data.

Underlying assumptions for the low catch option

Redfish in Div. 3LN has been under moratorium over the past ten years. A stepwise approach to direct fishery should start by a low exploitation regime associated with a high probability of keeping the stock biomass within its present safe zone. From the ASPIC bootstrap results (Appendix 2, ESTIMATES FROM BOOTSTRAPPED ANALYSIS, Line 14) this safe zone can be defined as $B/B_{msy} > 1.8$.

An ASPIC medium term projection was carried out under constant catch instead of constant fishing mortality. The reason for this option relates to the proposed approach to reopen the fishery keeping the biomass well above B_{msy},, until future assessments confirms a positive answer of the stock to exploitation as suggested by the present ASPIC results. This strategy turns the analysis of medium term projections under a range of F_{msy} percentages useless, since the purpose is to find a catch level that will keep fishing mortality well bellow F_{msy}.

On the side of catch, the analysis should include in principle medium term projections under MSY (27000 ton) and a catch of 20000 ton, a “real world” proxy of MSY corresponding to the average level of catches sustained by the stock over 21 years (1965-1985). However the purpose of this exercise is not compare the impact of different full exploitation regimes on the stock but to predict how biomass and fishing mortality react to the beginning of exploitation, just above the actual surplus production. Therefore ASPIC projection was carried out with a constant catch of 5000 tons for the next 10 years. This level of catch is on the border of the upper 80% CL of the bias corrected equilibrium yield for 2007 (Appendix 2, ESTIMATES FROM BOOTSTRAPPED ANALYSIS, Line 7).

The ASPICP program

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 50% and 80% confidence limits) but also provides projections of these trajectories to the future. ASPICP reads information from the 1000 trials of the BOOTSRAP results kept in a .BIO file and project each of these trials a number of years ahead, under an annual $F_{status\ quo}$ multiplier or yield. These constraints are specified by the user in a .CTL file (Appendix 3) that controls the projection.

The ASPICP run with a 2007 catch at the 2004-2006 average level (500 ton) and an annual catch of 5000 ton for the rest of the years (2008-2016). Results are in a .PRJ file presented in Appendix 4.

Projection results

The bootstrapped 1959–2017/ 2016 trajectories of biomass and fishing mortality rate (relative to B_{msy} and F_{msy}.) are presented in Appendix 4 and Fig. 11a and b. From the ASPICP results a low exploitation regime of 5000 ton will drive biomass from 1.97 B_{msy} at the beginning of 2008 down to 1.90 B_{msy} at the beginning of 2017 (80% CL’s, 1.89-1.91B_{msy}) while increasing fishing mortality from 0.01F_{msy} in 2008 to 0.10 F_{msy} in 2016 (80% CL’s, 0.09-0.11F_{msy}). In other words a constant catch level of 5000 ton will keep the redfish in Div. 3LN in its present safe zone, with the lower 80% CL of relative biomass well above the B_{msy} level and the upper 80% CL of relative fishing mortality rate well bellow the F_{msy} level.

Reference Points under Precautionary Approach

The ASPIC bias corrected results were input under the precautionary framework (Fig. 12). The NAFO SC Study Group recommendations from the meeting in Lorient in 2004 (SCS Doc. 04/12), 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}. Under the Schaeffer model used in the present ASPIC assessment this is 30% B_{msy}. However the stock biomass decline of the late 1980’s – early 1990’s didn’t reach such low level, having a minimum at 60% B_{msy}. Taking into account that bellow this level the dynamics of the stock is unknown, a B_{lim}= 60% B_{msy} can be regarded as first attempt to have a biomass LRP for redfish in Div. 3LN.

The stock trajectory presented under this precautionary approach framework shows a stock rapidly declining to bellow B_{msy} when fishing mortality rate rises from just above to well above F_{msy} (1986-1987), and a stock rapidly returning to above B_{msy} after fishing mortality drops to well bellow F_{msy} (1993-1994).

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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[a]	3425	18009	21439	
1963[a]	8191	12906	27362	
1964[a]	3898	4206	10261	
1965	18772	4694	23466	
1966	6927	10047	16974	
1967	7684	19504	27188	
1968[a]	2378	15265	17660	
1969[a]	2344	22356	24750	
1970[a]	1029	13359	14419	
1971[a]	10043	24310	34370	
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[b]	30342	40949	79031	25000
1988[b]	22317	23049	53266	25000
1989[b]	18947	12902	33649	25000
1990[b]	15538	9217	29105	25000
1991[b]	8892	12723	25815	14000
1992[b]	4630	10153	27283	14000
1993[b,c]	5897	9077	21308	14000
1994[b,c]	379	2274	5741	14000
1995	292	1697	1989	14000
1996	112	339	451	11000
1997	151	479	630	11000
1998	494	405	899	0
1999[b]	518	1318	2318	0
2000[b,c]	657	819	3141	0
2001[b]	653	245	1442	0
2002[b]	651	327	1216	0
2003	584	751	1334	0
2004	401	236	637	0
2005	581	78	659	0
2006[d]	182	25	207	0

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) From NAFO circular letters

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

Year	3L		3N		3LN		3LN	
	STATLANT Catch	Predicted Effort	STATLANT Catch	Predicted Effort	STATLANT Catch	Predicted Effort	CPUE annual	CPUE moving av
1959	34107	22604	10478	8659	44585	31263	1.426	1.514
1960	10015	5690	16547	10892	26562	16582	1.602	1.575
1961	8349	3610	14826	10049	23175	13659	1.697	1.643
1962	3425	2049	18009	11090	21434	13139	1.631	1.653
1963	8191	3973	12906	8958	21097	12931	1.632	1.692
1964	3898	1491	4206	2981	8104	4472	1.812	1.876
1965	18772	8190	4694	2551	23466	10741	2.185	1.926
1966	6927	4615	10047	4915	16974	9530	1.781	1.953
1967	7684	3793	19504	10569	27188	14362	1.893	1.532
1968	2378	1446	15265	17684	17643	19130	0.922	1.384
1969	2344	1354	22356	17109	24700	18463	1.338	1.209
1970	1029	499	13359	10026	14388	10525	1.367	1.350
1971	10043	5207	24310	20320	34353	25527	1.346	1.367
1972	3095	1877	25838	18982	28933	20859	1.387	1.459
1973	4709	2078	28588	18186	33297	20264	1.643	1.440
1974	11419	11907	10867	5374	22286	17281	1.290	1.534
1975	3838	2443	14033	8265	17871	10708	1.669	1.417
1976	15971	11335	4541	4537	20512	15872	1.292	1.404
1977	13452	10461	3064	2738	16516	13199	1.251	1.217
1978	6318	5961	5725	4925	12043	10886	1.106	1.270
1979	5584	3517	8483	6176	14067	9693	1.451	1.440
1980	4367	2873	11663	6229	16030	9102	1.761	1.602
1981	9407	6020	14873	9216	24280	15236	1.594	1.672
1982	7870	4812	13677	8160	21547	12972	1.661	1.603
1983	8657	4960	11090	7734	19747	12694	1.556	1.422
1984	2696	1804	12065	12263	14761	14067	1.049	1.230
1985	3677	2104	16880	16858	20557	18962	1.084	1.182
1986	27833	15247	14972	15057	42805	30304	1.413	1.340
1987	34212	22369	44819	29517	79031	51886	1.523	1.381
1988	26267	19629	26999	24453	53266	44082	1.208	1.351
1989	19847	10567	13802	14884	33649	25451	1.322	1.118
1990	17713	16774	11392	18513	29105	35287	0.825	0.938
1991	8892	12329	12723	20052	21615	32381	0.668	0.801
1992	4630	2452	10153	13755	14783	16207	0.912	0.794
1993	5897	1576	9077	17116	14974	18692	0.801	0.838
1994	379	410	2274	2900	2653	3310	0.802	0.801

Table 3a: Length composition (absolute frequencies in '000s) of the 3LN redfish commercial catch, 1990-2006.

Length	1990	1991	1992	1993	1994	1995	1996	1997	1998
10									
11									
12	12								
13	6								
14	21								
15	28	28							
16	73	103	9						
17	199	394	28			2			
18	286	1034	412		5	2		0.01	1
19	445	2157	1291	5	6	3	1	0.3	2
20	720	3313	2375		16	14	4	2	13
21	1309	3780	2943	235	287	9		11	57
22	2081	4922	3600	714	683	65	6	17	151
23	3212	7340	4358	1141	594	64	17	34	277
24	4164	7575	5552	2565	708	99	9	64	296
25	5216	6944	4981	5237	944	100	9	98	248
26	5560	5981	5145	5115	1297	277	12	118	221
27	5410	6197	4579	5433	1404	330	35	144	218
28	5217	5322	4063	5004	1182	300	75	114	173
29	4712	3354	4637	4437	1188	263	76	114	154
30	4751	4043	3911	3283	1011	310	182	114	120
31	4551	2695	3711	2964	912	313	197	154	129
32	3943	2478	2187	2313	944	309	98	146	119
33	3082	1582	1355	2291	596	226	67	131	110
34	2737	1179	1569	1527	526	189	30	71	66
35	2100	928	1604	1059	363	182	35	24	19
36	1681	831	1895	923	202	106	23	19	18
37	1416	580	1571	766	196	160	7	14	11
38	1128	482	1303	807	158	171	5	10	8
39	729	363	1114	489	124	100	11	3	3
40	458	292	790	505	69	144	2	4	3
41	321	188	558	320	49	63	3	1	2
42	255	117	420	306	23	1	1	1	0.1
43	227	68	203	137	15	3	2	2	0.1
44	157	83	85	175	7	3	2	1	1
45	84	33	76	107	1	3	2	0.1	
46	58	8	32	9	3			0.1	0.02
47	24		9	47	0.2				
48	11	2	8	5		3		0.1	
49	6		1		0.1				
50									
51	1	25			2				
52	2								
53	1								
54	2								
no ('000)	66410	74421	66375	47918	13517	3815	910	1411	2422
weight (tons)	29105	25815	27283	21308	5741	1989	451	630	899
mean weight (g)	438	347	411	445	425	521	496	446	371
mean length	29.3	26.6	28.4	29.6	29.1	31.6	31.2	29.8	27.4
length anomalies	0.02	-2.7	-0.9	0.3	-0.2	2.3	1.9	0.5	-1.9
%lengths <20cm	1.6%	**5.0%**	**2.6%**	0.0%	0.1%	0.2%	0.1%	0.0%	0.1%

Table 3a: cont.

Length	1999	2000	2001	2002	2003	2004	2005	2006
10								
11					0.03			
12					0.03			
13					1			
14					1			0.003
15					5			1
16			1	0.3	8			1
17	0.3	1	2	1	21	1	2	3
18		1	1	1	44	2	4	4
19	16	4	4	3	90	6	9	10
20	47	6	18	14	151	15	11	15
21	80	10	52	41	218	28	13	31
22	150	26	102	81	269	35	11	31
23	128	46	118	101	277	41	16	50
24	120	85	114	132	258	54	35	42
25	178	195	114	154	261	85	61	43
26	318	364	126	204	309	157	138	35
27	555	546	170	248	324	190	181	72
28	712	943	188	289	286	184	201	58
29	673	1003	179	289	245	184	223	50
30	520	1027	236	294	225	178	176	77
31	413	564	289	295	204	107	109	31
32	434	315	303	276	189	108	91	39
33	383	237	298	216	196	95	83	33
34	268	217	218	132	149	73	71	28
35	141	129	212	83	112	51	63	4
36	89	60	121	37	62	36	56	2
37	82	78	82	18	41	17	31	2
38	51	50	55	11	22	10	15	0.1
39	37	47	30	3	14	9	8	0.01
40	23	23	18	2	7	5	8	0.02
41	19	12	10	1	2	2	4	0.003
42	13	15	7	2	3	1	2	0.003
43	3	9	4	2	2	2	6	
44	3	1	3	1	2	1	3	
45		2	1		0.1	1	1	
46	0.2	1	1		2	0.2	0.3	
47		0.48	0.2		0.04	0.8	2	
48							0.04	
49								
50								
51					0.26			
52								
53								
54					0.31			
no ('000)	5457	6020	3075	2929	3999	1681	1632	661
weight (tons)	2318	2617	1442	1216	1334	637	659	207
mean weight (g)	425	435	469	415	334	379	404	313
mean length	29.9	30.1	30.8	29.5	27.5	29.5	30.1	27.7
length anomalies	0.6	0.8	1.5	0.2	-1.8	0.1	0.8	-1.6
%lengths <20cm	0.3%	0.1%	0.2%	0.2%	**4.2%**	0.5%	0.9%	**2.9%**

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., 2005-2007)

Year	*a*	*b*
1990-1998	0.1115	2.4353
1999	0.0689	2.5588
2000	0.0979	2.4602
2001	0.0769	2.5298
2002	0.0447	2.6885
2003	0.0095	3.1279
2004	0.0208	2.8851
2005	0.0208	2.8851
2006	0.0611	2.5597

Table 4a: 3LN spring survey abundance at length, 1991-2006 (thousands).

Length	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
4								
5								
6						466		20
7						228		39
8						149	685	8
9	849					298	360	39
10	1149			500		296	251	113
11	798	381	122	316		478	730	533
12	558	2988	1304	501		806	722	455
13	2523	7925	2397	462	108	919	540	172
14	321	5192	5646	494	272	408	1871	561
15	698	2862	11061	1228	278	712	1859	895
16	2249	382	13648	1611	967	846	1129	1505
17	3864	419	8798	2831	2852	1592	1201	2045
18	6225	1111	2720	2801	4295	4354	1860	2124
19	7747	2480	2475	1266	5026	9475	3280	2848
20	4521	2574	3841	763	2708	10903	4711	9468
21	3481	3559	5756	853	1818	12106	6367	24836
22	5146	1690	5304	717	1337	13832	7008	34249
23	7250	1732	5713	1132	1259	16619	8191	31104
24	6185	2721	4761	1439	1361	12491	10669	28361
25	3365	2865	3400	1700	1005	8315	9469	21270
26	1963	3250	3703	1522	1601	5648	7757	19508
27	1426	2411	4481	1014	1694	5102	4047	16076
28	952	1834	3286	775	1437	4897	2760	12714
29	1037	1506	2877	699	1154	4260	1871	9626
30	607	1048	2607	461	722	3320	1801	6118
31	534	1014	2970	304	474	2229	1354	6512
32	417	810	3088	234	548	1563	995	6155
33	369	825	2621	132	265	757	637	5685
34	399	540	2161	146	144	337	438	3286
35	251	544	1503	102	105	167	160	970
36	190	366	880	132	113	105	77	659
37	222	216	696	121	151	117	42	402
38	159	219	669	78	101	32	88	82
39	130	300	726	28	70	59	4	82
40	118	220	483	46	62	28		216
41	45	77	371	0	15	15		15
42	88	85	216	8	46	4		20
43	69	85	83	47	27	35	15	201
44	45	77	189	27	31		31	12
45	57	62				15	15	15
46		46	51			15	46	
47		4	20		15		15	
48	11	31	31					
49		31						
50								
abundance (millions)	66.0	54.5	110.7	24.5	32.1	124.0	83.1	249.0
biomass ('000 tons)	10.6	10.1	22.6	4.2	5.9	22.8	14.9	59.4
mean length (cm)	21.6	21.6	22.6	21.6	22.7	23.4	23.5	25.1
length anomalies (cm)	-1.7	-1.7	-0.7	-1.7	-0.6	0.1	0.2	1.8

Table 4a: cont.

Length	1999	2000	2001	2002	2003	2004	2005	2006(1)
4							40	
5				62		31		
6	16	185	109	170	293	804	108	
7	656	795	1512	472	2059	2399	540	309
8	3280	378	1302	1072	1684	1236	950	602
9	5878	89	484	1525	1525	2208	2891	494
10	1343	166	240	2517	1202	4106	4893	633
11	309	402	116	1085	418	2910	7296	1235
12	430	191	451	1645	1449	1653	8756	1343
13	517	412	346	853	1102	1330	9684	1575
14	369	353	1073	533	1279	639	7710	2903
15	179	1207	1741	766	2631	1235	7437	5775
16	774	2063	1666	1371	3567	1335	7357	8060
17	703	2651	3337	2595	6196	2764	8647	10731
18	3440	2954	5241	6444	8659	3668	16473	12769
19	2989	6491	8252	8160	15503	8994	31508	14607
20	5395	11472	9589	11325	21130	11904	33704	19192
21	16819	22819	14394	13957	23795	16955	33184	26681
22	31066	42444	15553	14930	19308	16583	30969	30001
23	38231	52730	15592	15596	15146	20421	30647	23763
24	45397	54039	14842	16048	10830	17002	28563	19146
25	21478	34955	10153	12608	8066	14655	24308	10685
26	30238	27243	10044	11223	6898	24394	18439	5466
27	21651	21635	11334	8886	5109	38931	20028	6300
28	15676	14299	10225	7495	3557	43212	15249	2764
29	14330	15399	10373	6418	2782	24423	11907	3258
30	6697	13924	9530	3736	2705	18143	8832	2640
31	5727	13111	10453	3588	2199	13712	5769	2038
32	4310	13224	8903	2238	2360	9705	3036	1868
33	3259	6491	5180	1378	1979	3487	2012	1328
34	2039	5984	3032	980	1015	5390	1618	371
35	877	3590	975	455	642	2248	832	262
36	537	1019	300	212	228	476	592	139
37	269	663	382	93	82	877	222	31
38	102	504	101	43	35	75	112	46
39	67	186	140	59	32	43	86	0
40	79	199	23		94	23	12	0
41	51	16	0	15		4	15	46
42	66	31	63	15		15	8	31
43	0	31	28		15	15		46
44	27	31	28				15	
45		31	15			8		
46	31	15						
47								
48								
49								
50								
abundance (millions)	285.3	374.4	187.1	160.6	175.6	318.0	384.4	217.1
biomass ('000 tons)	61.5	87.8	41.6	31.0	27.7	79.6	66.5	35.3
mean length (cm)	24.7	25.5	25.2	23.5	22.0	25.7	22.2	21.9
length anomalies (cm)	1.4	2.2	1.9	0.2	-1.3	2.4	-1.1	-1.4

(1) Survey data only from Division 3L

Table 4b: 3LN autumn survey abundance at length, 1991-2006 (thousands).

Length	**1991**	**1992(2)**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
4								
5				15	243	66	75	17
6					259	419	626	
7	203				139	103	16	39
8	1299				111	76	227	47
9	1237				241	168	918	251
10	7273		92	31	293	291	1613	214
11	22263	371	64	31	214	406	1070	203
12	62498	62	371	0	242	118	373	275
13	109476	3189	456	335	305	293	768	595
14	33919	27936	1768	551	515	1434	1017	894
15	14047	104299	1332	2362	969	739	926	1736
16	7819	113967	3258	3697	1617	969	1037	1377
17	7870	106449	5285	12985	9655	863	1386	7058
18	16212	95897	8711	28686	37959	2335	1767	12588
19	32254	71578	6427	29297	72230	5280	8721	10094
20	27223	113848	3908	15293	78338	6758	23419	40553
21	15830	148631	5308	7702	43446	6878	49398	75450
22	7924	153399	6377	5120	27694	6418	52015	103747
23	6144	89709	6578	6494	20177	6963	46245	103927
24	8384	28664	5161	5456	10338	5086	37485	71785
25	8951	14231	3944	6807	12971	4598	35505	42836
26	6607	13420	4115	8670	8576	4519	33288	23682
27	4025	14708	4357	7830	17498	2987	26053	23132
28	3779	8777	4235	8402	17645	2829	13431	21289
29	2528	4861	3500	7625	16465	2807	5507	15372
30	2112	3344	2760	6195	12821	2379	4260	9646
31	1961	3232	1945	4553	16433	3516	2886	6359
32	1315	2391	1897	2710	10724	2300	2434	5377
33	1213	3301	1668	1603	7330	1280	1310	4524
34	1117	1433	1283	916	3477	583	636	4940
35	1288	717	1042	610	1985	230	346	2537
36	1185	596	799	297	1180	135	382	1097
37	1005	386	459	211	338	74	320	606
38	1167	401	427	257	401	16	120	199
39	787	228	308	274	576	24	142	112
40	663	93	237	119	75	24	97	35
41	221	124	154	0	20	24	163	40
42	135	77	132	15	20			
43	102	31	37	32	32			35
44	129	46	99			49	67	17
45	46	15	69	15	36	33	34	17
46	24	46			12	16	17	
47	15	15	15	8		12		
48								
49		15						
50	15							
abundance (millions)	422	1130	89	175	434	74	356	593
biomass ('000 tons)	37.9	136.4	19.2	31.8	90.7	16.0	70.7	112.2
mean length (cm)	16.4	19.7	23.4	22.2	22.7	23.5	23.5	23.5
length anomalies (cm)	-1.7	-1.7	-0.7	-1.7	-0.6	0.1	0.2	1.8

(2) Original Div. 3N survey data

Table 4b: cont.

Length	1999	2000	2001	2002	2003	2004	2005	2006
4								
5		118	440	233	1090	34		84
6	251	482	937	932	2428	85	133	1418
7	50	675	755	868	2185	61	162	1831
8	37	603	2114	1624	2715	620	908	466
9	438	622	3147	1292	2096	1281	2236	829
10	171	389	4324	1131	2863	1720	1574	1457
11	402	232	2846	2846	1838	1047	3957	1709
12	786	202	1283	2257	1124	1132	9943	3083
13	868	321	1056	2086	1497	1437	11091	3970
14	2472	589	445	2560	1457	1015	10310	8256
15	1548	3653	407	1896	1950	538	8462	13285
16	717	4668	11014	2146	8394	880	6084	20910
17	1143	5483	31422	4703	15466	1985	5713	27174
18	3183	7038	57684	9077	26300	5471	7249	23007
19	6551	11929	74240	13656	39434	8226	10930	24341
20	9087	31700	80546	12557	46149	9796	15984	26792
21	15328	50192	65583	16499	43651	13141	25649	36447
22	23115	66827	130049	20161	40404	13640	23902	49628
23	28995	60122	118401	23556	40085	16741	29789	71776
24	26962	53001	85166	25378	32339	15467	20365	67363
25	29823	50556	64492	21327	21740	13073	15826	34947
26	27500	40214	39712	19867	18303	10438	12714	32335
27	25590	21893	33741	16414	17872	9402	10858	19109
28	24786	17449	20399	10516	14177	12141	12472	11650
29	16315	16404	14954	7233	7874	13958	12661	10147
30	11341	12158	11078	5064	4974	12274	9866	7475
31	7621	10211	9148	5083	3803	9071	7348	9530
32	6313	7170	5257	4618	3559	6791	5215	7469
33	5641	5032	4337	3830	3377	4639	4906	4870
34	4544	3391	2777	2678	2199	2961	3943	2096
35	3255	1306	1662	1440	1183	1761	2721	1118
36	1538	1111	675	581	508	1260	1456	537
37	339	516	631	334	200	765	1298	444
38	184	330	282	82	113	392	385	136
39	272	228	215	62	116	666	228	55
40	67	151	180	129		308	60	116
41	82	67	85			76	85	61
42		67	0	16		232	60	
43	50		4	19		99		
44	50	4		16				
45	50	76		16				
46		18	17					16
47	17							
48	17							
49								
50								
abundance (millions)	288	487	882	245	413	195	297	526
biomass ('000 tons)	72.0	100.5	132.6	50.1	71.9	49.9	58.6	91.9
mean length (cm)	25.3	23.9	22.3	23.3	21.8	24.9	22.5	22.3
length anomalies (cm)	1.4	2.2	1.9	0.2	-1.3	2.4	-1.1	-1.4

Table 5a: Beaked redfish female proportion maturity at length Div. 3L
(Power, 2001; Ávila de Melo et al. 2005)

	3L		3N	
Length	Sex ratio	Mat. og.	Sex ratio	Mat. og.
5	0.35	0.001	0.34	0.001
6	0.35	0.001	0.34	0.001
7	0.35	0.001	0.34	0.001
8	0.35	0.001	0.34	0.001
9	0.35	0.002	0.34	0.002
10	0.35	0.002	0.34	0.002
11	0.35	0.003	0.34	0.003
12	0.35	0.004	0.34	0.004
13	0.35	0.006	0.34	0.006
14	0.35	0.008	0.34	0.008
15	0.35	0.011	0.34	0.011
16	0.35	0.015	0.34	0.015
17	0.37	0.020	0.37	0.020
18	0.36	0.027	0.38	0.027
19	0.40	0.035	0.43	0.037
20	0.43	0.047	0.42	0.049
21	0.45	0.063	0.46	0.066
22	0.47	0.083	0.54	0.087
23	0.47	0.109	0.61	0.115
24	0.48	0.141	0.62	0.150
25	0.47	0.182	0.58	0.193
26	0.45	0.230	0.57	0.245
27	0.41	0.288	0.56	0.306
28	0.40	0.353	0.58	0.374
29	0.44	0.424	0.60	0.448
30	0.55	0.498	0.63	0.524
31	0.63	0.572	0.64	0.599
32	0.68	0.644	0.67	0.670
33	0.68	0.709	0.65	0.733
34	0.65	0.767	0.64	0.789
35	0.63	0.816	0.58	0.835
36	0.57	0.857	0.52	0.873
37	0.55	0.890	0.48	0.903
38	0.54	0.916	0.47	0.927
39	0.58	0.936	0.43	0.945
40	0.60	0.952	0.41	0.959
41	0.56	0.964	0.38	0.969
42	0.54	0.973	0.49	0.977
43	0.52	0.980	0.55	0.983
44	0.57	0.985	0.52	0.988
45	0.64	0.989	0.52	0.991
46	0.66	0.992	0.61	0.993
47	0.67	0.994	0.75	0.995
48	0.67	0.995	0.75	0.996
49	0.67	0.997	0.75	0.997
50	0.67	0.997	0.75	0.998
51	0.67	0.998	0.75	0.999
52	0.67	0.999	0.75	0.999
53	0.67	0.999	0.75	0.999

Table 5b: length weight relationships from Sebastes sp. Flemish Cap survey data used in the computation of 3LN survey biomass (SOP) and other sto related parameters (Casas, pers. comm. 2006).

Year	*a*	*b*
1991	0.0269	2.8140
1992	0.0302	2.7879
1993	0.0167	2.9652
1994	0.0212	2.8958
1995	0.0132	3.0340
1996	0.0209	2.8903
1997	0.0149	3.0009
1998	0.0140	3.0192
1999	0.0182	2.9280
2000	0.0223	2.8738
2001	0.0145	3.0083
2002	0.0138	3.0260
2003	0.0117	3.0553
2004	0.0119	3.0742
2005	0.0112	3.0879
2006	0.0112	3.0879

Table 6a: Campellen converted (1991-1995) and Campellen (1996-2006) spring survey biomass, female SSB and abundance indices.

		Campellen converted					**Campellen**										
		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006[1]
Div. 3L Spring	biomass ('000 ton)	6.3	7.4	6.5	2.3	3.3	16.8	9.3	27.6	21.3	36.2	26.2	9.1	10.5	14.4	36.5	35.3
	female SSB ('000 ton)	1.0	2.0	1.5	0.4	0.7	2.2	1.4	6.0	4.4	10.3	6.3	1.5	1.2	2.7	5.1	3.5
	abundance (millions)	34.5	23.6	23.2	10.0	15.1	83.3	44.5	90.4	73.4	120.6	101.2	50.3	72.2	71.8	224.7	217.1
	female spawners (millions)	2.6	4.1	3.4	1.1	1.6	7.4	4.4	14.2	11.5	24.5	17.4	4.6	4.5	7.6	15.5	11.9
	mean weight per tow (Kg/tow)	5.6	4.8	4.2	1.5	2.1	10.9	6.0	17.9	13.8	23.4	16.9	5.9	6.8	9.3	23.7	22.8
	SE Kg/tow	3.1	3.6	12.0	0.4	0.2	4.6	1.7	39.8	28.4	22.2	8.1	2.4	3.2	29.5	18.3	15.9
Div. 3N Spring	biomass ('000 ton)	4.4	2.7	16.1	1.9	2.6	6.0	5.7	31.8	40.2	51.7	15.4	21.8	17.2	65.3	29.9	28.9
	female SSB ('000 ton)	0.5	0.3	4.3	0.3	0.4	0.8	0.7	5.0	5.8	7.3	2.9	3.4	2.5	15.5	3.9	2.6
	abundance (millions)	31.5	30.8	87.5	14.5	17.0	40.7	38.6	158.6	211.9	253.8	85.9	110.3	103.4	246.2	159.7	
	female spawners (millions)	1.7	0.9	9.2	0.7	1.1	2.7	2.9	16.3	22.2	27.5	9.1	11.6	7.9	44.8	13.8	
	mean weight per tow (Kg/tow)	11.1	7.0	40.8	4.1	6.5	15.2	15.1	80.5	101.7	130.8	39.0	55.3	43.5	165.2	75.7	
	SE Kg/tow	7.7	1.7	153.1	0.6	2.3	6.2	6.6	59.9	436.1	201.8	8.5	168.4	106.5	831.0	61.1	
Div. 3LN Spring	biomass ('000 ton)	10.6	10.1	22.6	4.2	5.9	22.8	14.9	59.4	61.5	87.8	41.6	31.0	27.7	79.6	66.5	64.2
	biomas mav ('000 ton)	10.4	14.4	12.3	10.9	10.9	14.5	32.4	45.3	69.6	63.6	53.5	33.4	46.1	57.9	70.1	65.3
	female SSB ('000 ton)	1.5	2.3	5.8	0.7	1.0	2.9	2.1	10.9	10.2	17.6	9.2	4.9	3.8	18.2	9.0	6.1
	female SSB mav ('000 ton)	1.9	3.2	2.9	2.5	1.6	2.0	5.3	7.7	12.9	12.3	10.6	6.0	9.0	10.3	13.6	7.6
	abundance (millions)	66.0	54.5	110.7	24.5	32.1	124.0	83.1	249.0	285.3	374.4	187.1	160.6	175.6	318.0	384.4	
	abundance mav (millions)	60.3	77.1	63.2	55.7	60.2	79.7	152.0	205.8	302.9	282.3	240.7	174.4	218.1	292.7	358.0	
	female spawners (millions)	4.3	5.0	12.6	1.9	2.7	10.1	7.4	30.6	33.8	52.0	26.6	16.1	12.4	52.4	29.4	
	female spawners mav (millions)	4.7	7.3	6.5	5.7	4.9	6.7	16.0	23.9	38.8	37.5	31.6	18.4	27.0	31.4	40.9	
	mean weight per tow (Kg/tow)	6.7	5.2	11.6	2.0	3.0	11.8	7.9	30.7	31.7	45.3	21.4	16.0	14.3	41.1	34.3	
	SE Kg/tow	8.3	4.0	153.6	0.7	2.3	7.7	6.8	72.0	437.0	203.1	11.7	168.4	106.6	831.5	63.8	
	upper 95% CI	16.2	7.8	301.0	1.4	4.5	15.1	13.3	141.1	856.6	398.0	23.0	330.1	208.9	1629.8	125.0	

1) Generated 2006 biomass and female spawnning biomass for Div. 3N based on 2005 Div. 3N/Div. L ratios and 2006 Div. 3L survey indices (see text for details).

Table 6b: Campellen converted (1991-1994) and Campellen (1995-2006) autumn survey biomass, female SSB and abundance indices.

		Campellen converted				Campellen											
		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Div. 3L Autumn	biomass ('000 ton)	13.7	13.4	6.0	7.2	50.1	4.7	19.5	18.5	38.9	24.9	28.6	11.9	15.0	9.3	16.7	27.2
	female SSB ('000 ton)	3.9	3.1	1.8	1.2	13.7	0.9	2.6	4.5	7.1	5.4	6.1	2.5	3.0	1.7	2.5	3.7
	abundance (millions)	43.3	45.3	20.6	27.7	129.4	21.3	88.7	69.8	142.5	90.0	106.0	61.0	79.3	45.6	114.2	178.4
	female spawners (millions)	7.7	7.5	3.8	3.5	27.1	2.3	8.6	12.0	19.5	13.7	14.7	6.5	7.7	4.5	7.2	10.7
	mean weight per tow (Kg/tow)	8.8	8.7	3.9	4.6	31.8	3.2	11.7	11.1	23.2	14.9	17.0	7.1	9.0	11.0	10.6	16.2
	SE Kg/tow	3.3	2.1	2.1	2.1	181.8	1.0	23.2	7.6	72.5	7.5	46.1	2.7	5.2	4.1	3.5	4.0
Div. 3N Autumn	biomass ('000 ton)[1]	24.2	123.0	13.2	24.6	40.7	11.3	51.1	93.7	33.1	75.5	104.0	38.2	56.9	40.6	41.9	64.7
	biomass ('000 ton)[2]	24.2	23.8	13.2	24.6	40.7	11.3	51.1	93.7	33.1	75.5	104.0	38.2	56.9	40.6	41.9	64.7
	female SSB ('000 ton)[1]	1.3	6.3	2.5	4.2	3.3	2.2	6.0	11.0	6.9	10.4	10.1	6.5	6.4	10.4	9.5	9.5
	female SSB ('000 ton)[2]	1.3	1.2	2.5	4.2	3.3	2.2	6.0	11.0	6.9	10.4	10.1	6.5	6.4	10.4	9.5	9.5
	abundance (millions)	378.9	1085.2	68.0	147.5	304.2	52.8	267.4	522.9	145.0	397.2	775.5	183.8	334.2	149.0	182.3	347.5
	female spawners (millions)	5.8	34.3	6.8	12.5	13.4	6.5	22.8	43.8	20.3	38.5	51.6	20.8	23.5	26.2	24.9	34.4
	mean weight per tow (Kg/tow)	81.0	468.8	35.4	62.2	102.9	28.5	129.4	208.6	88.9	168.1	231.5	96.8	150.5	106.7	97.3	163.7
	SE Kg/tow	15.0	1827.6	55.9	48.9	412.0	66.1	300.2	462.4	42.4	358.5	669.4	179.9	100.3	65.4	72.2	77.7
Div. 3LN Autumn	biomass ('000 ton)[1]	37.9	136.4	19.2	31.8	90.7	16.0	70.7	112.2	72.0	100.5	132.6	50.1	71.9	49.9	58.6	91.9
	biomass ('000 ton)[2]	37.9	37.2	19.2	31.8	90.7	16.0	70.7	112.2	72.0	100.5	132.6	50.1	71.9	49.9	58.6	91.9
	biomas mav ('000 ton)[2]	37.6	31.4	29.4	47.2	46.2	59.1	66.3	85.0	94.9	101.7	94.4	84.9	57.3	60.1	66.8	75.2
	female SSB ('000 ton)[1]	5.2	9.4	4.3	5.4	17.0	3.1	8.6	15.6	14.1	15.7	16.2	9.0	9.4	12.1	11.9	13.2
	female SSB ('000 ton)[2]	5.2	4.3	4.3	5.4	17.0	3.1	8.6	15.6	14.1	15.7	16.2	9.0	9.4	12.1	11.9	13.2
	female SSB mav ('000 ton)[2]	4.8	4.6	4.7	8.9	8.5	9.6	9.1	12.7	15.1	15.3	13.6	11.5	10.2	11.1	12.4	12.6
	abundance (millions)	422.3	1130.5	88.6	175.2	433.6	74.1	356.1	592.7	287.5	487.2	881.5	244.8	413.5	194.6	296.5	525.9
	female spawners (millions)	13.6	41.7	10.6	15.9	40.5	8.8	31.4	55.8	39.8	52.1	66.3	27.3	31.2	30.8	32.2	45.1
	mean weight per tow (Kg/tow)	23.6	102.4	10.3	16.4	46.3	8.4	35.6	51.3	36.6	46.1	60.7	25.4	37.8	30.5	28.2	46.3
	SE Kg/tow	15.4	1827.6	55.9	48.9	450.4	66.1	301.1	462.5	84.0	358.5	671.0	179.9	100.4	65.5	72.3	77.8
	upper 95% CI	30.2	3582.1	109.6	95.9	882.7	129.6	590.1	906.5	164.7	702.7	1315.2	352.7	196.9	128.4	141.7	152.5

1) Original 1992 survey biomass and female spawnning biomass for Div. 3N.

2) Generated 1992 biomass and female spawnning biomass for Div. 3N based on 1991 Div. 3N/Div. 3L ratios and 1992 Div. 3L survey indices (see text for details).

Table 7a: ASPIC formulations included in sensitivity analysis

ASPIC Run	**Observed cpue and survey indices:**
ASPIC 01	CC(cpue 59-94 & catch 59-06)+I1+I2[1]
ASPIC 1	CC(cpue 59-94 & catch 59-06)+I1+I2
ASPIC Run	**Moving average cpue's and survey indices:**
ASPIC 2	CC(cpue 59-91 & catch 59-06)+I1+I2
ASPIC03	CC(cpue 59-94 & catch 59-06)+I1+I2[1]
ASPIC 3	CC(cpue 59-94 & catch 59-06)+I1+I2
ASPIC 4	CC(cpue 60-94 & catch 60-06)+I1+I2
ASPIC 5	CC(cpue 61-94 & catch 61-06)+I1+I2
ASPIC 6	CC(cpue 62-94 & catch 62-06)+I1+I2
ASPIC 7	CC(cpue 63-94 & catch 63-06)+I1+I2
ASPIC 8	CC(cpue 64-94 & catch 64-06)+I1+I2
ASPIC 9	CC(cpue 65-94 & catch 65-06)+I1+I2

CC = cpue, catch data series

cpue = standardized catch rate series for Div. 3LN utilizing hours fished as measure of effort (Power, 1997)

I1= spring survey biomass index for Div. 3LN, 1991-2006

I2= autumn survey biomass index for Div. 3LN, 1991-2006

Table 7b:Traffic light criteria used to rank ASPIC formulations

Weights	⬛	-4
	🟥	-2
	🟨	1
	🟩	2
N restarts	🟥	N>=20
	🟨	10<=N<20
	🟩	N<10
correlation among input series	🟥	R<0 or no overlap
	🟥	0<=R<=0.4
	🟨	0.4<R<0.6
	🟩	R>=0.6
R squared in CPUE	⬛	R<0
	🟥	0<=R<0.4
	🟨	0.4<=R<0.6
	🟩	R>=0.6
contrast index	🟥	C<0.6
	🟨	0.6<=C<0.7
	🟩	C>=0.7
nearness index	⬛	N#1.0000
	🟩	N=1.0000
Total objective function	🟥	Obj.>4.00
	🟨	3.00<=Obj.<4.00
	🟩	Obj.<3.00

Table 7c: Diagnostics and ranking of ASPIC formulations

ASPIC runs	N restarts	correlation among input series			R squared in CPUE			contrast	nearness	Total obj.	Ranking
		cpue/I1	cpue/I2	I1/I2	cpue	I1	I2	index	index	function	
ASPIC 0	5	-0.019	0.700	0.223	0.348	0.349	-0.215	0.66	1.0000	14.02	-6
ASPIC 1	7	-0.019	-0.083	0.443	0.272	0.387	0.198	0.70	1.0000	11.59	-5
ASPIC 2	7			0.762	0.124	0.644	0.409	0.70	1.0000	3.99	7
ASPIC 03	5	-0.059	-0.141	0.582	0.558	0.553	-0.867	0.61	1.0000	5.42	1
ASPIC 3	7	-0.059	-0.469	0.762	0.420	0.612	0.470	0.67	1.0000	4.10	**9**
ASPIC 4	7	-0.059	-0.469	0.762	0.455	0.610	0.475	0.67	1.0000	4.08	**9**
ASPIC 5	5	-0.059	-0.469	0.762	0.467	0.609	0.479	0.67	1.0000	4.07	**9**
ASPIC 6	5	-0.059	-0.469	0.762	0.463	0.609	0.481	0.67	1.0000	4.06	**9**
ASPIC 7	5	-0.059	-0.469	0.762	0.458	0.608	0.484	0.67	1.0000	4.06	**9**
ASPIC 8	5	-0.059	-0.469	0.762	0.436	0.608	0.484	0.67	1.0000	4.06	**9**
ASPIC 9	5	-0.059	-0.469	0.762	0.360	0.611	0.472	0.67	1.0000	4.04	6

Table 8: Deterministic estimates of ASPIC paranmeters for a selection of formulations

ASPIC run	K	B1/K	*r*	MSY	Fmsy	$F_{lastyear/}$Fmsy	$B_{lastyear+1/}$Bmsy
ASPIC 1	271400	0.81	0.383	25950	0.191	0.0041	1.938
ASPIC 2	256900	0.89	0.419	26910	0.210	0.0039	1.960
ASPIC 3	265100	0.86	0.405	26860	0.203	0.0040	1.958
ASPIC 6	263900	0.82	0.408	26940	0.204	0.0039	1.960

Table 9: ASPIC sensitivity analysis FIT results (see text for details).

	-25% random seed	Pessimistic start	ASPIC 3 formulation	+25% random seed	Optimistic start
B1/K	0.8645	0.8644	0.86	0.8644	0.8644
MSY	26860	26860	26860	26860	26860
K	265100	265100	265100	265100	265100
q1	8.147E-06	8.148E-06	8.147E-06	8.147E-06	8.147E-06
q2	0.1833	0.1833	0.1833	0.1833	0.1833
q3	0.3581	0.3581	0.3581	0.3581	0.3581
B/BMSY	1.958	1.958	1.958	1.958	1.958
F/FMSY	0.003953	0.003953	0.003953	0.003953	0.003953

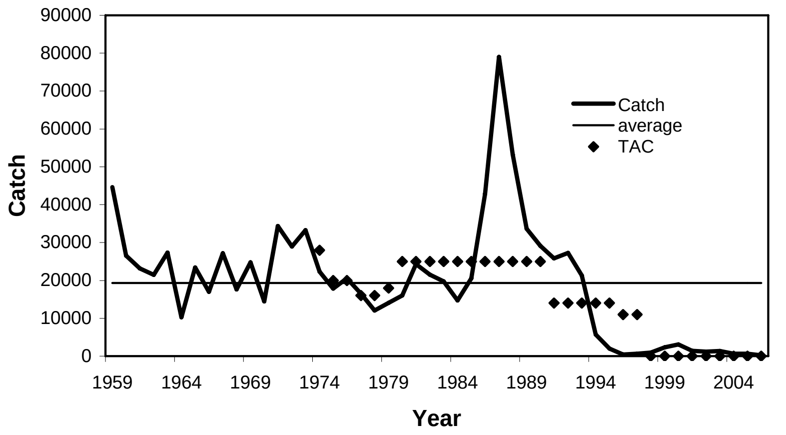

Fig. 1: redfish catch and TAC's in Div. 3LN

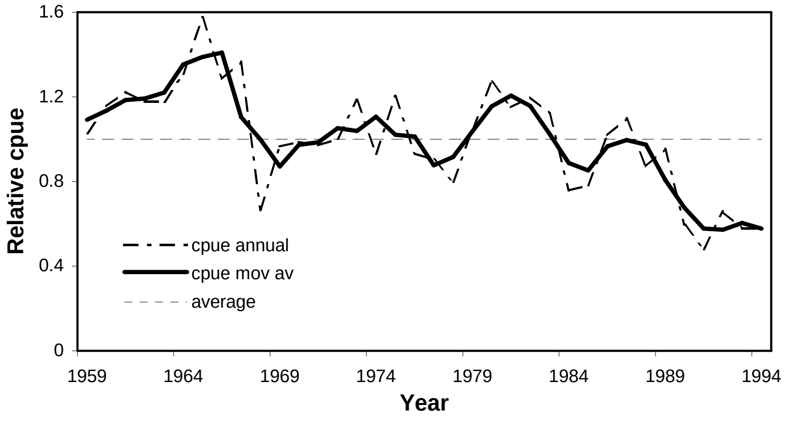

Fig. 2: Redfish Div. 3LN relative cpue 1959-1994

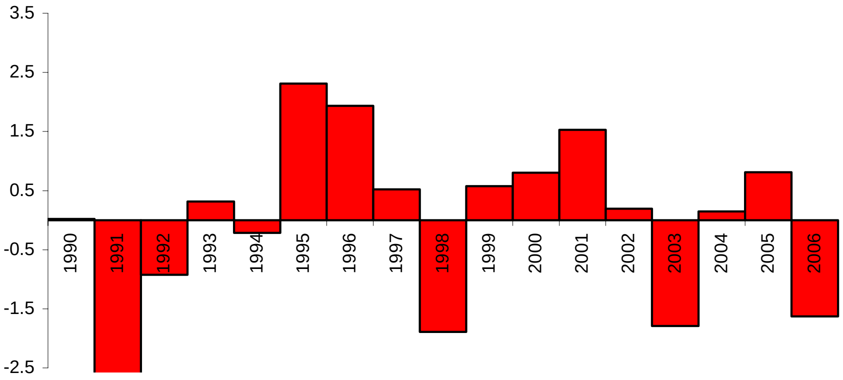

Fig. 3: Annual annomalies of the mean length of the commercial catch, 1990-2006

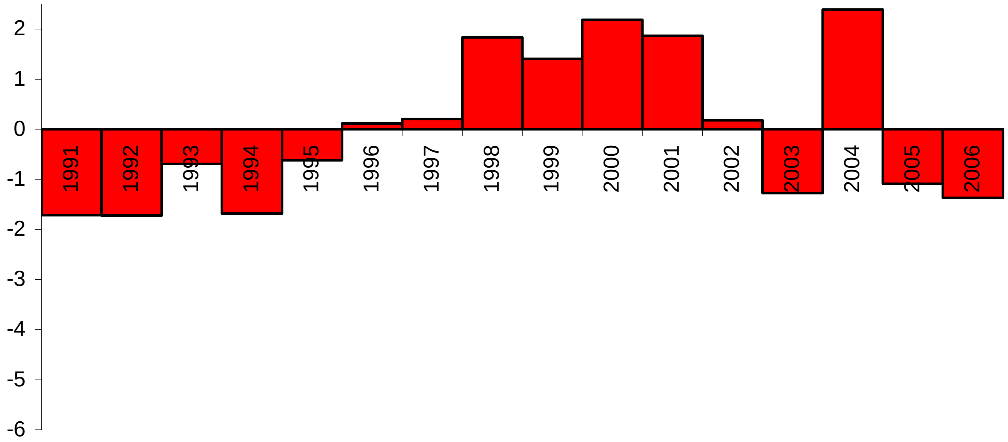

Fig. 4a: Annual annomalies of the mean length on the spring survey stock, 1991-2006

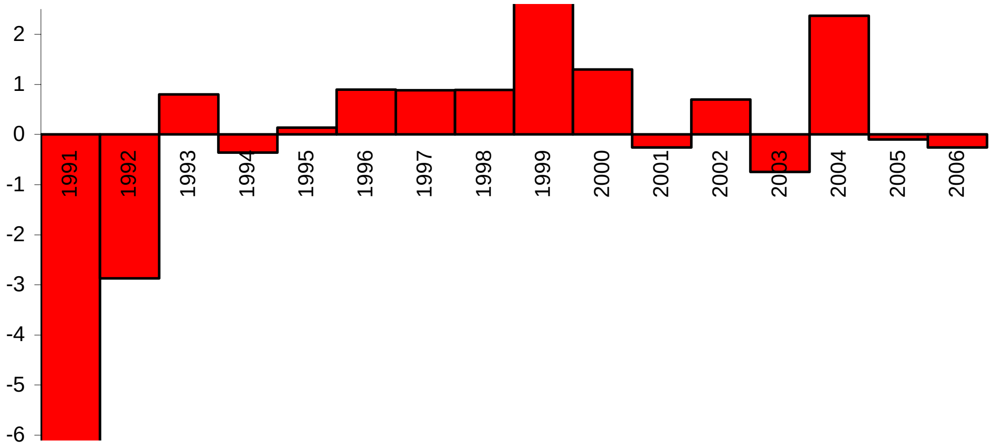

Fig. 4b: Annual annomalies of the mean length on the autumn survey stock, 1991-2006

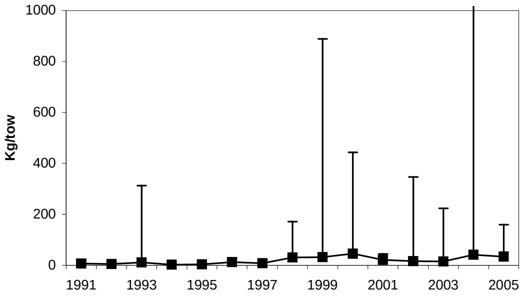

Fig. 5a: mean catch per tow for 3LN beaked refish (spring survey, 1991-2006) with upper 95% CI

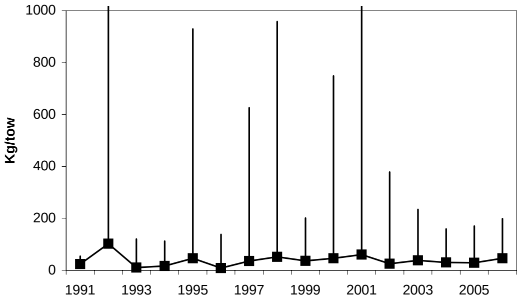

Fig. 5b: mean catch per tow for 3LN beaked refish (autumn survey, 1991-2006) with upper 95% CI

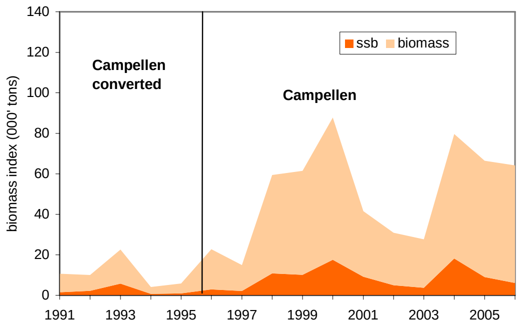

Fig. 6a: 3LN redfish biomass (spring survey, 1991-2006)

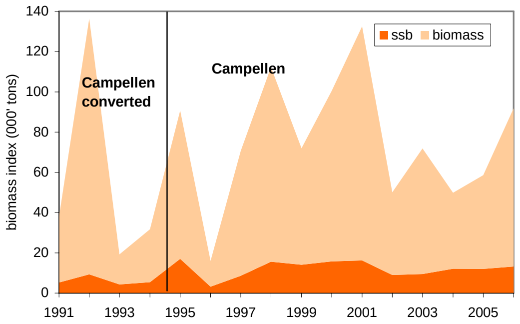

Fig. 6b: 3LN redfish biomass (autumn survey, 1991-2006)

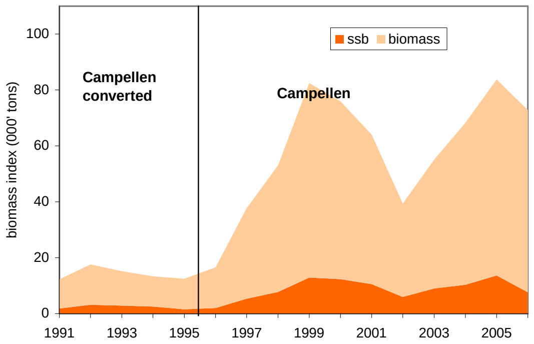

Fig. 6c: 3LN redfish biomass and ssb (spring survey 3 year moving averages, 1991-2006)

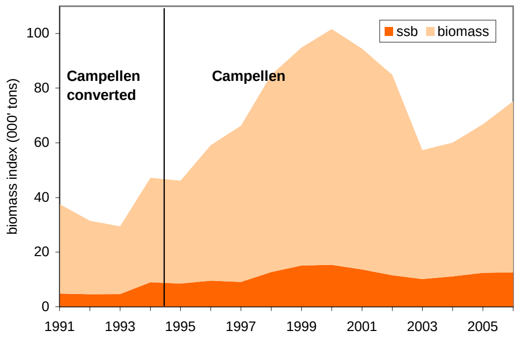

Fig. 6d: 3LN redfish biomass (autumn survey 3 year moving averages, 1991-2006)

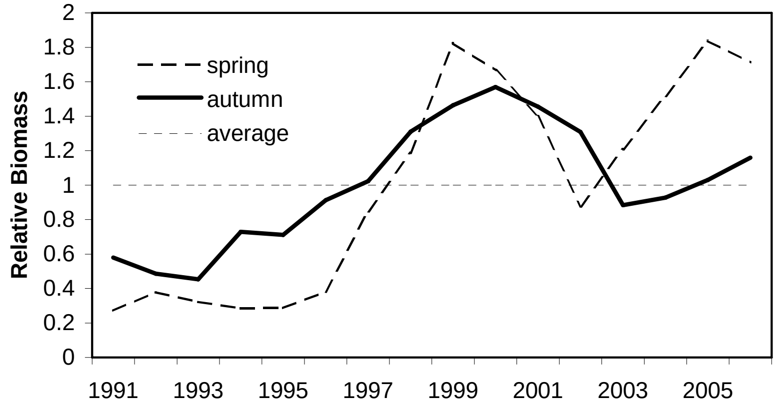

Fig. 7: Relative Spring and Autumn Biomass

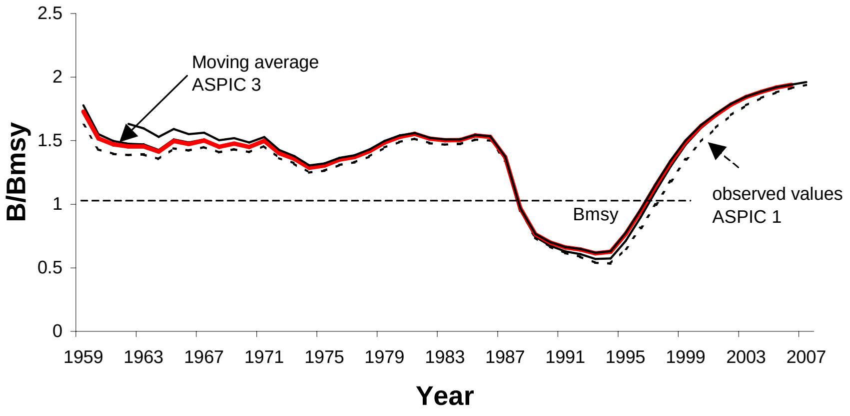

Fig. 8a: B/Bmsy trends for 4 ASPIC formulations

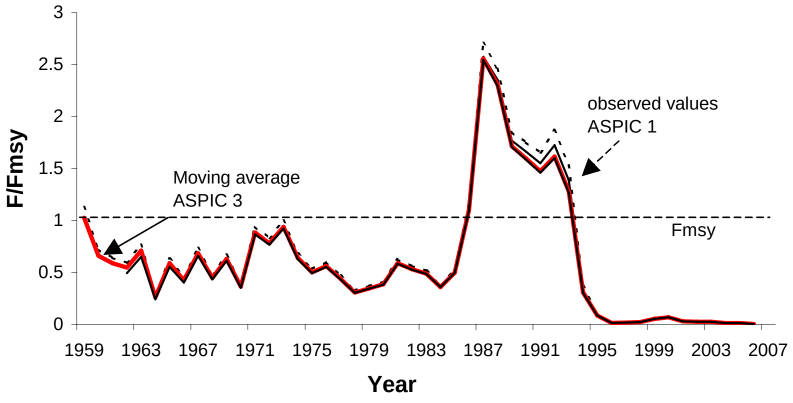

Fig. 8b: F/Fmsy trends for 4 ASPIC formulations

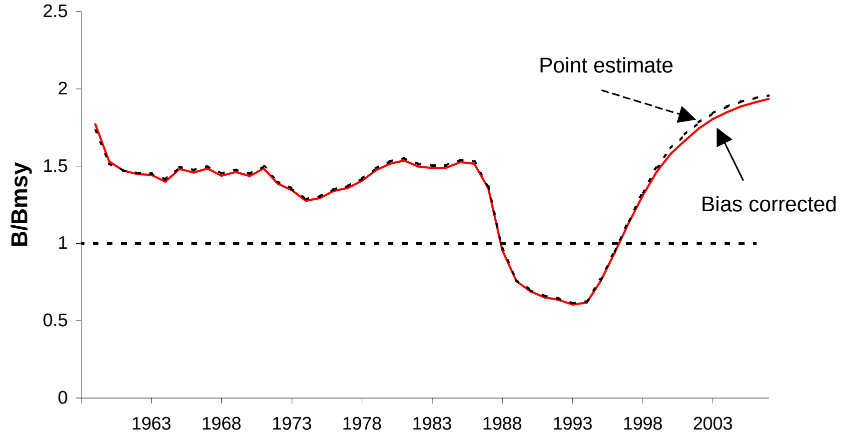

Fig. 9a: B/Bmsy deterministic and bootstrapped trajectories

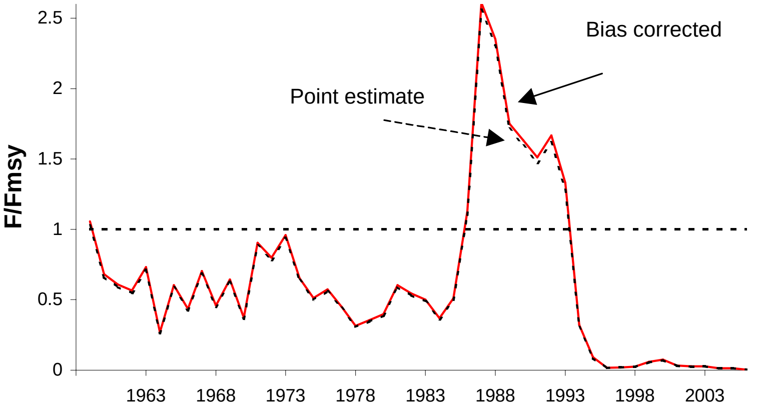

Fig. 9b: F/Fmsy deterministic and bootsrapped trajectories

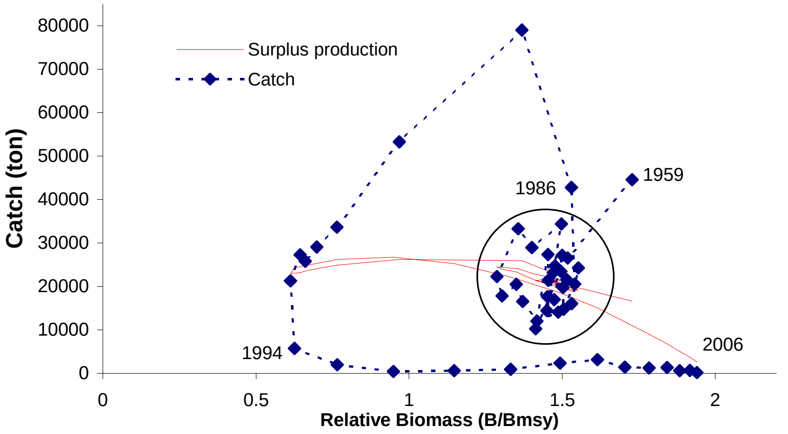

Fig. 10: Catch versus Surplus Production

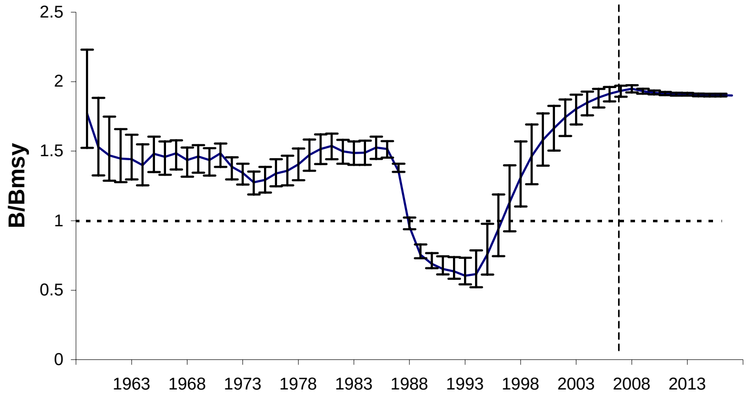

Fig. 11a: B/Bmsy trajectory and 2008-2017 projection under 5000 ton Yield (Bias corrected point estimates with approximate 80% CL's)

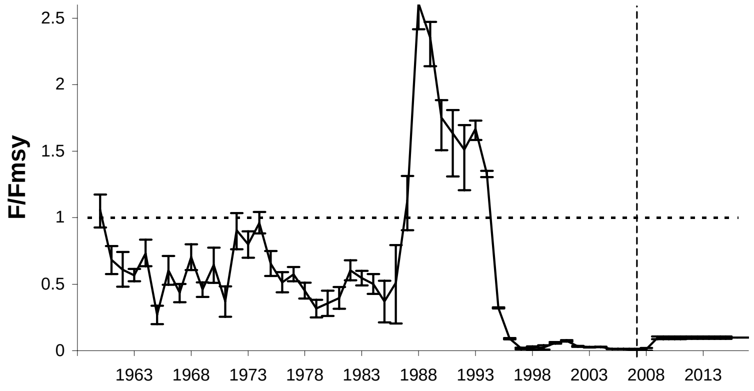

Fig. 11b: F/Fmsy trajectory and 2008-2016 projection under 5000 ton Yield (Bias corrected point estimates with approximate 80% CL's)

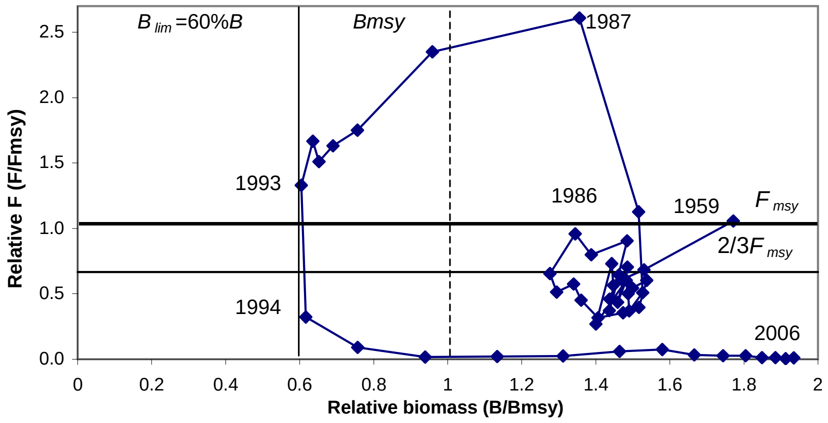

Fig. 12: Stock trajectory under a precautionary framework

Appendix 1:

ASPIC input file icluding the complete series of each biomass index. Moving averages as observed annual values for each biomass index (ASPIC 3 formulation).

```
FIT                     ## Run type (FIT, BOT, or IRF)
"3LN redfish"
LOGISTIC YLD SSE        ## See notes at end of this file
2                       ## Verbosity on screen (0-3); add 10 for SUM & PRN files
1000                     ## Number of bootstrap trials, <= 1000
0 20000                 ## 0=no MC search, 1=search, 2=repeated srch; N trials
1d-8                    ## Convergence crit. for simplex
3d-8    6               ## Convergence crit. for restarts, N restarts
1d-4    24              ## Conv. crit. for F; N steps/yr for gen. model
6d0                     ## Maximum F when cond. on yield
0d0                     ## Stat weight for B1>K as residual (usually 0 or 1)
3                       ## Number of fisheries (data series)
1d0  1d0  1d0          ## Statistical weights for data series
0.5d0                   ## B1/K (starting guess, usually 0 to 1)
2.0d4                   ## MSY (starting guess)
2.000E+05               ## K (carrying capacity) (starting guess)
9.007E-06  0.658d0  1.0d0   ## q (starting guesses -- 1 per data series)
1 1 1 1 1 1             ## Estimate flags (0 or 1) (B1/K,MSY,K,q1...qn)
0.5d4  5.0d4            ## Min and max constraints -- MSY
1.0d5  5.0d5            ## Min and max constraints -- K
3941285                 ## Random number seed (large integer)
48                      ## Number of years of data
'Statlant CPUE'         ## Title for first series
'CC'                    ## Moving average
1959      1.514     44585
1960      1.575     26562
1961      1.643     23175
1962      1.653     21439
1963      1.692     27362
1964      1.876     10261
1965      1.926     23466
1966      1.953     16974
1967      1.532     27188
1968      1.384     17660
1969      1.209     24750
1970      1.350     14419
1971      1.367     34370
1972      1.459     28933
1973      1.440     33297
1974      1.534     22286
1975      1.417     17871
1976      1.404     20513
1977      1.217     16516
1978      1.270     12043
1979      1.440     14067
1980      1.602     16030
1981      1.672     24280
1982      1.603     21547
1983      1.422     19747
1984      1.230     14761
1985      1.182     20557
1986      1.340     42805
1987      1.381     79031
1988      1.351     53266
1989      1.118     33649
1990      0.938     29105
1991      0.801     25815
1992      0.794     27283
1993      0.838     21308
1994      0.801     5741
1995      -0.001    1989
1996      -0.001    451
1997      -0.001    630
1998      -0.001    899
1999      -0.001    2318
2000      -0.001    3141
2001      -0.001    1442
2002      -0.001    1216
2003      -0.001    1334
2004      -0.001    637
2005      -0.001    659
2006      -0.001    207
'3LN spring survey'      ## Moving average
'I1'
 1959     -0.001
 1960     -0.001
 1961   -0.001
 1962   -0.001
 1963   -0.001
 1964   -0.001
 1965   -0.001
 1966   -0.001
 1967   -0.001
 1968   -0.001
 1969   -0.001
 1970   -0.001
 1971   -0.001
 1972   -0.001
```

```
 1973   -0.001
 1974   -0.001
 1975   -0.001
 1976   -0.001
 1977   -0.001
 1978   -0.001
 1979   -0.001
 1980   -0.001
 1981   -0.001
 1982   -0.001
 1983   -0.001
 1984   -0.001
 1985   -0.001
 1986   -0.001
 1987   -0.001
 1988   -0.001
 1989   -0.001
 1990   -0.001
 1991     10354.0
 1992     14427.0
 1993     12267.0
 1994     10863.7
 1995     10943.3
 1996     14532.0
 1997     32380.7
 1998     45275.3
 1999     69580.0
 2000     63637.1
 2001     53458.0
 2002     33410.7
 2003     46096.6
 2004     57931.0
 2005     70081.0
 2006     65306.0
'3LN autumn survey'      ## Moving average
'I2'
 1959     -0.001
 1960     -0.001
 1961   -0.001
 1962   -0.001
 1963   -0.001
 1964   -0.001
 1965   -0.001
 1966   -0.001
 1967   -0.001
 1968   -0.001
 1969   -0.001
 1970   -0.001
 1971   -0.001
 1972   -0.001
 1973   -0.001
 1974   -0.001
 1975   -0.001
 1976   -0.001
 1977   -0.001
 1978   -0.001
 1979   -0.001
 1980   -0.001
 1981   -0.001
 1982   -0.001
 1983   -0.001
 1984   -0.001
 1985   -0.001
 1986   -0.001
 1987   -0.001
 1988   -0.001
 1989   -0.001
 1990   -0.001
 1991     37551.9
 1992     31445.6
 1993     29402.6
 1994     47239.3
 1995     46151.0
 1996     59118.7
 1997     66284.3
 1998     84957.0
 1999     94890.7
 2000     101670.9
 2001     94383.1
 2002     84859.1
 2003     57306.2
 2004     60119.0
 2005     66783.8
 2006     75222.2
```

Appendix 2:

ASPIC FIT and BOT outputs (ASPIC 3 formulation)

```
3LN redfish                                                                                                      Page 1
                                                                                       Tuesday, 13 Mar 2007 at 15:27:58
ASPIC -- A Surplus-Production Model Including Covariates (Ver. 5.16)
                                                                                                       FIT program mode
Author:     Michael H. Prager; NOAA Center for Coastal Fisheries and Habitat Research               LOGISTIC model mode
            101 Pivers Island Road; Beaufort, North Carolina  28516  USA                               YLD conditioning
            Mike.Prager@noaa.gov                                                                       SSE optimization

Reference:  Prager, M. H. 1994. A suite of extensions to a nonequilibrium              ASPIC User's Manual is available
            surplus-production model.  Fishery Bulletin 92: 374-389.                            gratis from the author.

CONTROL PARAMETERS (FROM INPUT FILE)                                                              Input file: aspic.inp
------------------------------------------------------------------------------------------------------------------------
Operation of ASPIC:  Fit logistic (Schaefer) model by direct optimization.
Number of years analyzed:                        48             Number of bootstrap trials:                           0
Number of data series:                            3             Bounds on MSY (min, max):       5.000E+03     5.000E+04
Objective function:                   Least squares             Bounds on K (min, max):         1.000E+05     5.000E+05
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 appears to be violated.
Number of restarts required for convergence:      7


CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)
------------------------------------------------------------------------------------------------------------------------
                                       |
 1  Statlant CPUE                      |   1.000
                                       |      36
                                       |
 2  3LN spring survey                  |  -0.059   1.000
                                       |       4      16
                                       |
 3  3LN autumn survey                  |  -0.469   0.762   1.000
                                       |       4      16      16
                                       --------------------------------------------------
                                               1       2       3


GOODNESS-OF-FIT AND WEIGHTING (NON-BOOTSTRAPPED ANALYSIS)
------------------------------------------------------------------------------------------------------------------------
                                                     Weighted           Weighted      Current    Inv. var.    R-squared
Loss component number and title                           SSE     N          MSE       weight       weight      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                             1.062E+00    36    3.123E-02    1.000E+00    1.417E+00        0.420
Loss(2)   3LN spring survey                         2.255E+00    16    1.611E-01    1.000E+00    2.747E-01        0.612
Loss(3)   3LN autumn survey                         7.874E-01    16    5.624E-02    1.000E+00    7.868E-01        0.470
.............................................................................................
TOTAL OBJECTIVE FUNCTION, MSE, RMSE:           4.10420904E+00          6.620E-02    2.573E-01
Estimated contrast index (ideal = 1.0):                0.6725          C* = (Bmax-Bmin)/K
Estimated nearness index (ideal = 1.0):                1.0000          N* = 1 - |min(B-Bmsy)|/K
```

```
3LN redfish                                                                                                         Page 2

MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)
-----------------------------------------------------------------------------------------------------------------------
Parameter                                            Estimate     User/pgm guess    2nd guess    Estimated   User guess

B1/K      Starting relative biomass (in 1959)       8.645E-01         5.000E-01    7.427E-01            1            1
MSY       Maximum sustainable yield                 2.686E+04         2.000E+04    1.643E+04            1            1
K         Maximum population size                   2.651E+05         2.000E+05    1.800E+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                             8.147E-06         9.007E-06    8.557E-04            1            1
q(2)      3LN spring survey                         1.833E-01         6.580E-01    1.291E+00            1            1
q(3)      3LN autumn survey                         3.581E-01         1.000E+00    7.600E-01            1            1


MANAGEMENT and DERIVED PARAMETER ESTIMATES (NON-BOOTSTRAPPED)
-----------------------------------------------------------------------------------------------------------------------
Parameter                                            Estimate                Logistic formula           General formula

MSY       Maximum sustainable yield                 2.686E+04                            ----                      ----
Bmsy      Stock biomass giving MSY                  1.326E+05                             K/2           K*n**(1/(1-n))
Fmsy      Fishing mortality rate at MSY             2.026E-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(2007)/Bmsy                       1.958E+00                            ----                      ----
F./Fmsy   Ratio: F(2006)/Fmsy                       3.953E-03                            ----                      ----
Fmsy/F.   Ratio: Fmsy/F(2006)                       2.530E+02                            ----                      ----

Y.(Fmsy)  Approx. yield available at Fmsy in 2007   5.259E+04                     MSY*B./Bmsy              MSY*B./Bmsy
          ...as proportion of MSY                   1.958E+00                            ----                      ----
Ye.       Equilibrium yield available in 2007       2.204E+03            4*MSY*(B/K-(B/K)**2)      g*MSY*(B/K-(B/K)**n)
          ...as proportion of MSY                   8.205E-02                            ----                      ----

--------- Fishing effort rate at MSY in units of each CE or CC series ---------
fmsy(1)   Statlant CPUE                             2.487E+04                       Fmsy/q( 1)               Fmsy/q( 1)
```

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3LN redfish                                                                                                     Page 3

ESTIMATED POPULATION TRAJECTORY (NON-BOOTSTRAPPED)
------------------------------------------------------------------------------------------------------------------------

           Estimated   Estimated    Estimated     Observed        Model    Estimated     Ratio of     Ratio of
     Year      total    starting      average        total        total      surplus       F mort      biomass
Obs or ID     F mort     biomass      biomass        yield        yield   production      to Fmsy      to Bmsy

  1   1959     0.208   2.292E+05    2.141E+05    4.458E+04    4.458E+04    1.659E+04    1.028E+00    1.729E+00
  2   1960     0.134   2.012E+05    1.979E+05    2.656E+04    2.656E+04    2.033E+04    6.624E-01    1.518E+00
  3   1961     0.120   1.950E+05    1.939E+05    2.318E+04    2.318E+04    2.111E+04    5.899E-01    1.471E+00
  4   1962     0.111   1.929E+05    1.928E+05    2.144E+04    2.144E+04    2.131E+04    5.487E-01    1.455E+00
  5   1963     0.144   1.928E+05    1.898E+05    2.736E+04    2.736E+04    2.184E+04    7.112E-01    1.454E+00
  6   1964     0.053   1.872E+05    1.930E+05    1.026E+04    1.026E+04    2.127E+04    2.624E-01    1.413E+00
  7   1965     0.119   1.982E+05    1.967E+05    2.347E+04    2.347E+04    2.057E+04    5.887E-01    1.496E+00
  8   1966     0.086   1.953E+05    1.972E+05    1.697E+04    1.697E+04    2.048E+04    4.248E-01    1.474E+00
  9   1967     0.139   1.988E+05    1.955E+05    2.719E+04    2.719E+04    2.080E+04    6.864E-01    1.500E+00
 10   1968     0.091   1.925E+05    1.942E+05    1.766E+04    1.766E+04    2.104E+04    4.487E-01    1.452E+00
 11   1969     0.128   1.958E+05    1.939E+05    2.475E+04    2.475E+04    2.110E+04    6.298E-01    1.477E+00
 12   1970     0.074   1.922E+05    1.955E+05    1.442E+04    1.442E+04    2.079E+04    3.639E-01    1.450E+00
 13   1971     0.179   1.986E+05    1.917E+05    3.437E+04    3.437E+04    2.148E+04    8.846E-01    1.498E+00
 14   1972     0.158   1.857E+05    1.826E+05    2.893E+04    2.893E+04    2.303E+04    7.820E-01    1.401E+00
 15   1973     0.190   1.798E+05    1.749E+05    3.330E+04    3.330E+04    2.410E+04    9.393E-01    1.356E+00
 16   1974     0.130   1.706E+05    1.717E+05    2.229E+04    2.229E+04    2.451E+04    6.404E-01    1.287E+00
 17   1975     0.102   1.728E+05    1.760E+05    1.787E+04    1.787E+04    2.397E+04    5.011E-01    1.304E+00
 18   1976     0.114   1.789E+05    1.804E+05    2.051E+04    2.051E+04    2.336E+04    5.611E-01    1.350E+00
 19   1977     0.089   1.818E+05    1.850E+05    1.652E+04    1.652E+04    2.266E+04    4.407E-01    1.371E+00
 20   1978     0.062   1.879E+05    1.927E+05    1.204E+04    1.204E+04    2.131E+04    3.084E-01    1.418E+00
 21   1979     0.070   1.972E+05    2.002E+05    1.407E+04    1.407E+04    1.986E+04    3.467E-01    1.487E+00
 22   1980     0.078   2.030E+05    2.045E+05    1.603E+04    1.603E+04    1.895E+04    3.868E-01    1.531E+00
 23   1981     0.119   2.059E+05    2.032E+05    2.428E+04    2.428E+04    1.922E+04    5.896E-01    1.553E+00
 24   1982     0.108   2.008E+05    2.000E+05    2.155E+04    2.155E+04    1.991E+04    5.318E-01    1.515E+00
 25   1983     0.099   1.992E+05    1.993E+05    1.975E+04    1.975E+04    2.004E+04    4.888E-01    1.503E+00
 26   1984     0.073   1.995E+05    2.020E+05    1.476E+04    1.476E+04    1.949E+04    3.607E-01    1.505E+00
 27   1985     0.101   2.042E+05    2.035E+05    2.056E+04    2.056E+04    1.917E+04    4.985E-01    1.541E+00
 28   1986     0.224   2.028E+05    1.915E+05    4.280E+04    4.280E+04    2.150E+04    1.103E+00    1.530E+00
 29   1987     0.519   1.815E+05    1.524E+05    7.903E+04    7.903E+04    2.590E+04    2.559E+00    1.369E+00
 30   1988     0.467   1.284E+05    1.140E+05    5.327E+04    5.327E+04    2.624E+04    2.307E+00    9.686E-01
 31   1989     0.348   1.014E+05    9.682E+04    3.365E+04    3.365E+04    2.490E+04    1.715E+00    7.647E-01
 32   1990     0.323   9.262E+04    9.003E+04    2.910E+04    2.910E+04    2.409E+04    1.595E+00    6.987E-01
 33   1991     0.299   8.760E+04    8.647E+04    2.582E+04    2.582E+04    2.361E+04    1.473E+00    6.609E-01
 34   1992     0.328   8.540E+04    8.327E+04    2.728E+04    2.728E+04    2.315E+04    1.617E+00    6.443E-01
 35   1993     0.260   8.126E+04    8.211E+04    2.131E+04    2.131E+04    2.297E+04    1.281E+00    6.131E-01
 36   1994     0.062   8.292E+04    9.212E+04    5.741E+03    5.741E+03    2.432E+04    3.076E-01    6.256E-01
 37   1995     0.018   1.015E+05    1.135E+05    1.989E+03    1.989E+03    2.623E+04    8.645E-02    7.657E-01
 38   1996     0.003   1.257E+05    1.389E+05    4.510E+02    4.510E+02    2.671E+04    1.602E-02    9.486E-01
 39   1997     0.004   1.520E+05    1.645E+05    6.300E+02    6.300E+02    2.522E+04    1.890E-02    1.147E+00
 40   1998     0.005   1.766E+05    1.875E+05    8.990E+02    8.990E+02    2.218E+04    2.366E-02    1.332E+00
 41   1999     0.011   1.979E+05    2.063E+05    2.318E+03    2.318E+03    1.851E+04    5.545E-02    1.493E+00
 42   2000     0.014   2.141E+05    2.203E+05    3.141E+03    3.141E+03    1.507E+04    7.036E-02    1.615E+00
 43   2001     0.006   2.260E+05    2.315E+05    1.442E+03    1.442E+03    1.188E+04    3.074E-02    1.705E+00
 44   2002     0.005   2.364E+05    2.406E+05    1.216E+03    1.216E+03    9.020E+03    2.495E-02    1.784E+00
 45   2003     0.005   2.442E+05    2.471E+05    1.334E+03    1.334E+03    6.787E+03    2.664E-02    1.843E+00
 46   2004     0.003   2.497E+05    2.520E+05    6.370E+02    6.370E+02    5.036E+03    1.247E-02    1.884E+00
 47   2005     0.003   2.541E+05    2.557E+05    6.590E+02    6.590E+02    3.676E+03    1.272E-02    1.917E+00
 48   2006     0.001   2.571E+05    2.584E+05    2.070E+02    2.070E+02    2.645E+03    3.953E-03    1.940E+00
 49   2007              2.596E+05                                                                     1.958E+00
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3LN redfish                                                                                                     Page 4

RESULTS FOR DATA SERIES # 1 (NON-BOOTSTRAPPED)                                                            Statlant CPUE
------------------------------------------------------------------------------------------------------------------------
Data type CC: CPUE-catch series                                                                   Series weight:  1.000

                 Observed    Estimated    Estim     Observed        Model    Resid in      Statist
Obs    Year          CPUE         CPUE        F        yield        yield   log scale       weight

  1    1959    1.514E+00    1.744E+00    0.2082    4.458E+04    4.458E+04     0.14170    1.000E+00
  2    1960    1.575E+00    1.612E+00    0.1342    2.656E+04    2.656E+04     0.02341    1.000E+00
  3    1961    1.643E+00    1.580E+00    0.1195    2.318E+04    2.318E+04    -0.03941    1.000E+00
  4    1962    1.653E+00    1.571E+00    0.1112    2.144E+04    2.144E+04    -0.05090    1.000E+00
  5    1963    1.692E+00    1.547E+00    0.1441    2.736E+04    2.736E+04    -0.08975    1.000E+00
  6    1964    1.876E+00    1.572E+00    0.0532    1.026E+04    1.026E+04    -0.17675    1.000E+00
  7    1965    1.926E+00    1.603E+00    0.1193    2.347E+04    2.347E+04    -0.18376    1.000E+00
  8    1966    1.953E+00    1.606E+00    0.0861    1.697E+04    1.697E+04    -0.19535    1.000E+00
  9    1967    1.532E+00    1.593E+00    0.1391    2.719E+04    2.719E+04     0.03878    1.000E+00
 10    1968    1.384E+00    1.582E+00    0.0909    1.766E+04    1.766E+04     0.13398    1.000E+00
 11    1969    1.209E+00    1.580E+00    0.1276    2.475E+04    2.475E+04     0.26759    1.000E+00
 12    1970    1.350E+00    1.593E+00    0.0737    1.442E+04    1.442E+04     0.16549    1.000E+00
 13    1971    1.367E+00    1.562E+00    0.1793    3.437E+04    3.437E+04     0.13344    1.000E+00
 14    1972    1.459E+00    1.488E+00    0.1585    2.893E+04    2.893E+04     0.01935    1.000E+00
 15    1973    1.440E+00    1.425E+00    0.1903    3.330E+04    3.330E+04    -0.01028    1.000E+00
 16    1974    1.534E+00    1.399E+00    0.1298    2.229E+04    2.229E+04    -0.09194    1.000E+00
 17    1975    1.417E+00    1.434E+00    0.1016    1.787E+04    1.787E+04     0.01176    1.000E+00
 18    1976    1.404E+00    1.470E+00    0.1137    2.051E+04    2.051E+04     0.04577    1.000E+00
 19    1977    1.217E+00    1.507E+00    0.0893    1.652E+04    1.652E+04     0.21367    1.000E+00
 20    1978    1.270E+00    1.570E+00    0.0625    1.204E+04    1.204E+04     0.21219    1.000E+00
 21    1979    1.440E+00    1.631E+00    0.0703    1.407E+04    1.407E+04     0.12461    1.000E+00
 22    1980    1.602E+00    1.666E+00    0.0784    1.603E+04    1.603E+04     0.03922    1.000E+00
 23    1981    1.672E+00    1.656E+00    0.1195    2.428E+04    2.428E+04    -0.00983    1.000E+00
 24    1982    1.603E+00    1.629E+00    0.1078    2.155E+04    2.155E+04     0.01620    1.000E+00
 25    1983    1.422E+00    1.624E+00    0.0991    1.975E+04    1.975E+04     0.13291    1.000E+00
 26    1984    1.230E+00    1.645E+00    0.0731    1.476E+04    1.476E+04     0.29100    1.000E+00
 27    1985    1.182E+00    1.658E+00    0.1010    2.056E+04    2.056E+04     0.33832    1.000E+00
 28    1986    1.340E+00    1.560E+00    0.2236    4.280E+04    4.280E+04     0.15194    1.000E+00
 29    1987    1.381E+00    1.242E+00    0.5186    7.903E+04    7.903E+04    -0.10636    1.000E+00
 30    1988    1.351E+00    9.284E-01    0.4674    5.327E+04    5.327E+04    -0.37509    1.000E+00
 31    1989    1.118E+00    7.888E-01    0.3476    3.365E+04    3.365E+04    -0.34878    1.000E+00
 32    1990    9.380E-01    7.335E-01    0.3233    2.910E+04    2.910E+04    -0.24592    1.000E+00
 33    1991    8.010E-01    7.045E-01    0.2985    2.582E+04    2.582E+04    -0.12835    1.000E+00
 34    1992    7.940E-01    6.784E-01    0.3276    2.728E+04    2.728E+04    -0.15729    1.000E+00
 35    1993    8.380E-01    6.690E-01    0.2595    2.131E+04    2.131E+04    -0.22529    1.000E+00
 36    1994    8.010E-01    7.505E-01    0.0623    5.741E+03    5.741E+03    -0.06510    1.000E+00
 37    1995        *        9.250E-01    0.0175    1.989E+03    1.989E+03     0.00000    1.000E+00
 38    1996        *        1.132E+00    0.0032    4.510E+02    4.510E+02     0.00000    1.000E+00
 39    1997        *        1.340E+00    0.0038    6.300E+02    6.300E+02     0.00000    1.000E+00
 40    1998        *        1.528E+00    0.0048    8.990E+02    8.990E+02     0.00000    1.000E+00
 41    1999        *        1.681E+00    0.0112    2.318E+03    2.318E+03     0.00000    1.000E+00
 42    2000        *        1.795E+00    0.0143    3.141E+03    3.141E+03     0.00000    1.000E+00
 43    2001        *        1.886E+00    0.0062    1.442E+03    1.442E+03     0.00000    1.000E+00
 44    2002        *        1.960E+00    0.0051    1.216E+03    1.216E+03     0.00000    1.000E+00
 45    2003        *        2.013E+00    0.0054    1.334E+03    1.334E+03     0.00000    1.000E+00
 46    2004        *        2.053E+00    0.0025    6.370E+02    6.370E+02     0.00000    1.000E+00
 47    2005        *        2.083E+00    0.0026    6.590E+02    6.590E+02     0.00000    1.000E+00
 48    2006        *        2.105E+00    0.0008    2.070E+02    2.070E+02     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     0.1417                                             |======
1960     0.0234                                             |=
1961    -0.0394                                           ==|
1962    -0.0509                                           ==|
1963    -0.0897                                         ====|
1964    -0.1767                                      =======|
1965    -0.1838                                      =======|
1966    -0.1953                                     ========|
1967     0.0388                                             |==
1968     0.1340                                             |=====
1969     0.2676                                             |===========
1970     0.1655                                             |=======
1971     0.1334                                             |=====
1972     0.0193                                             |=
1973    -0.0103                                             |
1974    -0.0919                                         ====|
1975     0.0118                                             |
1976     0.0458                                             |==
1977     0.2137                                             |=========
1978     0.2122                                             |========
1979     0.1246                                             |=====
1980     0.0392                                             |==
1981    -0.0098                                             |
1982     0.0162                                             |=
1983     0.1329                                             |=====
1984     0.2910                                             |============
1985     0.3383                                             |==============
1986     0.1519                                             |======
1987    -0.1064                                         ====|
1988    -0.3751                              ===============|
1989    -0.3488                               ==============|
1990    -0.2459                                   ==========|
1991    -0.1283                                        =====|
1992    -0.1573                                       ======|
1993    -0.2253                                    =========|
1994    -0.0651                                          ===|
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                                             |
                   ------------------------------------------------------------------------------------
```

```
                Observed (O) and Estimated (*) CPUE for Data Series # 1 -- Statlant CPUE
           :
      2.4 -:
           :
           :
           :
           :
      2.1 -:                                                                                            **
           :                                                                                        * *
           :                           O                                                           *
           :                         O
           :                       O                                                             *
      1.8 -:                                                                                   *
           :               *
           :                    O O                           * 2     *                       *
           :                 *O      * **    *              * O  2 * *
           :                 O* * **    O * *  *    O      *            *
      1.5 -:               O                     *       *                                  *
           :                                     O2   2*    O      O
           :                              O    O    *  O                  OO
           :                                 O                          O                 *
           :                                               O              *
      1.2 -:                                O            O           OO
           :                                                                 O           *
           :
           :
           :                                                                   O
      0.9 -:                                                               *           *
           :                                                                        O
           :                                                                 *  O O  2
           :                                                                   **
           :                                                                      * *
      0.6 -:
           :........................................................................................................
            :         :         :         :         :         :         :         :         :         :         :
         1950.     1956.     1962.     1968.     1974.     1980.     1986.     1992.     1998.     2004.     2010.
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RESULTS FOR DATA SERIES # 2 (NON-BOOTSTRAPPED)                                                       3LN spring survey
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Data type I1: Abundance index (annual average)                                                   Series weight:  1.000

                Observed    Estimated    Estim     Observed        Model    Resid in      Statist
Obs    Year       effort       effort        F        index        index   log index       weight

  1    1959    0.000E+00    0.000E+00       --     *           3.925E+04     0.00000    1.000E+00
  2    1960    0.000E+00    0.000E+00       --     *           3.628E+04     0.00000    1.000E+00
  3    1961    0.000E+00    0.000E+00       --     *           3.554E+04     0.00000    1.000E+00
  4    1962    0.000E+00    0.000E+00       --     *           3.534E+04     0.00000    1.000E+00
  5    1963    0.000E+00    0.000E+00       --     *           3.480E+04     0.00000    1.000E+00
  6    1964    0.000E+00    0.000E+00       --     *           3.537E+04     0.00000    1.000E+00
  7    1965    0.000E+00    0.000E+00       --     *           3.606E+04     0.00000    1.000E+00
  8    1966    0.000E+00    0.000E+00       --     *           3.614E+04     0.00000    1.000E+00
  9    1967    0.000E+00    0.000E+00       --     *           3.583E+04     0.00000    1.000E+00
 10    1968    0.000E+00    0.000E+00       --     *           3.560E+04     0.00000    1.000E+00
 11    1969    0.000E+00    0.000E+00       --     *           3.555E+04     0.00000    1.000E+00
 12    1970    0.000E+00    0.000E+00       --     *           3.584E+04     0.00000    1.000E+00
 13    1971    0.000E+00    0.000E+00       --     *           3.515E+04     0.00000    1.000E+00
 14    1972    0.000E+00    0.000E+00       --     *           3.347E+04     0.00000    1.000E+00
 15    1973    0.000E+00    0.000E+00       --     *           3.207E+04     0.00000    1.000E+00
 16    1974    0.000E+00    0.000E+00       --     *           3.148E+04     0.00000    1.000E+00
 17    1975    0.000E+00    0.000E+00       --     *           3.226E+04     0.00000    1.000E+00
 18    1976    0.000E+00    0.000E+00       --     *           3.307E+04     0.00000    1.000E+00
 19    1977    0.000E+00    0.000E+00       --     *           3.390E+04     0.00000    1.000E+00
 20    1978    0.000E+00    0.000E+00       --     *           3.533E+04     0.00000    1.000E+00
 21    1979    0.000E+00    0.000E+00       --     *           3.670E+04     0.00000    1.000E+00
 22    1980    0.000E+00    0.000E+00       --     *           3.748E+04     0.00000    1.000E+00
 23    1981    0.000E+00    0.000E+00       --     *           3.725E+04     0.00000    1.000E+00
 24    1982    0.000E+00    0.000E+00       --     *           3.665E+04     0.00000    1.000E+00
 25    1983    0.000E+00    0.000E+00       --     *           3.654E+04     0.00000    1.000E+00
 26    1984    0.000E+00    0.000E+00       --     *           3.702E+04     0.00000    1.000E+00
 27    1985    0.000E+00    0.000E+00       --     *           3.730E+04     0.00000    1.000E+00
 28    1986    0.000E+00    0.000E+00       --     *           3.510E+04     0.00000    1.000E+00
 29    1987    0.000E+00    0.000E+00       --     *           2.794E+04     0.00000    1.000E+00
 30    1988    0.000E+00    0.000E+00       --     *           2.089E+04     0.00000    1.000E+00
 31    1989    0.000E+00    0.000E+00       --     *           1.775E+04     0.00000    1.000E+00
 32    1990    0.000E+00    0.000E+00       --     *           1.650E+04     0.00000    1.000E+00
 33    1991    1.000E+00    1.000E+00       --    1.035E+04    1.585E+04    -0.42585    1.000E+00
 34    1992    1.000E+00    1.000E+00       --    1.443E+04    1.526E+04    -0.05640    1.000E+00
 35    1993    1.000E+00    1.000E+00       --    1.227E+04    1.505E+04    -0.20452    1.000E+00
 36    1994    1.000E+00    1.000E+00       --    1.086E+04    1.689E+04    -0.44104    1.000E+00
 37    1995    1.000E+00    1.000E+00       --    1.094E+04    2.081E+04    -0.64283    1.000E+00
 38    1996    1.000E+00    1.000E+00       --    1.453E+04    2.547E+04    -0.56096    1.000E+00
 39    1997    1.000E+00    1.000E+00       --    3.238E+04    3.015E+04     0.07121    1.000E+00
 40    1998    1.000E+00    1.000E+00       --    4.528E+04    3.438E+04     0.27536    1.000E+00
 41    1999    1.000E+00    1.000E+00       --    6.958E+04    3.781E+04     0.60978    1.000E+00
 42    2000    1.000E+00    1.000E+00       --    6.364E+04    4.039E+04     0.45474    1.000E+00
 43    2001    1.000E+00    1.000E+00       --    5.346E+04    4.243E+04     0.23097    1.000E+00
 44    2002    1.000E+00    1.000E+00       --    3.341E+04    4.410E+04    -0.27749    1.000E+00
 45    2003    1.000E+00    1.000E+00       --    4.610E+04    4.530E+04     0.01742    1.000E+00
 46    2004    1.000E+00    1.000E+00       --    5.793E+04    4.620E+04     0.22631    1.000E+00
 47    2005    1.000E+00    1.000E+00       --    7.008E+04    4.687E+04     0.40225    1.000E+00
 48    2006    1.000E+00    1.000E+00       --    6.531E+04    4.737E+04     0.32114    1.000E+00

* Asterisk indicates missing value(s).
```

```
UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 2
                   -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    -0.4258                            =================|
1992    -0.0564                                           ==|
1993    -0.2045                                     ========|
1994    -0.4410                           ==================|
1995    -0.6428                   ==========================|
1996    -0.5610                       ======================|
1997     0.0712                                             |===
1998     0.2754                                             |===========
1999     0.6098                                             |========================
2000     0.4547                                             |==================
2001     0.2310                                             |=========
2002    -0.2775                                  ===========|
2003     0.0174                                             |=
2004     0.2263                                             |=========
2005     0.4023                                             |================
2006     0.3211                                             |=============
                   ------------------------------------------------------------------------------------
```

```
                Observed (O) and Estimated (*) CPUE for Data Series # 2 -- 3LN spring survey
           :
   90000. -:
           :
           :
           :
           :
   75000. -:
           :
           :                                                                                  O         O
           :                                                                                             O
           :                                                                                   O
   60000. -:
           :                                                                                          O
           :                                                                                     O
           :
           :                                                                                            **
   45000. -:                                                                                O      *2 *
           :                                                                                     *
           :               *                                                                  **
           :                 ** * ** * ** * ** *           ** * ** * ** *
           :                                     **   ** *                                O *      O
   30000. -:                                        *                                     *
           :                                                                      *
           :                                                                                 *
           :                                                               *           *
           :                                                                 * *     *
   15000. -:                                                                    * 2 *    O
           :                                                                        OO O
           :                                                                    O
           :
           :
       0. -:
           :........................................................................................................
            :         :         :         :         :         :         :         :         :         :         :
         1950.     1956.     1962.     1968.     1974.     1980.     1986.     1992.     1998.     2004.     2010.
```

```
RESULTS FOR DATA SERIES # 3 (NON-BOOTSTRAPPED)                                                        3LN autumn survey
------------------------------------------------------------------------------------------------------------------------
Data type I2: Abundance index (end of year)                                                       Series weight:  1.000

                Observed    Estimated    Estim     Observed        Model    Resid in      Statist
Obs    Year       effort       effort        F        index        index   log index       weight

  1    1959    0.000E+00    0.000E+00       --    *           7.204E+04     0.00000    1.000E+00
  2    1960    0.000E+00    0.000E+00       --    *           6.980E+04     0.00000    1.000E+00
  3    1961    0.000E+00    0.000E+00       --    *           6.907E+04     0.00000    1.000E+00
  4    1962    0.000E+00    0.000E+00       --    *           6.902E+04     0.00000    1.000E+00
  5    1963    0.000E+00    0.000E+00       --    *           6.704E+04     0.00000    1.000E+00
  6    1964    0.000E+00    0.000E+00       --    *           7.098E+04     0.00000    1.000E+00
  7    1965    0.000E+00    0.000E+00       --    *           6.994E+04     0.00000    1.000E+00
  8    1966    0.000E+00    0.000E+00       --    *           7.120E+04     0.00000    1.000E+00
  9    1967    0.000E+00    0.000E+00       --    *           6.891E+04     0.00000    1.000E+00
 10    1968    0.000E+00    0.000E+00       --    *           7.012E+04     0.00000    1.000E+00
 11    1969    0.000E+00    0.000E+00       --    *           6.882E+04     0.00000    1.000E+00
 12    1970    0.000E+00    0.000E+00       --    *           7.110E+04     0.00000    1.000E+00
 13    1971    0.000E+00    0.000E+00       --    *           6.649E+04     0.00000    1.000E+00
 14    1972    0.000E+00    0.000E+00       --    *           6.437E+04     0.00000    1.000E+00
 15    1973    0.000E+00    0.000E+00       --    *           6.108E+04     0.00000    1.000E+00
 16    1974    0.000E+00    0.000E+00       --    *           6.188E+04     0.00000    1.000E+00
 17    1975    0.000E+00    0.000E+00       --    *           6.406E+04     0.00000    1.000E+00
 18    1976    0.000E+00    0.000E+00       --    *           6.508E+04     0.00000    1.000E+00
 19    1977    0.000E+00    0.000E+00       --    *           6.728E+04     0.00000    1.000E+00
 20    1978    0.000E+00    0.000E+00       --    *           7.060E+04     0.00000    1.000E+00
 21    1979    0.000E+00    0.000E+00       --    *           7.267E+04     0.00000    1.000E+00
 22    1980    0.000E+00    0.000E+00       --    *           7.372E+04     0.00000    1.000E+00
 23    1981    0.000E+00    0.000E+00       --    *           7.191E+04     0.00000    1.000E+00
 24    1982    0.000E+00    0.000E+00       --    *           7.132E+04     0.00000    1.000E+00
 25    1983    0.000E+00    0.000E+00       --    *           7.143E+04     0.00000    1.000E+00
 26    1984    0.000E+00    0.000E+00       --    *           7.312E+04     0.00000    1.000E+00
 27    1985    0.000E+00    0.000E+00       --    *           7.262E+04     0.00000    1.000E+00
 28    1986    0.000E+00    0.000E+00       --    *           6.500E+04     0.00000    1.000E+00
 29    1987    0.000E+00    0.000E+00       --    *           4.597E+04     0.00000    1.000E+00
 30    1988    0.000E+00    0.000E+00       --    *           3.630E+04     0.00000    1.000E+00
 31    1989    0.000E+00    0.000E+00       --    *           3.316E+04     0.00000    1.000E+00
 32    1990    0.000E+00    0.000E+00       --    *           3.137E+04     0.00000    1.000E+00
 33    1991    1.000E+00    1.000E+00       --    3.755E+04    3.058E+04     0.20541    1.000E+00
 34    1992    1.000E+00    1.000E+00       --    3.145E+04    2.910E+04     0.07761    1.000E+00
 35    1993    1.000E+00    1.000E+00       --    2.940E+04    2.969E+04    -0.00980    1.000E+00
 36    1994    1.000E+00    1.000E+00       --    4.724E+04    3.634E+04     0.26221    1.000E+00
 37    1995    1.000E+00    1.000E+00       --    4.615E+04    4.502E+04     0.02472    1.000E+00
 38    1996    1.000E+00    1.000E+00       --    5.912E+04    5.443E+04     0.08270    1.000E+00
 39    1997    1.000E+00    1.000E+00       --    6.628E+04    6.323E+04     0.04714    1.000E+00
 40    1998    1.000E+00    1.000E+00       --    8.496E+04    7.085E+04     0.18155    1.000E+00
 41    1999    1.000E+00    1.000E+00       --    9.489E+04    7.665E+04     0.21346    1.000E+00
 42    2000    1.000E+00    1.000E+00       --    1.017E+05    8.092E+04     0.22826    1.000E+00
 43    2001    1.000E+00    1.000E+00       --    9.438E+04    8.466E+04     0.10872    1.000E+00
 44    2002    1.000E+00    1.000E+00       --    8.486E+04    8.745E+04    -0.03013    1.000E+00
 45    2003    1.000E+00    1.000E+00       --    5.731E+04    8.941E+04    -0.44479    1.000E+00
 46    2004    1.000E+00    1.000E+00       --    6.012E+04    9.098E+04    -0.41434    1.000E+00
 47    2005    1.000E+00    1.000E+00       --    6.678E+04    9.206E+04    -0.32101    1.000E+00
 48    2006    1.000E+00    1.000E+00       --    7.522E+04    9.294E+04    -0.21146    1.000E+00

* Asterisk indicates missing value(s).
```

```
3LN redfish                                                                                                     Page 9

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     0.2054                                             |========
1992     0.0776                                             |===
1993    -0.0098                                             |
1994     0.2622                                             |==========
1995     0.0247                                             |=
1996     0.0827                                             |===
1997     0.0471                                             |==
1998     0.1816                                             |=======
1999     0.2135                                             |=========
2000     0.2283                                             |=========
2001     0.1087                                             |====
2002    -0.0301                                            =|
2003    -0.4448                           ==================|
2004    -0.4143                            =================|
2005    -0.3210                                =============|
2006    -0.2115                                     ========|
                   ------------------------------------------------------------------------------------


                Observed (O) and Estimated (*) CPUE for Data Series # 3 -- 3LN autumn survey
           :
  120000. -:
           :
           :
           :
           :
  100000. -:                                                                                   O
           :                                                                                  O  O
           :                                                                                          * **
           :                                                                                       **
           :                                                                                O    * O
   80000. -:                                                                                   *
           :                                                                                  *          O
           :               *       *   *  *  *             ** * ** * **                     *
           :                 ** * *  *  *   *  *         *                                O             O
           :                                     *    **                *                 *
   60000. -:                                      * *                                    O            O
           :                                                                             *          O
           :
           :                                                                         O O
           :                                                              *            *
   40000. -:
           :                                                               *    O    *
           :                                                                 * ** O
           :                                                                      * 2
           :
   20000. -:
           :
           :
           :
           :
       0. -:
           :........................................................................................................
            :         :         :         :         :         :         :         :         :         :         :
         1950.     1956.     1962.     1968.     1974.     1980.     1986.     1992.     1998.     2004.     2010.
```

```
3LN redfish                                                                                                     Page 7

ESTIMATES FROM BOOTSTRAPPED ANALYSIS
------------------------------------------------------------------------------------------------------------------------
                       Estimated  Estimated      Bias-corrected approximate confidence limits         Inter-
Param          Point  bias in pt   relative    ------------------------------------------------     quartile   Relative
name        estimate    estimate       bias    80% lower    80% upper    50% lower    50% upper        range   IQ range

B1/K       8.645E-01    2.098E-02      2.43%    7.186E-01    1.212E+00    7.937E-01    1.046E+00    2.525E-01      0.292
K          2.651E+05    6.521E+03      2.46%    2.210E+05    3.211E+05    2.402E+05    2.901E+05    4.989E+04      0.188

q(1)       8.147E-06    4.873E-08      0.60%    6.881E-06    9.460E-06    7.393E-06    8.866E-06    1.473E-06      0.181
q(2)       1.833E-01    2.834E-03      1.55%    1.570E-01    2.086E-01    1.682E-01    1.954E-01    2.719E-02      0.148
q(3)       3.581E-01    4.921E-03      1.37%    3.035E-01    4.086E-01    3.272E-01    3.859E-01    5.874E-02      0.164

MSY        2.686E+04   -3.443E+01     -0.13%    2.445E+04    2.947E+04    2.563E+04    2.820E+04    2.574E+03      0.096
Ye(2007)   2.204E+03    8.463E+02     38.40%    9.308E+02    5.460E+03    1.365E+03    3.526E+03    2.160E+03      0.980
Y.@Fmsy    5.259E+04   -5.747E+02     -1.09%    4.584E+04    5.848E+04    4.940E+04    5.573E+04    6.328E+03      0.120

Bmsy       1.326E+05    3.261E+03      2.46%    1.105E+05    1.606E+05    1.201E+05    1.451E+05    2.495E+04      0.188
Fmsy       2.026E-01    1.487E-03      0.73%    1.535E-01    2.653E-01    1.777E-01    2.349E-01    5.717E-02      0.282

fmsy(1)    2.487E+04   -1.542E+02     -0.62%    2.104E+04    2.909E+04    2.304E+04    2.721E+04    4.169E+03      0.168
fmsy(2)    1.105E+00   -1.236E-02     -1.12%    9.015E-01    1.373E+00    1.015E+00    1.249E+00    2.338E-01      0.212
fmsy(3)    5.659E-01   -4.895E-03     -0.86%    4.520E-01    6.950E-01    5.091E-01    6.381E-01    1.291E-01      0.228

B./Bmsy    1.958E+00   -2.305E-02     -1.18%    1.882E+00    1.984E+00    1.929E+00    1.976E+00    4.691E-02      0.024
F./Fmsy    3.953E-03    9.814E-05      2.48%    3.547E-03    4.560E-03    3.726E-03    4.219E-03    4.935E-04      0.125
Ye./MSY    8.205E-02    3.877E-02     47.25%    3.149E-02    2.224E-01    4.839E-02    1.377E-01    8.933E-02      1.089

q2/q1      2.250E+04    3.551E+02      1.58%    1.982E+04    2.530E+04    2.102E+04    2.371E+04    2.694E+03      0.120
q3/q1      4.395E+04    6.224E+02      1.42%    3.831E+04    4.902E+04    4.080E+04    4.592E+04    5.117E+03      0.116


INFORMATION FOR REPAST (Prager, Porch, Shertzer, & Caddy. 2003. NAJFM 23: 349-361)
------------------------------------------------------------------------------------------------------------------------
Unitless limit reference point in F (Fmsy/F.):               253.0
CV of above (from bootstrap distribution):                  0.1040


NOTES ON BOOTSTRAPPED ESTIMATES:
------------------------------------------------------------------------------------------------------------------------
- Bootstrap results were computed from 1000 trials.
- Results are conditional on bounds set on MSY and K in the input file.
- All bootstrapped intervals are approximate. The statistical literature recommends using at least 1000 trials
  for accurate 95% intervals. The default 80% intervals used by ASPIC should require fewer trials for equivalent
  accuracy. Using at least 500 trials is recommended.
- Bias estimates are typically of high variance and therefore may be misleading.

Trials replaced for lack of convergence:       0           Trials replaced for MSY out of bounds:                 0
Trials replaced for q out-of-bounds:           0
Trials replaced for K out-of-bounds:           3           Residual-adjustment factor:                       1.0473
```

Appendix 3:

ASPICP control file

```
'Projection with 5000 Y'    ## Projection title
'aspic.bio'                 ## BIO file to read
'red3lnprj.txt'             ## Projection file to write
0                           ## Not used at present; set to 0d0
0                      ## Years to drop at start of plots
10                    ## Years of projections
500 Y                 ## Specification for projection year 1.
5000 Y                 ## Specification for projection year 2.
5000 Y                 ## Specification for projection year 3.
5000 Y                 ## Specification for projection year 4.
5000 Y                 ## Specification for projection year 5.
5000 Y                 ## Specification for projection year 6.
5000 Y                 ## Specification for projection year 7.
5000 Y                 ## Specification for projection year 8.
5000 Y                 ## Specification for projection year 9.
5000 Y                 ## Specification for projection year 10.
```

Note: the years of projection should have on each line:

1. A real number, the projected yield or effort.
   - If yield, it is in the same units as for the initial fit.
   - If effort, it is a unitless number: the multiple of the effort in the last year of the fit.
2. A character*1 indicator of whether the number is effort or yield.
   - This should be the capital letter 'Y' or 'F'.
3. Comments if desired may follow the letter, but must be delimited from it by at least one space.

Appendix 4: The trajectories of biomass (1959-2017) and fishing mortality rate (1959-2016).

```
Results from ASPICP.EXE, version 3.16                                                           23 Mar 2007 at 16:19.32
3LN redfish                                                                                                      Page 1
Projection with 5000 Y

USER CONTROL INFORMATION (FROM INPUT FILE)
----------------------------------------------------------------------------------------------------
Control (CTL) file read was:                                                              aspicp.ctl
Biomass (BIO) file read was:                                                               aspic.bio
Output file (this file) written was:                                                      aspicp.prj
Production-model type:                                                                      Logistic
Number of years of projections:                                                                   10
Type of confidence intervals:                                              Bias-corrected percentile
Confidence interval smoothing:                                                                    ON
Year          Input data          User data type
----          -----------         --------------
2007           5.000E+02           TAC
2008           5.000E+03           TAC
2009           5.000E+03           TAC
2010           5.000E+03           TAC
2011           5.000E+03           TAC
2012           5.000E+03           TAC
2013           5.000E+03           TAC
2014           5.000E+03           TAC
2015           5.000E+03           TAC
2016           5.000E+03           TAC

TRAJECTORY OF RELATIVE BIOMASS B/Bmsy (BOOTSTRAPPED)
-----------------------------------------------------------------------------------------------------------------------
                                                                                                      Inter-
             Point    Estimated    Relative   Approx 80%   Approx 80%   Approx 50%   Approx 50%     quartile   Relative
Year      estimate         bias        bias     lower CL     upper CL     lower CL     upper CL        range   IQ range
1959     1.729E+00    4.196E-02       2.43%    1.437E+00    2.424E+00    1.437E+00    2.424E+00    5.050E-01      0.292
1960     1.518E+00    1.209E-02       0.80%    1.283E+00    1.990E+00    1.283E+00    1.990E+00    3.704E-01      0.244
1961     1.471E+00   -7.899E-04      -0.05%    1.266E+00    1.825E+00    1.266E+00    1.825E+00    2.949E-01      0.201
1962     1.455E+00   -7.505E-03      -0.52%    1.266E+00    1.726E+00    1.266E+00    1.726E+00    2.429E-01      0.167
1963     1.454E+00   -1.115E-02      -0.77%    1.274E+00    1.655E+00    1.274E+00    1.655E+00    2.002E-01      0.138
1964     1.413E+00   -1.286E-02      -0.91%    1.255E+00    1.576E+00    1.255E+00    1.576E+00    1.683E-01      0.119
1965     1.496E+00   -1.413E-02      -0.94%    1.337E+00    1.631E+00    1.337E+00    1.631E+00    1.495E-01      0.100
1966     1.474E+00   -1.469E-02      -1.00%    1.328E+00    1.583E+00    1.328E+00    1.583E+00    1.315E-01      0.089
1967     1.500E+00   -1.492E-02      -0.99%    1.357E+00    1.596E+00    1.357E+00    1.596E+00    1.219E-01      0.081
1968     1.452E+00   -1.458E-02      -1.00%    1.322E+00    1.531E+00    1.322E+00    1.531E+00    1.037E-01      0.071
1969     1.477E+00   -1.426E-02      -0.97%    1.343E+00    1.551E+00    1.343E+00    1.551E+00    1.010E-01      0.068
1970     1.450E+00   -1.380E-02      -0.95%    1.320E+00    1.516E+00    1.320E+00    1.516E+00    9.332E-02      0.064
1971     1.498E+00   -1.365E-02      -0.91%    1.373E+00    1.571E+00    1.373E+00    1.571E+00    9.162E-02      0.061
1972     1.401E+00   -1.291E-02      -0.92%    1.291E+00    1.459E+00    1.291E+00    1.459E+00    7.616E-02      0.054
1973     1.356E+00   -1.194E-02      -0.88%    1.254E+00    1.413E+00    1.254E+00    1.413E+00    7.307E-02      0.054
1974     1.287E+00   -1.086E-02      -0.84%    1.192E+00    1.341E+00    1.192E+00    1.341E+00    6.904E-02      0.054
1975     1.304E+00   -1.021E-02      -0.78%    1.206E+00    1.372E+00    1.206E+00    1.372E+00    7.564E-02      0.058
1976     1.350E+00   -1.027E-02      -0.76%    1.248E+00    1.432E+00    1.248E+00    1.432E+00    8.891E-02      0.066
1977     1.371E+00   -1.079E-02      -0.79%    1.267E+00    1.464E+00    1.267E+00    1.464E+00    9.346E-02      0.068
1978     1.418E+00   -1.174E-02      -0.83%    1.300E+00    1.514E+00    1.300E+00    1.514E+00    1.009E-01      0.071
1979     1.487E+00   -1.320E-02      -0.89%    1.359E+00    1.587E+00    1.359E+00    1.587E+00    1.095E-01      0.074
1980     1.531E+00   -1.470E-02      -0.96%    1.402E+00    1.626E+00    1.402E+00    1.626E+00    1.104E-01      0.072
1981     1.553E+00   -1.576E-02      -1.01%    1.429E+00    1.641E+00    1.429E+00    1.641E+00    1.044E-01      0.067
1982     1.515E+00   -1.589E-02      -1.05%    1.405E+00    1.589E+00    1.405E+00    1.589E+00    8.995E-02      0.059
1983     1.503E+00   -1.552E-02      -1.03%    1.399E+00    1.571E+00    1.399E+00    1.571E+00    8.484E-02      0.056
1984     1.505E+00   -1.507E-02      -1.00%    1.404E+00    1.572E+00    1.404E+00    1.572E+00    8.285E-02      0.055
1985     1.541E+00   -1.485E-02      -0.96%    1.438E+00    1.612E+00    1.438E+00    1.612E+00    8.619E-02      0.056
1986     1.530E+00   -1.451E-02      -0.95%    1.433E+00    1.595E+00    1.433E+00    1.595E+00    8.016E-02      0.052
1987     1.369E+00   -1.303E-02      -0.95%    1.295E+00    1.412E+00    1.295E+00    1.412E+00    5.508E-02      0.040
1988     9.686E-01   -1.033E-02      -1.07%    9.535E-01    1.013E+00    9.535E-01    1.013E+00    3.080E-02      0.032
1989     7.647E-01   -9.009E-03      -1.18%    7.358E-01    8.200E-01    7.358E-01    8.200E-01    4.274E-02      0.056
1990     6.987E-01   -8.741E-03      -1.25%    6.646E-01    7.623E-01    6.646E-01    7.623E-01    4.971E-02      0.071
1991     6.609E-01   -8.755E-03      -1.32%    6.212E-01    7.300E-01    6.212E-01    7.300E-01    5.643E-02      0.085
1992     6.443E-01   -8.812E-03      -1.37%    5.977E-01    7.269E-01    5.977E-01    7.269E-01    6.331E-02      0.098
1993     6.131E-01   -8.852E-03      -1.44%    5.524E-01    7.074E-01    5.524E-01    7.074E-01    7.726E-02      0.126
1994     6.256E-01   -8.901E-03      -1.42%    5.550E-01    7.466E-01    5.550E-01    7.466E-01    1.013E-01      0.162
1995     7.657E-01   -8.919E-03      -1.16%    6.601E-01    9.271E-01    6.601E-01    9.271E-01    1.428E-01      0.186
1996     9.486E-01   -9.891E-03      -1.04%    7.945E-01    1.159E+00    7.945E-01    1.159E+00    1.805E-01      0.190
1997     1.147E+00   -1.373E-02      -1.20%    9.409E-01    1.384E+00    9.409E-01    1.384E+00    2.193E-01      0.191
1998     1.332E+00   -2.067E-02      -1.55%    1.101E+00    1.577E+00    1.101E+00    1.577E+00    2.405E-01      0.181
1999     1.493E+00   -2.873E-02      -1.92%    1.254E+00    1.723E+00    1.254E+00    1.723E+00    2.431E-01      0.163
2000     1.615E+00   -3.538E-02      -2.19%    1.378E+00    1.808E+00    1.378E+00    1.808E+00    2.202E-01      0.136
2001     1.705E+00   -3.914E-02      -2.30%    1.483E+00    1.859E+00    1.483E+00    1.859E+00    1.915E-01      0.112
2002     1.784E+00   -4.001E-02      -2.24%    1.582E+00    1.905E+00    1.582E+00    1.905E+00    1.593E-01      0.089
2003     1.843E+00   -3.852E-02      -2.09%    1.669E+00    1.934E+00    1.669E+00    1.934E+00    1.275E-01      0.069
2004     1.884E+00   -3.541E-02      -1.88%    1.736E+00    1.951E+00    1.736E+00    1.951E+00    1.034E-01      0.055
2005     1.917E+00   -3.144E-02      -1.64%    1.795E+00    1.966E+00    1.795E+00    1.966E+00    8.013E-02      0.042
2006     1.940E+00   -2.719E-02      -1.40%    1.842E+00    1.975E+00    1.842E+00    1.975E+00    6.151E-02      0.032
2007     1.958E+00   -2.305E-02      -1.18%    1.882E+00    1.984E+00    1.882E+00    1.984E+00    4.691E-02      0.024
2008     1.969E+00   -1.923E-02      -0.98%    1.907E+00    1.987E+00    1.907E+00    1.987E+00    3.483E-02      0.018
2009     1.948E+00   -1.566E-02      -0.80%    1.905E+00    1.957E+00    1.905E+00    1.957E+00    2.214E-02      0.011
2010     1.934E+00   -1.252E-02      -0.65%    1.902E+00    1.939E+00    1.902E+00    1.939E+00    1.493E-02      0.008
2011     1.924E+00   -9.938E-03      -0.52%    1.901E+00    1.929E+00    1.901E+00    1.929E+00    1.070E-02      0.006
2012     1.917E+00   -7.879E-03      -0.41%    1.899E+00    1.922E+00    1.899E+00    1.922E+00    9.109E-03      0.005
2013     1.913E+00   -6.268E-03      -0.33%    1.897E+00    1.918E+00    1.897E+00    1.918E+00    8.582E-03      0.004
2014     1.909E+00   -5.023E-03      -0.26%    1.896E+00    1.916E+00    1.896E+00    1.916E+00    8.299E-03      0.004
2015     1.907E+00   -4.065E-03      -0.21%    1.894E+00    1.914E+00    1.894E+00    1.914E+00    8.434E-03      0.004
2016     1.906E+00   -3.331E-03      -0.17%    1.893E+00    1.913E+00    1.893E+00    1.913E+00    8.576E-03      0.005
2017     1.905E+00   -2.769E-03      -0.15%    1.893E+00    1.912E+00    1.893E+00    1.912E+00    8.861E-03      0.005
NOTE: Confidence intervals are approximate.
At least 500 to 1000 trials are recommended when estimating confidence intervals.
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Results from ASPICP.EXE, version 3.16                                                          23 Mar 2007 at 16:19.32
3LN redfish                                                                                                     Page 2
Projection with 5000 Y

TRAJECTORY OF RELATIVE FISHING MORTALITY RATE F/Fmsy (BOOTSTRAPPED)
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                                                                                                      Inter-
             Point    Estimated    Relative   Approx 80%   Approx 80%   Approx 50%   Approx 50%     quartile   Relative
Year      estimate         bias        bias     lower CL     upper CL     lower CL     upper CL        range   IQ range

1959     1.028E+00    3.004E-02       2.92%    7.431E-01    1.291E+00    7.431E-01    1.291E+00    2.763E-01      0.269
1960     6.624E-01    2.046E-02       3.09%    5.086E-01    8.182E-01    5.086E-01    8.182E-01    1.556E-01      0.235
1961     5.899E-01    1.803E-02       3.06%    4.754E-01    7.233E-01    4.754E-01    7.233E-01    1.260E-01      0.214
1962     5.487E-01    1.629E-02       2.97%    4.570E-01    6.684E-01    4.570E-01    6.684E-01    1.081E-01      0.197
1963     7.112E-01    2.053E-02       2.89%    6.049E-01    8.647E-01    6.049E-01    8.647E-01    1.314E-01      0.185
1964     2.624E-01    7.331E-03       2.79%    2.256E-01    3.191E-01    2.256E-01    3.191E-01    4.575E-02      0.174
1965     5.887E-01    1.586E-02       2.69%    5.070E-01    7.073E-01    5.070E-01    7.073E-01    9.789E-02      0.166
1966     4.248E-01    1.108E-02       2.61%    3.667E-01    5.029E-01    3.667E-01    5.029E-01    6.734E-02      0.159
1967     6.864E-01    1.731E-02       2.52%    5.939E-01    8.095E-01    5.939E-01    8.095E-01    1.054E-01      0.154
1968     4.487E-01    1.099E-02       2.45%    3.874E-01    5.246E-01    3.874E-01    5.246E-01    6.672E-02      0.149
1969     6.298E-01    1.504E-02       2.39%    5.476E-01    7.418E-01    5.476E-01    7.418E-01    9.264E-02      0.147
1970     3.639E-01    8.536E-03       2.35%    3.163E-01    4.265E-01    3.163E-01    4.265E-01    5.348E-02      0.147
1971     8.846E-01    2.023E-02       2.29%    7.685E-01    1.034E+00    7.685E-01    1.034E+00    1.263E-01      0.143
1972     7.820E-01    1.735E-02       2.22%    6.807E-01    9.097E-01    6.807E-01    9.097E-01    1.093E-01      0.140
1973     9.393E-01    2.045E-02       2.18%    8.161E-01    1.090E+00    8.161E-01    1.090E+00    1.319E-01      0.140
1974     6.404E-01    1.396E-02       2.18%    5.547E-01    7.511E-01    5.547E-01    7.511E-01    9.340E-02      0.146
1975     5.011E-01    1.128E-02       2.25%    4.330E-01    5.960E-01    4.330E-01    5.960E-01    7.864E-02      0.157
1976     5.611E-01    1.312E-02       2.34%    4.816E-01    6.703E-01    4.816E-01    6.703E-01    9.196E-02      0.164
1977     4.407E-01    1.069E-02       2.43%    3.772E-01    5.290E-01    3.772E-01    5.290E-01    7.420E-02      0.168
1978     3.084E-01    7.765E-03       2.52%    2.634E-01    3.699E-01    2.634E-01    3.699E-01    5.252E-02      0.170
1979     3.467E-01    8.934E-03       2.58%    2.968E-01    4.152E-01    2.968E-01    4.152E-01    5.945E-02      0.171
1980     3.868E-01    9.988E-03       2.58%    3.319E-01    4.615E-01    3.319E-01    4.615E-01    6.417E-02      0.166
1981     5.896E-01    1.494E-02       2.53%    5.101E-01    6.990E-01    5.101E-01    6.990E-01    9.396E-02      0.159
1982     5.318E-01    1.311E-02       2.47%    4.629E-01    6.278E-01    4.629E-01    6.278E-01    8.201E-02      0.154
1983     4.888E-01    1.177E-02       2.41%    4.263E-01    5.753E-01    4.263E-01    5.753E-01    7.423E-02      0.152
1984     3.607E-01    8.527E-03       2.36%    3.143E-01    4.243E-01    3.143E-01    4.243E-01    5.480E-02      0.152
1985     4.985E-01    1.154E-02       2.31%    4.351E-01    5.855E-01    4.351E-01    5.855E-01    7.456E-02      0.150
1986     1.103E+00    2.431E-02       2.20%    9.700E-01    1.283E+00    9.700E-01    1.283E+00    1.547E-01      0.140
1987     2.559E+00    5.136E-02       2.01%    2.304E+00    2.894E+00    2.304E+00    2.894E+00    2.944E-01      0.115
1988     2.307E+00    4.480E-02       1.94%    2.130E+00    2.537E+00    2.130E+00    2.537E+00    2.011E-01      0.087
1989     1.715E+00    3.579E-02       2.09%    1.557E+00    1.855E+00    1.557E+00    1.855E+00    1.459E-01      0.085
1990     1.595E+00    3.702E-02       2.32%    1.417E+00    1.750E+00    1.417E+00    1.750E+00    1.662E-01      0.104
1991     1.473E+00    3.888E-02       2.64%    1.269E+00    1.644E+00    1.269E+00    1.644E+00    1.854E-01      0.126
1992     1.617E+00    5.063E-02       3.13%    1.344E+00    1.843E+00    1.344E+00    1.843E+00    2.550E-01      0.158
1993     1.281E+00    4.904E-02       3.83%    1.025E+00    1.513E+00    1.025E+00    1.513E+00    2.556E-01      0.200
1994     3.076E-01    1.379E-02       4.48%    2.385E-01    3.829E-01    2.385E-01    3.829E-01    7.203E-02      0.234
1995     8.645E-02    4.362E-03       5.05%    6.538E-02    1.117E-01    6.538E-02    1.117E-01    2.261E-02      0.262
1996     1.602E-02    8.898E-04       5.55%    1.209E-02    2.116E-02    1.209E-02    2.116E-02    4.416E-03      0.276
1997     1.890E-02    1.112E-03       5.89%    1.436E-02    2.492E-02    1.436E-02    2.492E-02    5.298E-03      0.280
1998     2.366E-02    1.411E-03       5.97%    1.833E-02    3.098E-02    1.833E-02    3.098E-02    6.235E-03      0.264
1999     5.545E-02    3.213E-03       5.79%    4.430E-02    7.189E-02    4.430E-02    7.189E-02    1.348E-02      0.243
2000     7.036E-02    3.823E-03       5.43%    5.789E-02    8.988E-02    5.789E-02    8.988E-02    1.552E-02      0.221
2001     3.074E-02    1.521E-03       4.95%    2.597E-02    3.847E-02    2.597E-02    3.847E-02    6.050E-03      0.197
2002     2.495E-02    1.098E-03       4.40%    2.149E-02    3.082E-02    2.149E-02    3.082E-02    4.444E-03      0.178
2003     2.664E-02    1.027E-03       3.85%    2.330E-02    3.209E-02    2.330E-02    3.209E-02    4.253E-03      0.160
2004     1.247E-02    4.168E-04       3.34%    1.103E-02    1.476E-02    1.103E-02    1.476E-02    1.820E-03      0.146
2005     1.272E-02    3.665E-04       2.88%    1.134E-02    1.485E-02    1.134E-02    1.485E-02    1.709E-03      0.134
2006     3.953E-03    9.814E-05       2.48%    3.547E-03    4.560E-03    3.547E-03    4.560E-03    4.935E-04      0.125
2007     9.479E-03    2.032E-04       2.14%    8.544E-03    1.081E-02    8.544E-03    1.081E-02    1.112E-03      0.117
2008     9.509E-02    1.765E-03       1.86%    8.603E-02    1.074E-01    8.603E-02    1.074E-01    1.057E-02      0.111
2009     9.594E-02    1.549E-03       1.61%    8.704E-02    1.076E-01    8.704E-02    1.076E-01    1.016E-02      0.106
2010     9.653E-02    1.373E-03       1.42%    8.767E-02    1.077E-01    8.767E-02    1.077E-01    9.951E-03      0.103
2011     9.694E-02    1.232E-03       1.27%    8.806E-02    1.078E-01    8.806E-02    1.078E-01    9.841E-03      0.102
2012     9.722E-02    1.123E-03       1.15%    8.830E-02    1.079E-01    8.830E-02    1.079E-01    9.791E-03      0.101
2013     9.742E-02    1.038E-03       1.07%    8.846E-02    1.079E-01    8.846E-02    1.079E-01    9.778E-03      0.100
2014     9.755E-02    9.722E-04       1.00%    8.855E-02    1.079E-01    8.855E-02    1.079E-01    9.784E-03      0.100
2015     9.765E-02    9.219E-04       0.94%    8.861E-02    1.080E-01    8.861E-02    1.080E-01    9.799E-03      0.100
2016     9.771E-02    8.833E-04       0.90%    8.865E-02    1.080E-01    8.865E-02    1.080E-01    9.816E-03      0.100

Note: no yield(s) were estimated in the projection.


NOTE: Confidence intervals are approximate.
At least 500 to 1000 trials are recommended when estimating confidence intervals.
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Results from ASPICP.EXE, version 3.16                                                          23 Mar 2007 at 16:19.32
3LN redfish                                                                                                     Page 3
Projection with 5000 Y

TRAJECTORY OF ABSOLUTE BIOMASS (BOOTSTRAPPED)
-----------------------------------------------------------------------------------------------------------------------
                                                                                                      Inter-
             Point    Estimated     Relative   Approx 80%   Approx 80%   Approx 50%   Approx 50%     quartile     Relative
Year      estimate         bias         bias     lower CL     upper CL     lower CL     upper CL        range     IQ range

1959     2.292E+05    9.289E+03       4.05%    1.748E+05    3.014E+05    1.748E+05    3.014E+05    6.609E+04      0.288
1960     2.012E+05    5.517E+03       2.74%    1.561E+05    2.637E+05    1.561E+05    2.637E+05    5.545E+04      0.276
1961     1.950E+05    3.755E+03       1.93%    1.562E+05    2.512E+05    1.562E+05    2.512E+05    5.018E+04      0.257
1962     1.929E+05    2.770E+03       1.44%    1.588E+05    2.438E+05    1.588E+05    2.438E+05    4.603E+04      0.239
1963     1.928E+05    2.192E+03       1.14%    1.626E+05    2.413E+05    1.626E+05    2.413E+05    4.311E+04      0.224
1964     1.872E+05    1.849E+03       0.99%    1.595E+05    2.310E+05    1.595E+05    2.310E+05    3.954E+04      0.211
1965     1.982E+05    1.637E+03       0.83%    1.721E+05    2.396E+05    1.721E+05    2.396E+05    3.650E+04      0.184
1966     1.953E+05    1.533E+03       0.78%    1.711E+05    2.352E+05    1.711E+05    2.352E+05    3.502E+04      0.179
1967     1.988E+05    1.496E+03       0.75%    1.753E+05    2.370E+05    1.753E+05    2.370E+05    3.339E+04      0.168
1968     1.925E+05    1.502E+03       0.78%    1.694E+05    2.275E+05    1.694E+05    2.275E+05    3.188E+04      0.166
1969     1.958E+05    1.521E+03       0.78%    1.725E+05    2.292E+05    1.725E+05    2.292E+05    3.055E+04      0.156
1970     1.922E+05    1.549E+03       0.81%    1.688E+05    2.240E+05    1.688E+05    2.240E+05    2.986E+04      0.155
1971     1.986E+05    1.575E+03       0.79%    1.760E+05    2.299E+05    1.760E+05    2.299E+05    2.976E+04      0.150
1972     1.857E+05    1.611E+03       0.87%    1.635E+05    2.166E+05    1.635E+05    2.166E+05    2.896E+04      0.156
1973     1.798E+05    1.628E+03       0.91%    1.587E+05    2.098E+05    1.587E+05    2.098E+05    2.753E+04      0.153
1974     1.706E+05    1.615E+03       0.95%    1.506E+05    1.991E+05    1.506E+05    1.991E+05    2.622E+04      0.154
1975     1.728E+05    1.563E+03       0.90%    1.543E+05    2.001E+05    1.543E+05    2.001E+05    2.487E+04      0.144
1976     1.789E+05    1.472E+03       0.82%    1.610E+05    2.054E+05    1.610E+05    2.054E+05    2.393E+04      0.134
1977     1.818E+05    1.358E+03       0.75%    1.641E+05    2.072E+05    1.641E+05    2.072E+05    2.327E+04      0.128
1978     1.879E+05    1.238E+03       0.66%    1.699E+05    2.128E+05    1.699E+05    2.128E+05    2.308E+04      0.123
1979     1.972E+05    1.127E+03       0.57%    1.783E+05    2.223E+05    1.783E+05    2.223E+05    2.351E+04      0.119
1980     2.030E+05    1.061E+03       0.52%    1.822E+05    2.283E+05    1.822E+05    2.283E+05    2.398E+04      0.118
1981     2.059E+05    1.067E+03       0.52%    1.833E+05    2.321E+05    1.833E+05    2.321E+05    2.506E+04      0.122
1982     2.008E+05    1.138E+03       0.57%    1.774E+05    2.283E+05    1.774E+05    2.283E+05    2.586E+04      0.129
1983     1.992E+05    1.233E+03       0.62%    1.754E+05    2.269E+05    1.754E+05    2.269E+05    2.665E+04      0.134
1984     1.995E+05    1.329E+03       0.67%    1.753E+05    2.270E+05    1.753E+05    2.270E+05    2.699E+04      0.135
1985     2.042E+05    1.422E+03       0.70%    1.790E+05    2.319E+05    1.790E+05    2.319E+05    2.776E+04      0.136
1986     2.028E+05    1.525E+03       0.75%    1.769E+05    2.311E+05    1.769E+05    2.311E+05    2.795E+04      0.138
1987     1.815E+05    1.629E+03       0.90%    1.562E+05    2.096E+05    1.562E+05    2.096E+05    2.775E+04      0.153
1988     1.284E+05    1.643E+03       1.28%    1.063E+05    1.550E+05    1.063E+05    1.550E+05    2.543E+04      0.198
1989     1.014E+05    1.510E+03       1.49%    8.155E+04    1.263E+05    8.155E+04    1.263E+05    2.346E+04      0.231
1990     9.262E+04    1.308E+03       1.41%    7.545E+04    1.160E+05    7.545E+04    1.160E+05    2.257E+04      0.244
1991     8.760E+04    1.080E+03       1.23%    7.173E+04    1.097E+05    7.173E+04    1.097E+05    2.158E+04      0.246
1992     8.540E+04    8.388E+02       0.98%    7.078E+04    1.066E+05    7.078E+04    1.066E+05    2.023E+04      0.237
1993     8.126E+04    5.773E+02       0.71%    6.733E+04    1.022E+05    6.733E+04    1.022E+05    1.877E+04      0.231
1994     8.292E+04    2.908E+02       0.35%    6.894E+04    1.029E+05    6.894E+04    1.029E+05    1.860E+04      0.224
1995     1.015E+05   -2.828E+01      -0.03%    8.602E+04    1.197E+05    8.602E+04    1.197E+05    1.793E+04      0.177
1996     1.257E+05   -4.754E+02      -0.38%    1.110E+05    1.448E+05    1.110E+05    1.448E+05    1.741E+04      0.138
1997     1.520E+05   -1.163E+03      -0.77%    1.384E+05    1.717E+05    1.384E+05    1.717E+05    1.700E+04      0.112
1998     1.766E+05   -2.017E+03      -1.14%    1.639E+05    1.975E+05    1.639E+05    1.975E+05    1.650E+04      0.093
1999     1.979E+05   -2.772E+03      -1.40%    1.868E+05    2.201E+05    1.868E+05    2.201E+05    1.752E+04      0.089
2000     2.141E+05   -3.167E+03      -1.48%    2.021E+05    2.366E+05    2.021E+05    2.366E+05    1.855E+04      0.087
2001     2.260E+05   -3.102E+03      -1.37%    2.111E+05    2.483E+05    2.111E+05    2.483E+05    2.013E+04      0.089
2002     2.364E+05   -2.629E+03      -1.11%    2.166E+05    2.596E+05    2.166E+05    2.596E+05    2.386E+04      0.101
2003     2.442E+05   -1.857E+03      -0.76%    2.191E+05    2.704E+05    2.191E+05    2.704E+05    2.791E+04      0.114
2004     2.497E+05   -9.172E+02      -0.37%    2.177E+05    2.787E+05    2.177E+05    2.787E+05    3.204E+04      0.128
2005     2.541E+05    7.686E+01       0.03%    2.181E+05    2.876E+05    2.181E+05    2.876E+05    3.625E+04      0.143
2006     2.571E+05    1.045E+03       0.41%    2.188E+05    2.957E+05    2.188E+05    2.957E+05    3.985E+04      0.155
2007     2.596E+05    1.938E+03       0.75%    2.193E+05    3.007E+05    2.193E+05    3.007E+05    4.255E+04      0.164
2008     2.610E+05    2.732E+03       1.05%    2.194E+05    3.052E+05    2.194E+05    3.052E+05    4.421E+04      0.169
2009     2.582E+05    3.408E+03       1.32%    2.162E+05    3.042E+05    2.162E+05    3.042E+05    4.521E+04      0.175
2010     2.563E+05    3.958E+03       1.54%    2.142E+05    3.038E+05    2.142E+05    3.038E+05    4.569E+04      0.178
2011     2.550E+05    4.393E+03       1.72%    2.130E+05    3.043E+05    2.130E+05    3.043E+05    4.588E+04      0.180
2012     2.541E+05    4.733E+03       1.86%    2.122E+05    3.047E+05    2.122E+05    3.047E+05    4.585E+04      0.180
2013     2.535E+05    4.996E+03       1.97%    2.118E+05    3.044E+05    2.118E+05    3.044E+05    4.601E+04      0.181
2014     2.531E+05    5.200E+03       2.05%    2.115E+05    3.041E+05    2.115E+05    3.041E+05    4.613E+04      0.182
2015     2.528E+05    5.357E+03       2.12%    2.113E+05    3.040E+05    2.113E+05    3.040E+05    4.620E+04      0.183
2016     2.526E+05    5.478E+03       2.17%    2.112E+05    3.040E+05    2.112E+05    3.040E+05    4.623E+04      0.183
2017     2.525E+05    5.572E+03       2.21%    2.112E+05    3.041E+05    2.112E+05    3.041E+05    4.623E+04      0.183

NOTE: Confidence intervals are approximate.
At least 500 to 1000 trials are recommended when estimating confidence intervals.
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Results from ASPICP.EXE, version 3.16                                                          23 Mar 2007 at 16:19.32
3LN redfish                                                                                                      Page 4
Projection with 5000 Y

TRAJECTORY OF ABSOLUTE FISHING MORTALITY RATE (BOOTSTRAPPED)
-----------------------------------------------------------------------------------------------------------------------
                                                                                                      Inter-
             Point    Estimated    Relative   Approx 80%   Approx 80%   Approx 50%   Approx 50%     quartile   Relative
Year      estimate         bias        bias     lower CL     upper CL     lower CL     upper CL        range   IQ range

1959     2.082E-01    2.398E-03       1.15%    1.586E-01    2.708E-01    1.586E-01    2.708E-01    5.929E-02      0.285
1960     1.342E-01    2.011E-03       1.50%    1.031E-01    1.703E-01    1.031E-01    1.703E-01    3.416E-02      0.254
1961     1.195E-01    1.721E-03       1.44%    9.426E-02    1.474E-01    9.426E-02    1.474E-01    2.858E-02      0.239
1962     1.112E-01    1.429E-03       1.28%    8.927E-02    1.331E-01    8.927E-02    1.331E-01    2.470E-02      0.222
1963     1.441E-01    1.683E-03       1.17%    1.159E-01    1.700E-01    1.159E-01    1.700E-01    2.993E-02      0.208
1964     5.318E-02    5.121E-04       0.96%    4.335E-02    6.173E-02    4.335E-02    6.173E-02    1.011E-02      0.190
1965     1.193E-01    9.592E-04       0.80%    9.878E-02    1.369E-01    9.878E-02    1.369E-01    2.084E-02      0.175
1966     8.609E-02    6.040E-04       0.70%    7.160E-02    9.761E-02    7.160E-02    9.761E-02    1.447E-02      0.168
1967     1.391E-01    8.846E-04       0.64%    1.163E-01    1.578E-01    1.163E-01    1.578E-01    2.241E-02      0.161
1968     9.092E-02    5.061E-04       0.56%    7.750E-02    1.034E-01    7.750E-02    1.034E-01    1.421E-02      0.156
1969     1.276E-01    6.236E-04       0.49%    1.093E-01    1.452E-01    1.093E-01    1.452E-01    1.943E-02      0.152
1970     7.375E-02    3.042E-04       0.41%    6.342E-02    8.338E-02    6.342E-02    8.338E-02    1.097E-02      0.149
1971     1.793E-01    7.174E-04       0.40%    1.542E-01    2.031E-01    1.542E-01    2.031E-01    2.711E-02      0.151
1972     1.585E-01    6.105E-04       0.39%    1.359E-01    1.798E-01    1.359E-01    1.798E-01    2.420E-02      0.153
1973     1.903E-01    6.564E-04       0.34%    1.631E-01    2.157E-01    1.631E-01    2.157E-01    2.873E-02      0.151
1974     1.298E-01    3.367E-04       0.26%    1.116E-01    1.461E-01    1.116E-01    1.461E-01    1.905E-02      0.147
1975     1.016E-01    1.732E-04       0.17%    8.806E-02    1.132E-01    8.806E-02    1.132E-01    1.385E-02      0.136
1976     1.137E-01    1.687E-04       0.15%    9.960E-02    1.261E-01    9.960E-02    1.261E-01    1.469E-02      0.129
1977     8.930E-02    1.460E-04       0.16%    7.857E-02    9.874E-02    7.857E-02    9.874E-02    1.093E-02      0.122
1978     6.249E-02    1.244E-04       0.20%    5.529E-02    6.901E-02    5.529E-02    6.901E-02    7.477E-03      0.120
1979     7.026E-02    1.848E-04       0.26%    6.241E-02    7.793E-02    6.241E-02    7.793E-02    8.320E-03      0.118
1980     7.839E-02    2.603E-04       0.33%    6.957E-02    8.771E-02    6.957E-02    8.771E-02    9.450E-03      0.121
1981     1.195E-01    4.728E-04       0.40%    1.054E-01    1.347E-01    1.054E-01    1.347E-01    1.508E-02      0.126
1982     1.078E-01    4.474E-04       0.42%    9.473E-02    1.222E-01    9.473E-02    1.222E-01    1.419E-02      0.132
1983     9.906E-02    3.912E-04       0.39%    8.693E-02    1.126E-01    8.693E-02    1.126E-01    1.329E-02      0.134
1984     7.309E-02    2.594E-04       0.35%    6.427E-02    8.318E-02    6.427E-02    8.318E-02    9.945E-03      0.136
1985     1.010E-01    3.407E-04       0.34%    8.873E-02    1.155E-01    8.873E-02    1.155E-01    1.395E-02      0.138
1986     2.236E-01    8.619E-04       0.39%    1.948E-01    2.591E-01    1.948E-01    2.591E-01    3.318E-02      0.148
1987     5.186E-01    3.546E-03       0.68%    4.389E-01    6.149E-01    4.389E-01    6.149E-01    9.293E-02      0.179
1988     4.674E-01    5.689E-03       1.22%    3.814E-01    5.734E-01    3.814E-01    5.734E-01    1.014E-01      0.217
1989     3.476E-01    5.496E-03       1.58%    2.782E-01    4.300E-01    2.782E-01    4.300E-01    8.288E-02      0.238
1990     3.233E-01    5.524E-03       1.71%    2.583E-01    3.949E-01    2.583E-01    3.949E-01    7.831E-02      0.242
1991     2.985E-01    5.243E-03       1.76%    2.393E-01    3.627E-01    2.393E-01    3.627E-01    7.151E-02      0.240
1992     3.276E-01    6.234E-03       1.90%    2.615E-01    3.945E-01    2.615E-01    3.945E-01    7.483E-02      0.228
1993     2.595E-01    5.432E-03       2.09%    2.083E-01    3.116E-01    2.083E-01    3.116E-01    5.804E-02      0.224
1994     6.232E-02    1.167E-03       1.87%    5.122E-02    7.357E-02    5.122E-02    7.357E-02    1.203E-02      0.193
1995     1.752E-02    2.696E-04       1.54%    1.502E-02    2.026E-02    1.502E-02    2.026E-02    2.661E-03      0.152
1996     3.246E-03    4.812E-05       1.48%    2.848E-03    3.605E-03    2.848E-03    3.605E-03    3.838E-04      0.118
1997     3.830E-03    6.158E-05       1.61%    3.412E-03    4.169E-03    3.412E-03    4.169E-03    3.735E-04      0.098
1998     4.794E-03    8.492E-05       1.77%    4.299E-03    5.098E-03    4.299E-03    5.098E-03    4.188E-04      0.087
1999     1.124E-02    2.109E-04       1.88%    1.012E-02    1.189E-02    1.012E-02    1.189E-02    9.439E-04      0.084
2000     1.426E-02    2.689E-04       1.89%    1.295E-02    1.519E-02    1.295E-02    1.519E-02    1.212E-03      0.085
2001     6.229E-03    1.116E-04       1.79%    5.684E-03    6.735E-03    5.684E-03    6.735E-03    5.804E-04      0.093
2002     5.055E-03    8.197E-05       1.62%    4.579E-03    5.563E-03    4.579E-03    5.563E-03    5.310E-04      0.105
2003     5.398E-03    7.652E-05       1.42%    4.861E-03    6.103E-03    4.861E-03    6.103E-03    6.745E-04      0.125
2004     2.527E-03    3.033E-05       1.20%    2.250E-03    2.920E-03    2.250E-03    2.920E-03    3.510E-04      0.139
2005     2.577E-03    2.548E-05       0.99%    2.264E-03    3.017E-03    2.264E-03    3.017E-03    3.875E-04      0.150
2006     8.011E-04    6.359E-06       0.79%    6.938E-04    9.452E-04    6.938E-04    9.452E-04    1.290E-04      0.161
2007     1.921E-03    1.196E-05       0.62%    1.648E-03    2.278E-03    1.648E-03    2.278E-03    3.236E-04      0.168
2008     1.927E-02    9.380E-05       0.49%    1.641E-02    2.297E-02    1.641E-02    2.297E-02    3.371E-03      0.175
2009     1.944E-02    7.104E-05       0.37%    1.645E-02    2.325E-02    1.645E-02    2.325E-02    3.491E-03      0.180
2010     1.956E-02    4.923E-05       0.25%    1.645E-02    2.341E-02    1.645E-02    2.341E-02    3.552E-03      0.182
2011     1.964E-02    3.032E-05       0.15%    1.643E-02    2.352E-02    1.643E-02    2.352E-02    3.587E-03      0.183
2012     1.970E-02    1.476E-05       0.07%    1.642E-02    2.358E-02    1.642E-02    2.358E-02    3.610E-03      0.183
2013     1.974E-02    2.367E-06       0.01%    1.643E-02    2.363E-02    1.643E-02    2.363E-02    3.634E-03      0.184
2014     1.977E-02   -7.309E-06      -0.04%    1.645E-02    2.365E-02    1.645E-02    2.365E-02    3.648E-03      0.185
2015     1.979E-02   -1.477E-05      -0.07%    1.645E-02    2.367E-02    1.645E-02    2.367E-02    3.657E-03      0.185
2016     1.980E-02   -2.047E-05      -0.10%    1.645E-02    2.368E-02    1.645E-02    2.368E-02    3.661E-03      0.185

NOTE: Confidence intervals are approximate.
At least 500 to 1000 trials are recommended when estimating confidence intervals.
```

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Results from ASPICP.EXE, version 3.16                                                          23 Mar 2007 at 16:19.32
3LN redfish                                                                                                      Page 5
Projection with 5000 Y

                   Time Plot of B/Bmsy (#) with Bias-Corrected (BC) 80% Confidence Interval (^v)
                   (Dashed reference line is 1.0)

           :
           :
           :
           :
     2.75 -:
           :
           :
           :
           :
     2.50 -:
           :
           :                   v
           :
           :
     2.25 -:
           :
           :
           :
           :
     2.00 -:                    v                                                        v vv
           :                                                                          vvv# ##22 v
           :                                                                        v  ##  ^^^^ 2333 333
           :                                                                       v  #  ^
           :                     v                                                v #   ^
     1.75 -:                   #  v                                                    ^
           :                                                                     v #
           :                        v v                  vv                           ^
           :                         v v v              v  v   vv              v  # ^
           :                              vv  v          ##  vv##
     1.50 -:                    #     #  # #v #       v #  # ##                  # ^
           :                   ^ ## #  #  # #  v    vv    ^    ^^
           :                         #         #v     #  ^ ^ ^^   v           v   ^
           :                          ^^ ^ ^  ^ #v v##  ^         #            #
           :                    ^         ^ ^  ^ # #  ^           ^
     1.25 -:                     ^^ ^^          ^   ^^                           ^
           :                                     ^ ^
           :                                                                 v#
           :                                                                   ^
           :
     1.00 -:       - ---- ---- ---- ---- ---- ---- ---- ---- ---- -2-- ---- ---- ---- ---- ---- ---- ---- --
           :                                                       2        v#^
           :
           :
           :                                                        v        ^
     0.75 -:                                                        2v vv v #
           :                                                         #   v
           :                                                         ^ ## # ^
           :                                                           ^^#
           :                                                             ^^
     0.50 -:
           :
           :
           :
           :
     0.25 -:
           :
           :
           :
           :
     0.00 -:
           :.........................................................................................................
            :         :         :         :         :         :         :         :         :         :         :
         1944.     1952.     1960.     1968.     1976.     1984.     1992.     2000.     2008.     2016.     2024.

         NOTE: Estimates beginning in 2008 depend on the user projection data listed on page 1.
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Results from ASPICP.EXE, version 3.16                                                          23 Mar 2007 at 16:19.32
3LN redfish                                                                                                      Page 6
Projection with 5000 Y


                   Time Plot of F/Fmsy (#) with 80% Bias-Corrected (BC) Confidence Interval (^v)
                   (Dashed reference line is 1.0)

           :
           :
           :
           :
      3.3 -:
           :
           :
           :
           :
      3.0 -:
           :
           :                                                      v
           :
           :
      2.7 -:
           :
           :                                                      #
           :                                                       v
           :
      2.4 -:
           :
           :                                                      ^#
           :
           :
      2.1 -:                                                       ^
           :
           :
           :
           :                                                        v   v
      1.8 -:
           :                                                        #v
           :
           :                                                         # v#
           :                                                        ^
      1.5 -:                                                           # v
           :                                                         ^
           :
           :                   v                                        ^
           :                                                    v      ^ #
      1.2 -:
           :
           :                                    v               #
           :       - ---- ---- 2--- ---- ---- 2--- ---- ---- ---- ---- --2- ---- ---- ---- ---- ---- ---- --
           :                                    #               ^
      0.9 -:                                  #v

           :                    v   v           ^
           :                             v    ^# v
           :                   ^ v  # v    v              v
           :                    # v      #     ^ #  v
      0.6 -:                     #  ^ #  ^ #       v      #v v v
           :                      #       v^     ^  #v    ^#
           :                    ^^^   ^v           #^    v ^ # #
           :                           #  # v      ^ #  v    ^v^
           :                           ^  ^ #        ^v #2    #           v
      0.3 -:                         v      ^         # ^     ^           #
           :                         2                ^                   ^
           :
           :                                                                v               222 2222 22
           :                                                                2  v 332v v     ^^^ ^^^^ ^^
      0.0 -:                                                                 332   ^2 2333 3
           :.........................................................................................................
            :         :         :         :         :         :         :         :         :         :         :
         1944.     1952.     1960.     1968.     1976.     1984.     1992.     2000.     2008.     2016.     2024.

         NOTE: Estimates beginning in 2007 depend on the user projection data listed on page 1.
```