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Collection of Working Papers for the Scientific Council Precautionary Approach Workshop of 2003

by

Designated Experts

The following information presented by Designated Experts is a collection of Working Papers presented at the September 2002 Scientific Council Meeting.

The papers are compiled herein (alphabetically by author – see list below) to preserve the record of the available material, in preparation for the 2003 Scientific Council Precautionary Approach Workshop. An Introductory paper describes the proposed Workshop goals and objectives.

Author(s) and Title

Proposed Second Scientific Council Workshop on the Precautionary Approach to Fisheries Management, 2003: proposed goals and objectives.

ALPOIM, R. Background on reference points for Division 3M American Plaice.

ÁVILA DE MELO, A.. Available data for a PA framework for 3M redfish.

BOWERING, W. R. Data time series available for potential use in developing biological reference points for Greenland halibut in SA2+Div. 3KLMNO.

BRODIE, W. B. Indices of abundance available for yellowtail flounder in Divisions 3LNO.

HEALEY, B. P., and D. E. STANSBURY. Continuing the implementation of the Precautionary Approach Framework in assessing NAFO Divisions 3NO Cod.

MORGAN, M. J. Background on reference points for Divisions 3LNO American Plaice.

ORR, D. Precautionary Approach for Scientific Council September 2002.

VAZQUEZ, A. Available data for a PA framework for the cod stock in Division 3M.

Proposed Second Scientific Council Workshop on the Precautionary Approach to Fisheries Management, 2003: Proposed Goals and Objectives

Background

Since 1997, Scientific Council has dedicated considerable resources towards the development of a framework for implementing the Precautionary Approach. A proposed general framework was developed in 1997 (Serchuk *et al.*, 1997) to include limit and buffer reference points for fishing mortality and biomass. A Scientific Council Workshop on the Precautionary Approach to Fisheries Management was held in March 1998 (NAFO, 1998a) with the following Terms of Reference:

- Describe procedures for determining limit and target PA reference points,
- Determine limit and target PA reference points for all stocks under the responsibility of the NAFO Fisheries Commission,
- Specify decision rules (courses of action) to achieve target reference points and avoid limit reference points,
- Develop re-opening criteria,
- Identify data collection and monitoring activities required to evaluate resource status with respect to reference points,
- Define research requirements to improve quantification and evaluation of uncertainty, and
- Indicate time frames and funding is required to implement the precautionary approach.

Some of these objectives were achieved at the Workshop for some stocks, but for many stocks, considerable work remained. For most stocks, data requirements were identified, and one or more analytical methods were applied to determine reference points. Detailed analyses were developed for American plaice in Div. 3LNO as a case study. Other stocks including Greenland halibut in SA 2 and Div. 3KLMNO, Shrimp in Div. 3M, redfish in Div. 3M, and Northern shortfin squid in SA 3&4 were analyzed using one or more models appropriate to the available data.

The report of the Workshop was presented in May 1998 to the initial meeting of the Joint Fisheries Commission/Scientific Council Working Group on the Precautionary Approach. The Working Group thanked the Scientific Council for their work and then discussed the issue of the roles of scientists and managers with respect to implementation of the Precautionary Approach. The Joint Working Group (NAFO, 1998b) defined the role of scientists as:

- Determine status of stocks.
- Classify stock status with respect to biomass/fishing mortality zones,
- Calculate limit reference points and security margins (buffers),
- Describe and characterize uncertainty, and
- Conduct risk assessments

The roles of managers were defined as:

- Specify management objectives, select target reference points, and set limit reference points,
- Specify management strategies (courses of action) for biomass/fishing mortality zones,
- Specify time horizons for stock rebuilding and for fishing mortality adjustments, and
- Specify acceptable levels of risk.

The Scientific Council held another meeting (NAFO, 1999a) in advance of the second meeting of the Joint Fisheries Commission/Scientific Council Working Group on the Precautionary Approach that convened in May 1999. At its 1999 meeting, the Scientific Council focused on three stocks for further development of the PA methodology and estimation of reference points: cod in Div. 3NO (closed fishery), yellowtail flounder in Div. 3LNO (Open fishery), and shrimp in Div. 3M (data limited fishery. Reference points derived for these stocks were as follows: B_{lim}, B_{msy} and MSY for 3NO cod and F_{lim} (F_{msy}) and F_{buf} for 3LNO yellowtail flounder. The Traffic Light approach (Caddy 1998) was applied to 3M shrimp but the results were treated in a qualitative manner.

At the May 1999 Joint Working Group meeting (NAFO, 1999b), the analyses for the three stocks were reviewed and a set of management strategies was developed for each stock. The Working Group recommended that the Fisheries Commission and the Scientific Council consider these strategies in designing and formulating further action in implementing the precautionary approach in 2000 and beyond. It was also recommended that similar actions be taken for other stocks with related characteristics that are under the NAFO purview.

A third meeting of the Joint Working Group was held in 2000 (NAFO, 2000). This meeting focused on operationalizing the precautionary approach into management plans for the three stocks evaluated in 1999, but the Working Group also developed an implementation plan for American plaice in Div. 3LNO based on a template for 3NO cod. The implementation plans were defined as next steps and included detailed management objectives and strategies, data collection procedures and supportive management measures/good practices.

At its June 2001 meeting (NAFO, 2001), the Scientific Council developed an estimate of Blim for American plaice in Div. 3LNO, and in June 2002 (NAFO, 2002a), an estimate of Blim for American plaice in Div. 3M. For most other stocks there has been little progress with respect to the original terms of reference of the 1998 Scientific Council Workshop. .

In 2002, the Fisheries Commission charged a Working Group of Technical Experts to meet to develop recommendations for future work of the Joint FC/SC Working Group. This meeting occurred in June 2002 (NAFO, 2002b) and the Working Group agreed that the specific issues and the general question of implementation of the Precautionary Approach would benefit NAFO by addressing specific cases and problems.

The Way Forward

To regain the momentum of the 1997-1999 period, it is proposed that Scientific Council convene a second workshop on the precautionary approach, with a focus on those stocks, which may be categorized as data limited. Because fisheries are closed for many stocks assessed by the Scientific Council, survey-based approaches for defining proxies for biomass and fishing mortality are essential. Such approaches may best be applied to the following stocks:

1. Stocks under the Purview of the NAFO Fisheries Commission
   - Cod in Div. 3M
   - Redfish in Div. 3LN
   - American plaice in Div. 3M
   - Witch flounder in Div. 3NO
   - Witch flounder in Div. 2J3KL

2. Other Stocks
   - Roundnose Grenadier in SA 0&1
   - Roundnose Grenadier in SA 2&3
   - Redfish in SA 1
   - Other Finfish in SA 1

Several other stocks support ongoing fisheries but may be categorized as data moderate. These include:

1. Stocks under the Purview of the NAFO Fisheries Commission
   - Redfish in Div. 3M
   - Northern shortfin squid in SA 3&4
   - Shrimp in Div. 3M
   - Shrimp in Div. 3LNO

2. Other Stocks
   - Greenland halibut in SA 0&1
   - Shrimp in SA 0&1
   - Shrimp in Denmark Strait

For the remaining stocks, there appears to be sufficient data available to conduct quantitative analyses on an age disaggregated basis or through age aggregated production models.

These include:

- Greenland halibut in SA 2 and Div. 3LKMNO
- American plaice in Div. 3LNO
- Cod in Div. 3NO
- Yellowtail flounder in Div. 3LNO

It is proposed, therefore, that the second Workshop address all stocks evaluated by the Scientific Council. The basis for reference points that have already been identified by Scientific Council should also be reviewed.

Possible Terms of Reference for the Workshop are:

- Review the basis for existing PA reference points.
- Determine appropriate methodology to calculate reference points for data-limited stocks.
- Develop PA reference points from available data for all remaining stocks for which sufficient data exist.

The Joint Working Group and the Working Group of Technical Experts have identified several managerial areas of concern with the specification of the PA framework originally proposed by the Scientific Council. In particular, the WG questioned the requirement for a linear reduction in F between B_{target} and B_{lim}, and a fishery closure when F is below B_{lim}. Therefore, an additional term of reference is proposed for the Scientific Council Workshop:

- Re-examine the PA framework as described in Serchuk *et al.* (1997), and develop more precise definitions of terms and concepts consistent with the role of scientists and managers as agreed in NAFO (1998b).

A small Study Group working by correspondence in advance of the proposed Scientific Council Workshop may address this last term of reference.

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NAFO. 1998b. Report of the Working Group on Precautionary Approach, 12-13 May 1998. NAFO FC Doc., No. 2, Serial No. N3067.

NAFO. 1999a. Scientific Council Reports, Part A. Scientific Council Meeting on Precautionary Approach, 27 April-1 May 1999. p. 5-26.

NAFO. 1999b. Report of the Working Group on Precautionary Approach, 3-5 May 1999. NAFO FC Doc., No. 2, Serial No. N4051.

NAFO. 2000. Report of the Joint Scientific Council and Fisheries Commission Working Group on Precautionary Approach, 29 February-2 March 2000. NAFO FC Doc., NO. 2, Serial No. N4207.

NAFO. 2001. Scientific Council Reports, Part A. Report of Scientific Council Meeting 31 May-14 June 2001. p. 5-198.

NAFO. 2002a. Scientific Council Meeting June 2002. NAFO SCS Doc., No. 19, Serial No. N4698.

NAFO. 2002b. Report of the Working Group of Technical Experts on the Precautionary Approach (PA), 20-21 June 2002. NAFO FC Doc., No. 12, Serial No. N4704.

Serchuk, F. M., D. Rivard, J. Casey, and R. Mayo. 1997. Report of the Ad hoc Working Group of the NAFO Scientific Council on the Precautionary Approach. NAFO SCS Doc., No. 12, Serial No. N 2911.

Background on Reference Points for Division 3M American Plaice

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History

A XSA was accepted by the Scientific Council in the last assessment presented during the 2002 June meeting (Anon. 2002).

Reference points have been identified for this stock. No medium term projections were presented.

The next full assessment will be conducted on Div. 3M American plaice in 2004.

Available Data

Below is a list of data sets available for assessment of Div. 3M American plaice.

RV Surveys

1. Canadian Series: 1978-1985.
2. Russian Survey: 1972 - 2001.
3. EU Series: 1988-2001.

VPA

1. Catch-at-age for 1988-2001 ages 1-16+
2. Average annual weights-at-age for 1988-2001 ages 1-16+.
3. RV series used: EU survey

VPA Structure

XSA structure for 3M American plaice from the 2002 assessment (Alpoim *et al.*, 2002):

1. Accepted XSA using the Lowestoft VPA Suite (Darby and Flatman, 1994).
2. Natural Mortality (M) assumed to be 0.2 for all ages.
3. Age 16 in the catch-at-age is a plus group.
4. No year weights were applied, due to the short time series.
5. Age 10 was considered to be the first age at which q is independent of age.
6. A shrink survivor estimates with a mean F for the last 5 years and the 5 older true ages was used.
7. The Log (S.E.) for the F means to which the estimates are shrunk.
8. 1994 was the earliest year to be used for tuning the VPA.
9. 0.5 minimum Log (S.E.) for the terminal population estimates derived from each fleet (Threshold se).

From the 12 points available from the XSA to examine a stock/recruitment relationship, very poor recruitment occurs at SSB below 5 000 tons.

References

Anon. 2002. Report of the Scientific Council Meeting - June 2002. NAFO SCS Doc., No. 19, 195 p.

Alpoim, R., C. Darby, and A. Avila de Melo. An assessment of American plaice (*Hippoglossoides platessoides*) in NAFO Division 3M. NAFO SCR Doc., No. 62, 36 p.

Darby, C. and S. Flatman, 1994. Virtual population analysis: version 3.1 (Windows/Dos) user guide. *Info. Tech. Ser., MAFF Direct. Fish. Res.*, Lowestoft, (1): 85 p.

Available Data for a PA Framework for Division 3M Redfish

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During the 2002 a full assessment was presented to STACFIS, including the following parameters and model runs:

1. **Female maturity ogive** based on the mean proportion of mature females found in survey stock abundance-at-age.

2. **Partial recruitment vector** from the ratio between the 1989-2000 age composition of the total catch, including redfish by-catch in the shrimp fishery, and beaked redfish survey abundance.

3. **Extended Survival Analysis** (XSA) for the most recent period of 1989-2001, with natural mortality assumed constant at 0.1.The input catch-at-age was is mentioned bellow. The above mentioned female maturity ogive used. The first age group considered was age 4 and a plus group was set at age 19. EU survey abundance at age was used for calibration.

4. **Logistic surplus production model** (ASPIC) was applied using the 1959-2001 STACFIS catch estimates with the standardized STATLANT commercial catch and effort data (1959-1993) and the age 4+ EU bottom biomass (1988-2000). A starting estimate for the intrinsic rate of biomass increase was derived from $F_{0.1}$ determined by the yield-per-recruit analysis. Catchability (q) of the EU survey was fixed based on mean age 4 + survey bottom biomass/XSA stock biomass ratio for the 1992-2001 period. ASPIC was first run on the FIT mode. Effort and survey residuals were runned afterwards through bootstrap analysis in order to derive bias corrected estimates and probability distribution of the parameters.

5. **Prelimenary SR scatterplot** from the XSA results the 1994-2001 recruitment at age 4 and the 1989-1997 female SSB´s, as well as trends in stock reproductive potential over the eight more recent years.

6. **Short and medium term projections** with the XSA survivors and recruitment randomly resampled from the 1999-2001 geometric mean, under three fishing mortality options. Besides F*statusquo* these *F* options corresponded to a short term yield abide to the vicinity of the actual TAC of 5 000 tons (60% of F*statusquo*) or within the average level of recent catches (3 000 tons-4 000 tons).

The following sets of commercial sets of commercial and survey data were available for the 1989-2001 period:

1. **Commercial data.** Length and age composition of the catch including the 1993-2001 by-catch for the Div. 3M shrimp. Mean weights at age of the commercial catch.

2. **CPUE data**. A STATLANT 21B CPUE series incorporating catch and effort data for most of the components of the fishery (1959-1993) was used in the surplus production analysis.

3. **Survey bottom biomass** and survey female spawning biomass of Div. 3M beaked redfish (*S. mentella* plus *S. fasciatus*).

4. **Survey abundance at age** and mean weights at age in the 3M beaked redfish stock. Same information available for the mature female stock component.

References

Ávila de Melo, A. M., R. Alpoim, and F. Saborido-Rey. 2002. The present status of beaked redfish (*S. mentella and S. fasciatus*) in NAFO Division 3M and medium term projections under a low commercial catch/ high shrimp fishery by-catch regime. NAFO SCR Doc., No. 54, Serial No. N4666, 59 p.

NAFO 2002. Scientific Council Reports 2001. Northwest Atlantic Fisheries Organization, Dartmouth, Nova Scotia, 339 p.

Data Time Series Available for Potential Use in Developing Biological Reference Points for Greenland halibut in SA2+Divisions 3KLMNO

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Survey Time Series

Canadian Surveys

Div. 2GH	1978-79; 87-88; 91; 96-99; 01
Div. 2J3K	1978-2001
Div. 3L	1996-2001 (both spring and fall)
Div. 3M	1996-2001
Div. 3N	1996-2001 (poor coverage in 1996-97; 99)
Div. 3O	1996-2001 (poor coverage in 1996-97; 99)

Biomass and abundance indices: length, sex, maturity and age data are available from all of the above. However, there are several major shortfalls that complicate the data sets:

1) Depth coverage can be highly variable over time and in most cases the surveys do not cover the entire range of Greenland halibut distribution.
2) The older part of the population and especially the spawners are poorly represented in the surveys.
3) Although considerable data on maturity are available and published, the maturity schedule is very difficult to elucidate.

Survey biomass trends by division are illustrated in Fig. 1 with the biomass and abundance indices for Div. 2J and 3K combined (the longest complete time series) are shown in Fig. 2.

EU Flemish Cap Surveys (July)

Div. 3M 1988-2001

Biomass and abundance indices are available for all years. Age and length distributions are available since 1991. However, survey coverage is limited to depths less than 730 m.

Survey biomass and abundance trends are illustrated in Fig. 3.

EU (Spain) Surveys in the NRA

Div. 3NO 1996-2001

**Surveys coverage is limited to the portions of Div. 3NO in the NAFO Regulatory Area (NRA) but cover depths generally up to near 1 500 m.

Survey biomass and abundance trends are illustrated in Fig. 4.

Commercial Data

Catch and Effort

1) International CPUE from trawlers, 1975-2001 based on both days fished and hours fished:

The hours fished data are comprised mainly of Canadian trawler data collected from fishing within the Canadian 200-mile limit and represents a small of the fishery in recent years.

On the other hand, the days fished data are much more inclusive and include the major prosecutors of the fishery in the NRA.

CPUE trends for both series are illustrated in Fig. 5.

2) Portuguese CPUE from trawlers fishing the NRA, 1988-2001:

The CPUE trend is illustrated in Fig. 6.

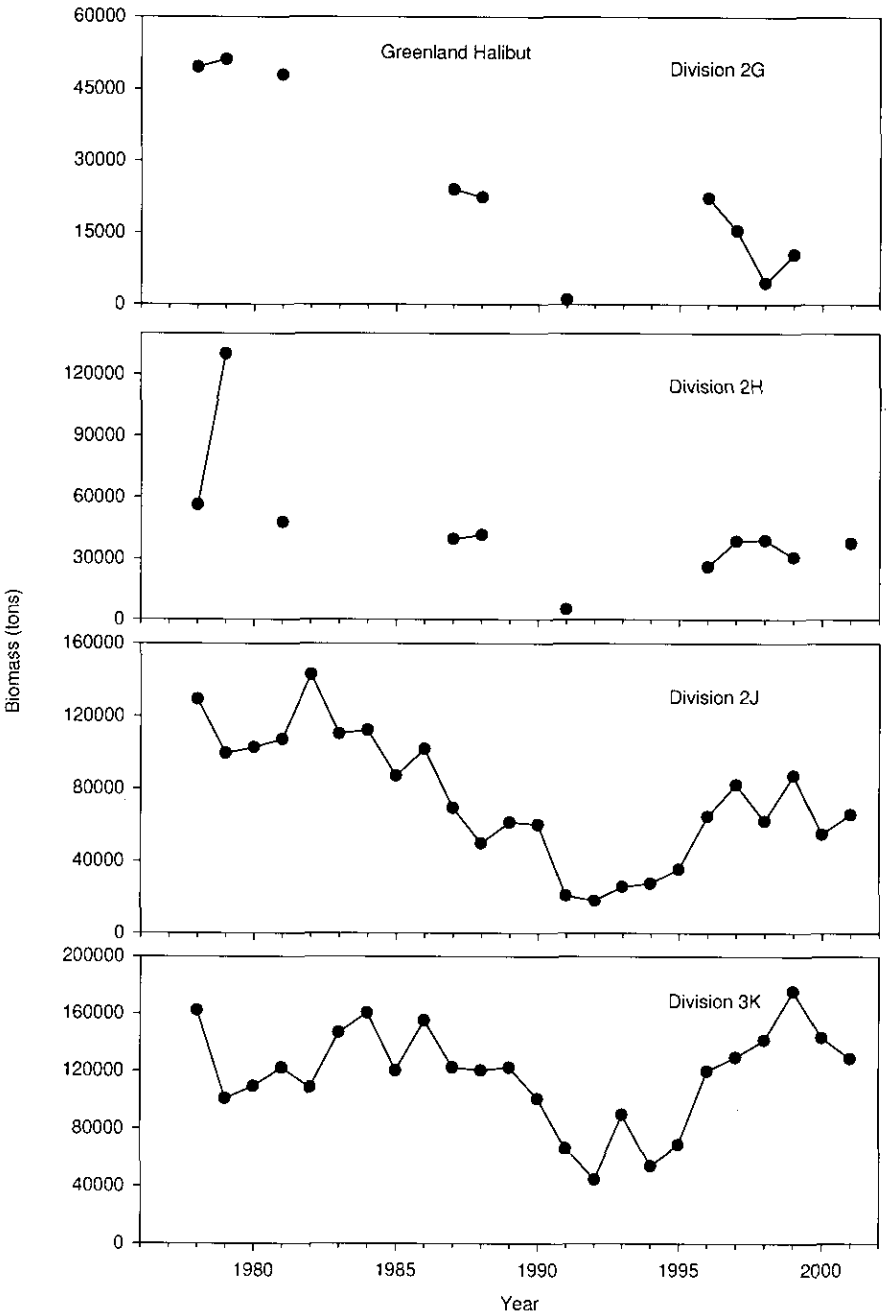

Fig. 1. Campelen biomass estimates by NAFO Division from Canadian fall surveys during 1978-2001.

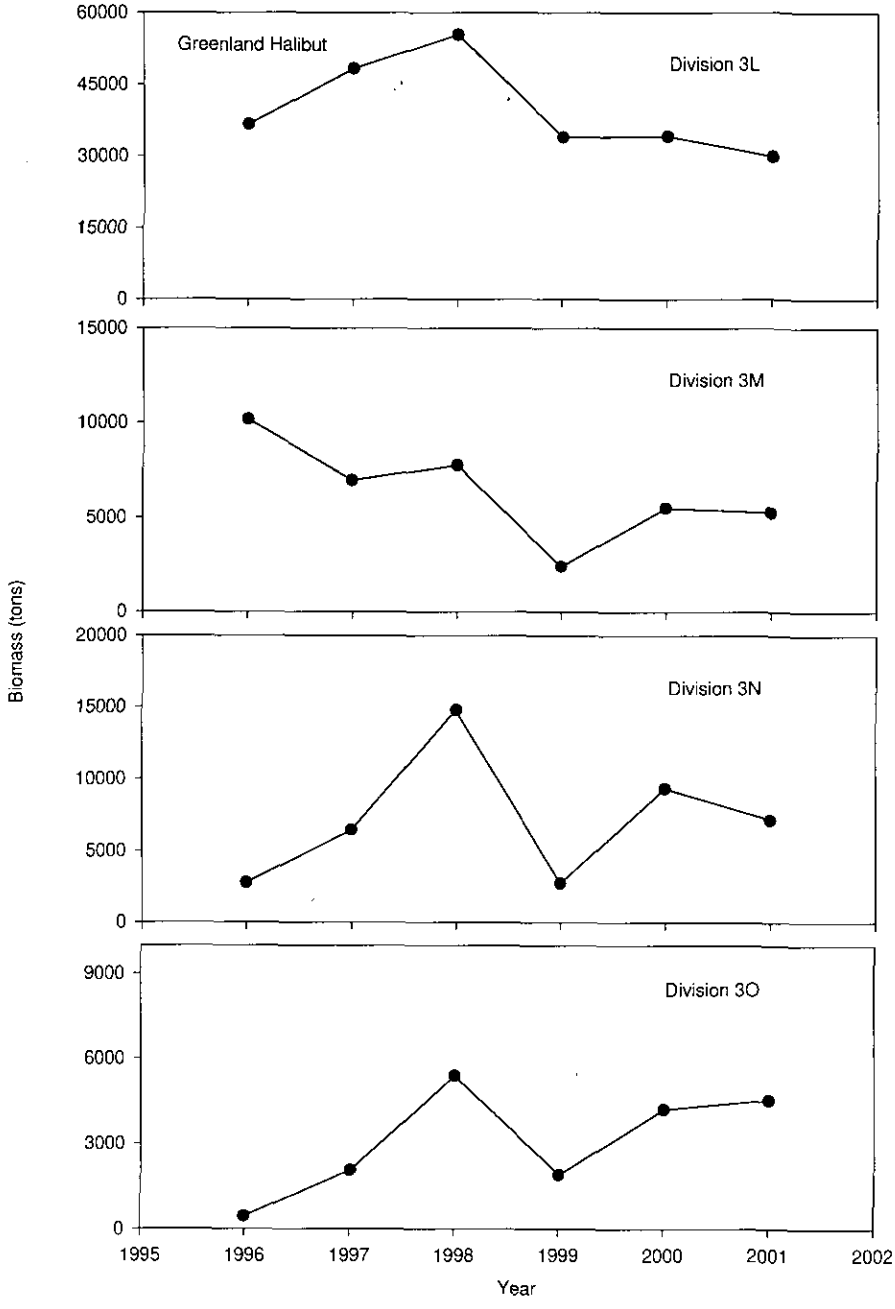

Fig. 1 (cont'd). Campelen biomass estimates by NAFO Division from Canadian fall surveys during 1978-2001.

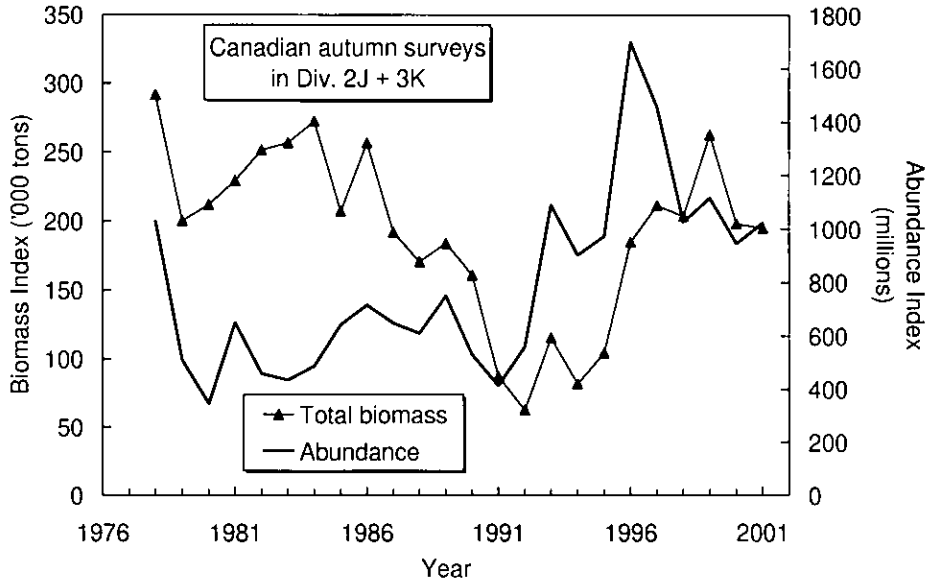

Fig. 2. Biomass and abundance indices from Canadian fall surveys in Div. 2J3K during 1978-2001.

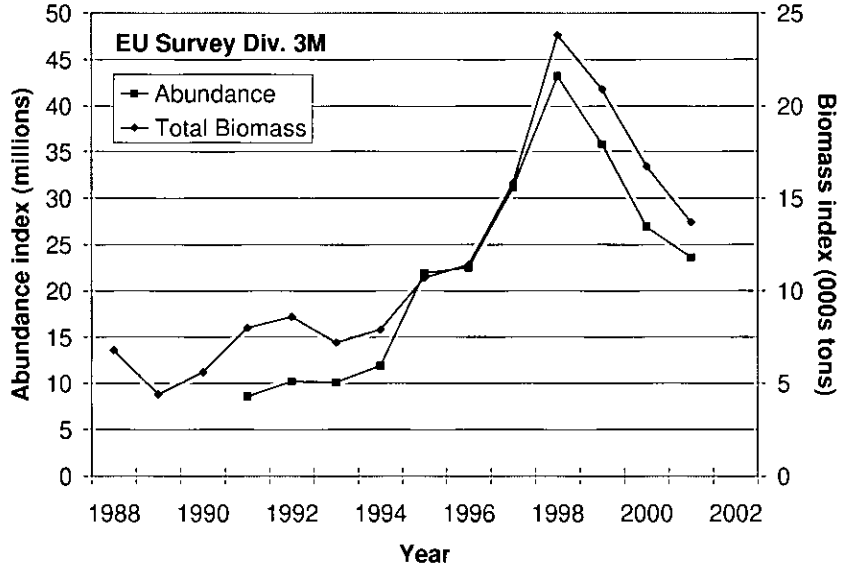

Fig. 3. Biomass and abundance indices from EU surveys in Div. 3M during July month from 1988-2001.

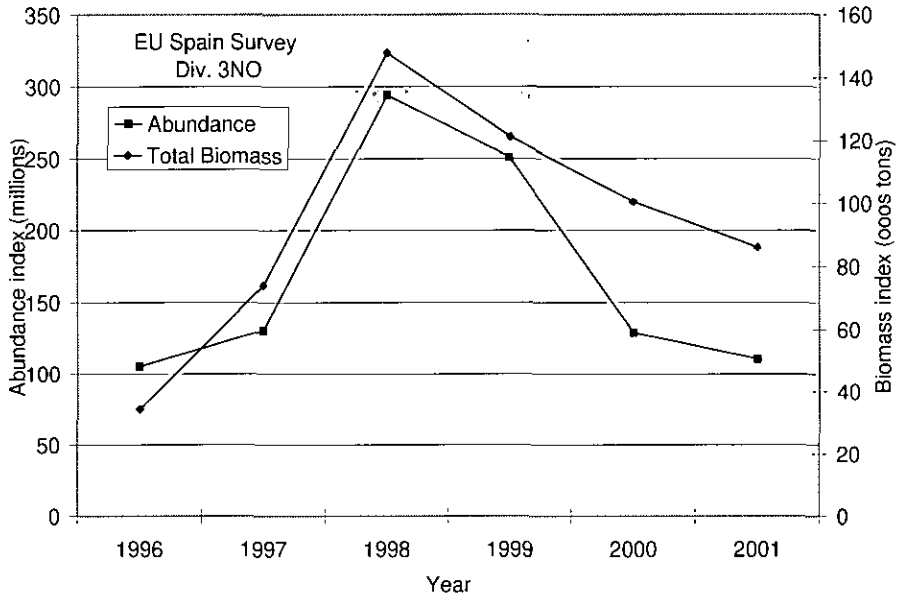

Fig. 4. Biomass and abundance indices from EU (Spain) surveys in the NRA portion of Div. 3NO during spring from 1988-2001.

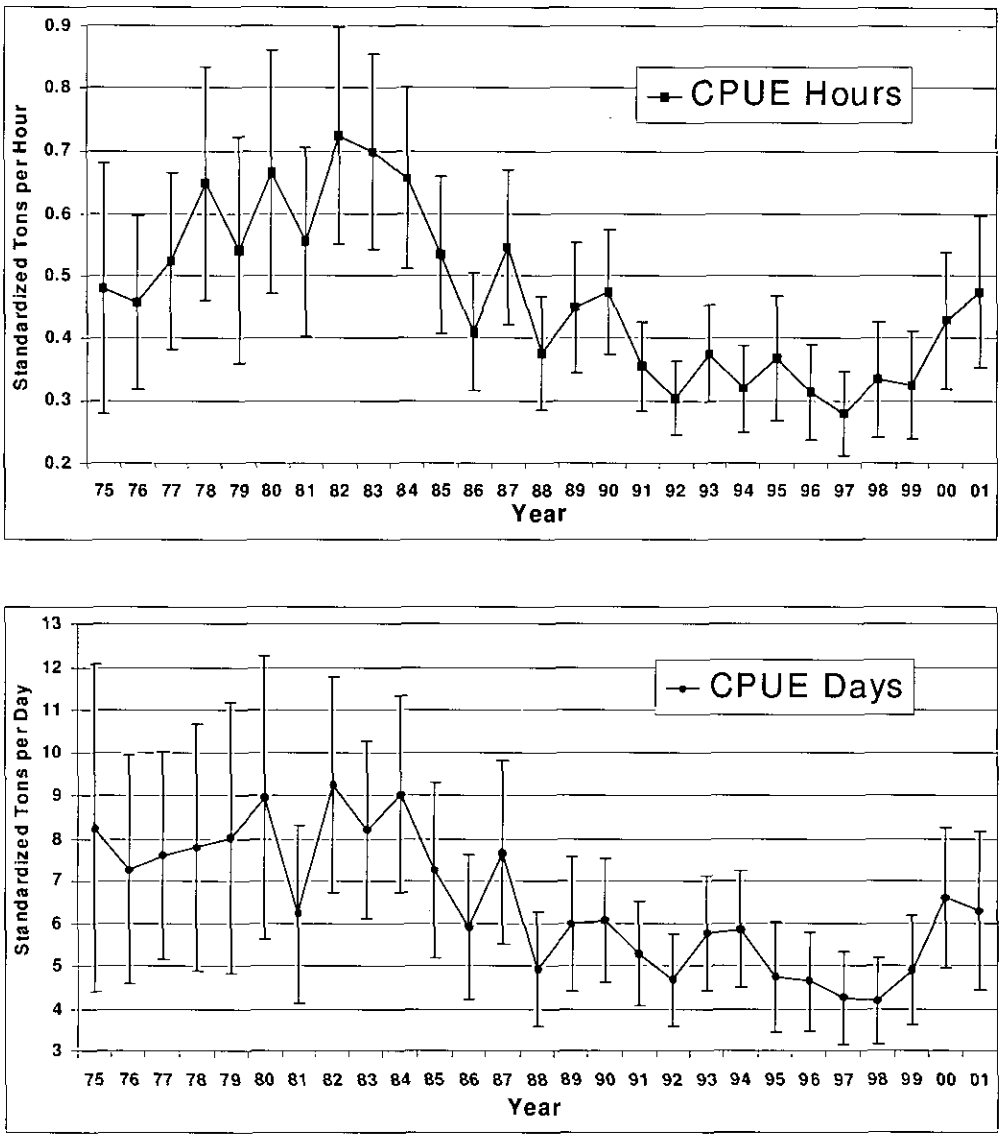

Fig. 5. Standardized CPUE ± 2 standard errors for Greenland Halibut in SA2 + Div. 3KLMNO from 1975-2000 (preliminary) utilizing effort in HOURS fished (upper panel) and DAYS fished.

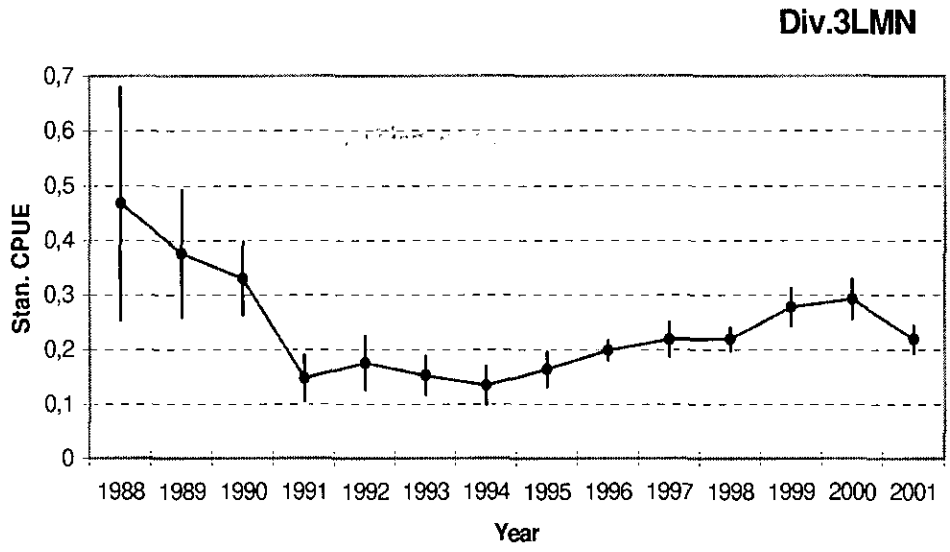

Fig. 6. Standardized Portuguese CPUE (t/hr) ± 2 standard errors for Greenland Halibut in the NRA from 1988-2001.

Indices of Abundance Available for Yellowtail Flounder in Divisions 3LNO

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The following table, based on Table 1 of Walsh and Cadrin (2000), lists available indices which have been considered in the stock assessments of yellowtail flounder in Divisions 3LNO.

Index	Time-series	Comments
Can. spring Yankee survey*	1971-1982	No data after 1982; no conversion to link with current surveys.
Can. spring Campelen survey*	1984-2002[1]	Longest time series; covers entire stock range; used to derive maturity/SSB estimates. Different trawl pre 1996.
Can. fall Campelen survey*	1990-2001[2]	Covers entire stock range; comparable with spring survey. Different trawl pre-1995.
USSR/Russia spring survey*	1972-82, 84-91	No data after 1991; no ageing information.
Spanish spring survey*	1995-2002	Short time series; covers only the NRA in Div. 3NO.
Can. juvenile survey	1985-94	Data on juveniles+ adults; no data since 1994.
DFO-FPI grid survey	1996-2002	Commercial vessel and trawl; short time series; does not cover all of stock area.
Canadian commercial CPUE	1965-93, 1998-2002	Standardized CPUE; may not be good indicator of biomass due to changes in fishery in early 90's, and since 1998.
Sequential population analysis	1968-1986	SPA rejected as basis of assessment. Recent studies show problems with ageing of older yellowtail otoliths.
Index of recruitment	Cohorts after 1979	Multiplicative model of cohort strength using age 3-4 data from spring and fall Campelen surveys.
ASPIC production model	1965-2002	Basis of recent assessments. Used to provide PA reference F's and Biomass. No SSB/R relationship and model is not age-based.

* Indicates indices used in the formulation of ASPIC in the 2002 stock assessment.
[1] Data from 1984-95 are from an Engels trawl and are converted to Campelen trawl equivalents.
[2] Data from 1990-94 are from an Engels trawl and are converted to Campelen trawl equivalents.

There are 7 survey series, 4 of which are still active. The 2 Campelen series contain Engel data converted to Campelen equivalents prior to 1995 (fall) and prior to 1996 (spring). SPA has not been used to assess this stock since the early- to mid-1980s, due mainly to problems with interpreting F's on the older ages. Subsequent studies (e.g. Dwyer *et al.*, 2001) have indicated that yellowtail live much longer than previously estimated, so those models which used age-based methods are inaccurate, particularly for the older fish in the population.

At present, ASPIC is used to derive biomass and fishing mortality estimates, based on stock production modelling. The five indices used in the current formulation of the model are marked with an asterisk in the table. This model allows PA reference points for F (e.g. $2/3F_{MSY}$) to be calculated, as well as reference points based on total estimated biomass. Survey-based indices of SSB and recruitment have been calculated outside ASPIC, but limited attempts to model stock-recruit relationships have been unsuccessful. This stock was chosen as an example for earlier PA work by Scientific Council, and the results (based on ASPIC modelling) are contained in SCS Doc 99/4. Figure 1 shows the ASPIC results from the 2002 assessment, including projections, cast in the precautionary approach framework proposed by Scientific Council. Biomass and F's are shown relative to MSY reference points.

References

Dwyer, K. S., M. F.Veitch, and S. J.Walsh. 2001. Age and growth of yellowtail flounder in NAFO Divisions 3LNO: an update. NAFO SCR Doc., No. 52, Serial No. N4430, 8 p.

Walsh, S. J., and S. X. Cadrin. 2000. Evaluating total allowable catch projections for Yellowtail flounder on the Grand Bank using multiple indices and surplus production analysis. NAFO SCR Doc., No. 44, Serial No. N4275, 40 p.

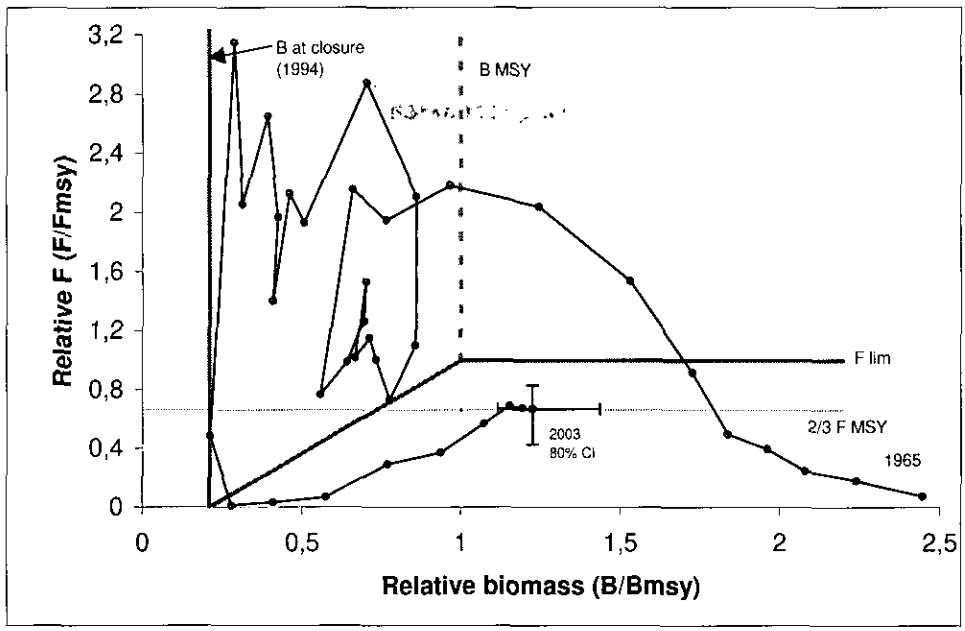

Fig 1. Results of 2002 assessment, 3LNO yellowtail flounder, presented in the PA framework.

In this framework, F_{lim} is F/F_{MSY} and B_{tr} would be B/B_{MSY}. 2/3 F_{MSY} represents a level of fishing mortality at which projections are requested by Fisheries Commission, so this is perhaps similar to a fishing mortality target. Buffer points are not shown, but could be calculated from bootstrapped ASPIC results, eg. F_{buf} could be the 10^{th} percentile of the F_{MSY} estimate. Alternatively, B_{buf} could be assigned a value e.g. reasonable value proposed for B_{buf} has been 2/3 B_{MSY}. No B_{lim} value is indicated, and this value would presumably be at or preferably above the 1994 point, which is the lowest observed biomass. As noted above, a current difficulty with this approach is that any biomass reference points are relative to total biomass, and not spawning biomass.

Continuing the Implementation of the Precautionary Approach Framework in Assessing NAFO Divisions 3NO Cod

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Introduction

The cod stock in NAFO Div. 3NO is one of the few stocks under the jurisdiction of Scientific Council that includes precautionary approach (PA) considerations in stock assessment. Reference points have been identified for this stock, and in the last two assessments of this stock conducted in 1999 and 2001, medium-term projections were presented to demonstrate stock dynamics with respect to the reference points.

In preparation for the proposed SC 2003 PA workshop, we summarize the available data which may be used in PA methods, and describe the precautionary approach considerations currently implemented for this stock.

In 2002, a full assessment was not conducted on Div. 3NO cod, as it is currently on a two-year assessment cycle. However, the stock update (Healey *et al.*, 2002) concluded that: "Nearly all of the abundance and biomass indices observed in the Canadian fall and spring surveys are declining, with no evidence of any strong year-classes since the 1989 cohort. Removals from this stock have increased steadily despite a moratorium on directed fishing. High levels of fishing mortality indicate poor prospects for this stock in the near future."

Available Data

Below is a list of data sets available for assessment of Div. 3NO cod within the PA framework (data tabled in Stansbury *et al.*, 2001):

- RV Surveys
  4. Canadian Fall RV Series: 1984-2001, ages 1-19.
  5. Canadian Spring RV Series: 1990-2001, ages 1-19.
  6. Canadian Juvenile RV Series: 1989-1994, ages 1-14.

  Note: The Canadian fall and spring survey series include the Engels to Campelen gear changeover in the fall of 1995.

- Catch at age for 1959-2000 ages 3-13+.
- Maturities at age for 1959-2001 ages 3-13. (Estimated from probit model.)
- Average annual weights at age for 1959-2000 ages 3-13+.

Production Modeling

In the last assessment of this stock (Stansbury *et al.*, 2001), a production model was fit to the survey indices for Div. 3NO cod:

- Results are considered somewhat tenuous, and it was concluded that production modelling of this stock required further investigation.
- Catchabilities >1 were estimated suggesting that "spatial extrapolation of stratum means is inappropriate or that the net is somehow concentrating fish within its path".
- Two formulations were considered, one including and excluding the Canadian Juvenile Index. The run excluding this index closely agreed with the final VPA in the assessment.

VPA

VPA structure and results for Div. 3NO cod from the 2001 assessment (Stansbury *et al.*, 2001):

- Accepted VPA using the ADAPTive framework (Gavaris, 1988).

- Natural Mortality (M) assumed constant at 0.2.
- Fishing mortality on the oldest age (12) set equal to the average F for ages 6 to 9 for years 1959-1995.
- There is no "plus" age-class in the VPA.
- Due to inadequate sampling of removals, total catch for 1996-1998 was proportioned by age using the average partial recruitment vector from 1990-93 (from an earlier VPA).
- Survivors were estimated for 2001 (ages 3-12), and terminal numbers (age 12) were also estimated for 1994-2000.
- Estimates of numbers at age (and subsequently Biomass, SSB, Recruits) are available for 1959-2001, ages 2-12.
- Estimates of fishing mortality at age available for 1959-2000, ages 2-12. Reference F's for ages 4-6 and 6-9 computed in the last assessment to examine patterns in F since imposition of moratorium in February 1994.
- Retrospective analysis indicated that both population numbers and spawning stock biomass were continually underestimated, but that the reference fishing mortality $\bar{F}_{6\text{-}9}$ consistent as successive years of data were excluded.

Reference Points & Projections

During the SC 1999 meeting on the PA in San Sebastian, Spain, a biomass limit reference point (B_{lim}) was established for Div. 3NO cod based on recruitment trends below B_{lim}=60 000 tons. In the report of this meeting, SC also "*recommended that the Scientific Council reveiew in detail the biological reference points in the context of the PA framework when the SSB has reached half the current estimate of* B_{lim}". The 2001 estimate of SSB from the last assessment of the stock is much lower than $\frac{1}{2} B_{lim}$.

To evaluate future stock trends with respect to various levels of fishing mortality, medium term (10 year) projections have been carried out for this stock during the last two assessments. Survivors are randomly generated using the estimated values and their standard errors. This population is then projected forward by a) generating recruitment by dividing the historic recruitment into quartiles, then randomly selecting a recruitment value from the quartile corresponding to the projection SSB and b) removing a "catch" generated by a given partial recruitment vector and fully selected fishing mortality. Projection results are compared to B_{lim}. Projections conducted during the 2001 assessment (NAFO, 2001) indicate that it is highly unlikely that the stock will reach B_{lim} in the near future.

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Background on Reference Points for Divisions 3LNO American Plaice

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History

Divisions 3LNO American plaice was one of the stocks reviewed during the 1998 workshop (Anon., 1998). During that workshop extensive analyses were conducted and a preliminary B_{lim} of 150 000 tons of SSB was set. It was pointed out in 1999 that this limit needed to be reevaluated (NAFO, 2000). This was partly the result of using a new formulation of the VPA which included more years of data and a change in *M*, but the main impact was from using an inappropriate maturity schedule (9+) at the workshop (Fig. 1). There have been large changes in maturity at age over time in this stock and the age at 50% maturity at the beginning of the time series was around 11 years, compared to 8 years presently.

In 2001, it was suggested that a B_{lim} of 50 000 tons of SSB might be appropriate (NAFO, 2002). This was based on an examination of the stock recruit (S/R) scatter which seemed to indicate only poor recruitment below that level. However, at that time it was considered too preliminary to set the B_{lim}. Part of the objection to the use of 50 000 tons as the B_{lim} was the time trends in the S/R scatter, in particular since the 1986 year-class (Fig. 2).

In 2002, 50 000 tons of SSB was once again suggested as a B_{lim} and at this time it was accepted. There is currently no suggested *F* reference point.

Available Data

Below is a list of data sets available for assessment of Div. 3LNO American plaice.

RV Surveys

7. Canadian Spring RV Series: 1985-2001, ages 0-20 (Campelen or equivalent)
8. Canadian Spring RV Series: 1975-1995, ages 1-20 (Engel)
9. Canadian Fall RV Series: 1990-2001, ages 0-20 (Campelen or equivalent)
10. EU Spain Spring RV Series: 1995-2001, ages 1-20 (Padreira)

VPA

4. Catch-at-age for 1960-2001 ages 5-15+
5. Estimated proportion mature-at-age for 1960-2010
6. Average annual weights-at-age for 1960-2001 ages 5-15+.
7. RV series used: Canadian spring and autumn ages 5-14

VPA Structure

VPA structure for 3LNO American plaice from the 2002 assessment (Morgan *et al.*, 2002):

10. Accepted VPA using the ADAPTive framework (Gavaris, 1988).
11. Natural Mortality (M) assumed to be 0.2 for all ages except assumed to be 0.53 from 1989-1996.
12. Age 15 in the catch-at-age is a plus group.
13. *F* on the plus group assumed to be equal to *F* on the last true age.
14. All indices given equal weight.

Future

There are currently no *F* reference points or any B_{buf}. Many potential *F* reference points depend on a S/R relationship and the current B_{lim} has been derived from the S/R scatter. There are two potential difficulties here. One is the time trend in the S/R data. The stock was apparently in a low recruitment regime from 1986 to at least 1992 (Fig. 2 and 3). This may cause difficulties in choosing the correct S/R relationship. A second, related problem

is that fitted S/R relationships tend to overestimate recruitment during this 'low period' and so do not capture this portion of the S/R dynamic.

However, compared to the 37 year time period of S/R data this period of low productivity appears to be relatively short and may be over (although the last estimate of recruitment relative to SSB is low Fig. 3). It would seem that Div. 3LNO American plaice provides one of the best possibilities for deriving a full suite of reference points. If this is done S/R relationship would need to continue to be examined (e.g. to see if 'low productivity' is to be the norm) to determine if the reference points needed to be adjusted.

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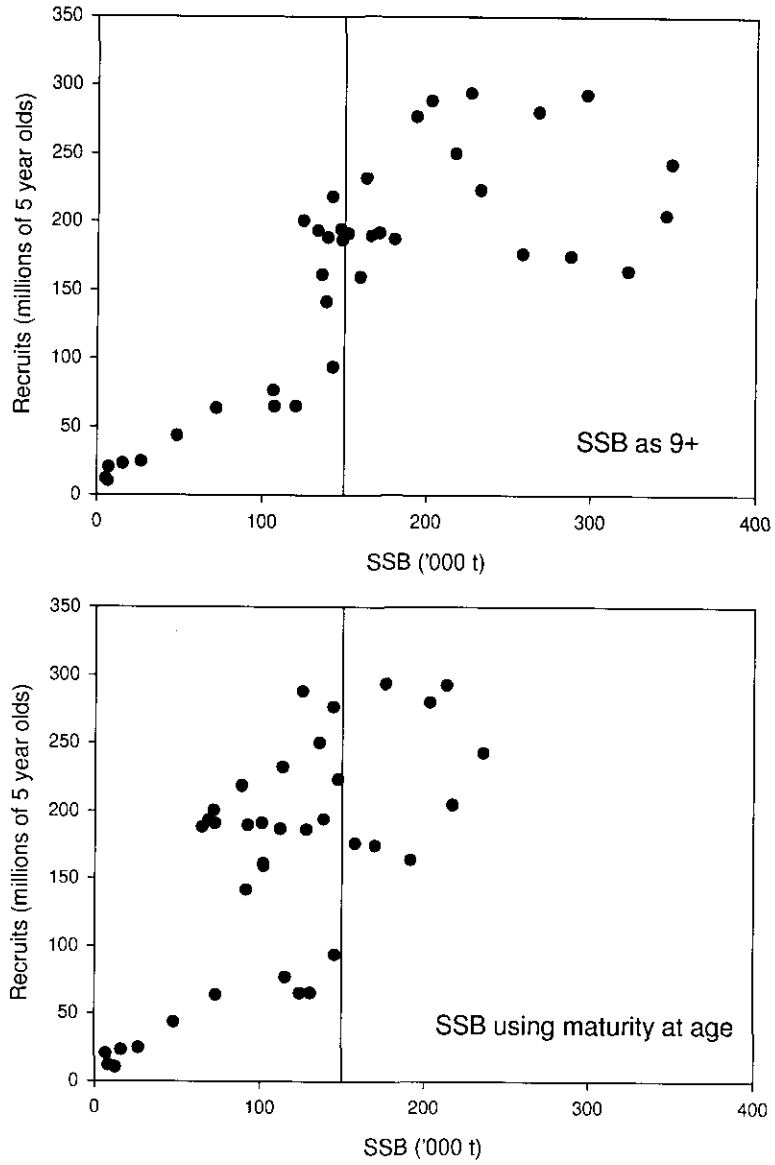

Fig. 1. The effect of different maturity schedules on stock/recruit. Both panels use the same numbers and weights-at-age. The top panel uses 9+ biomass as a proxy for SSB while the bottom panel uses estimated proportion mature-at-age for each cohort multiplied by biomass at age. 150 000 tons of SSB is marked on each panel by a vertical line.

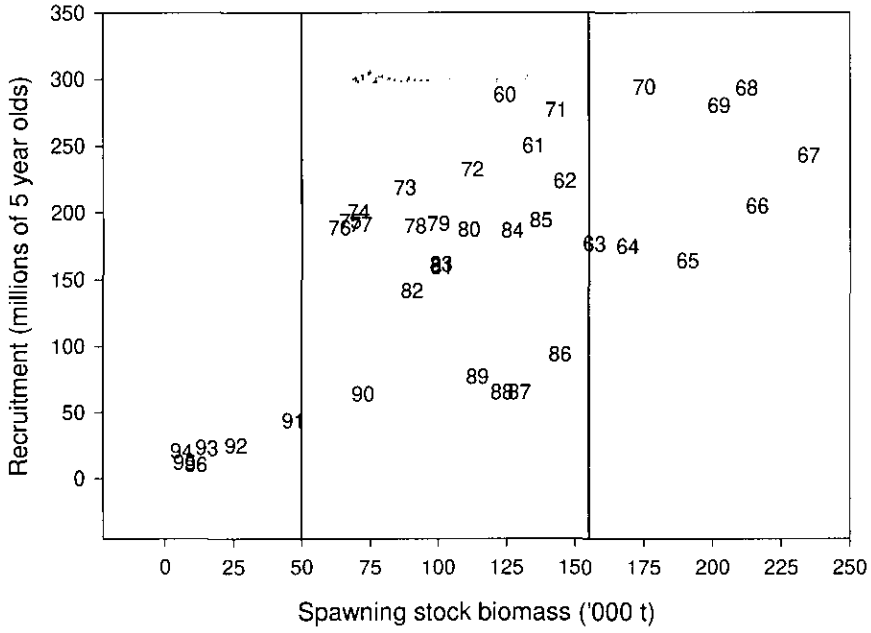

Fig. 2. Observed stock recruit scatter from 2002 assessment. Vertical lines illustrate the 3 levels of recruitment. The symbols give the year-classes.

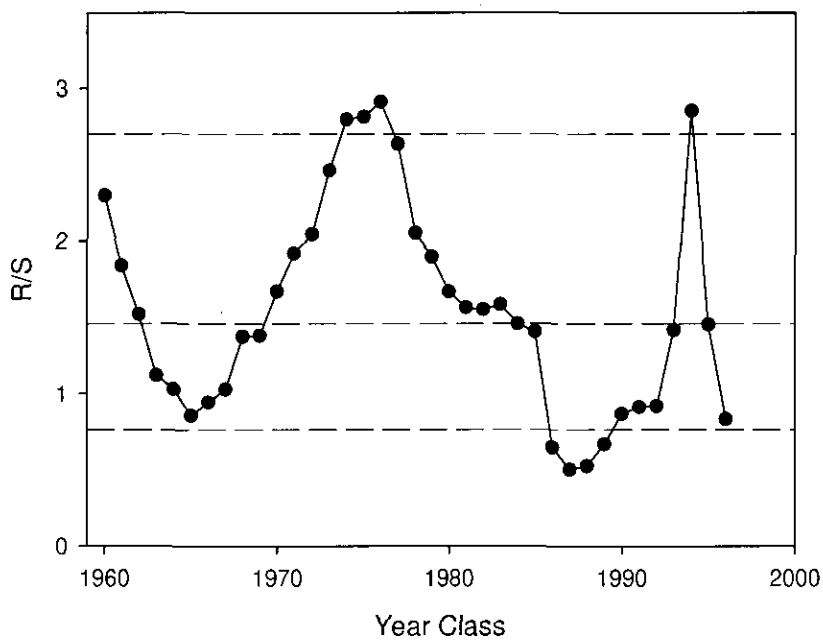

Fig. 3. Thousands of recruits per ton of SSB (R/S). The horizontal lines indicate the 10^{th}, 50^{th}, and 90^{th} percentiles of observed R/S.

Precautionary Approach for Scientific Council September 2002

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Description of the Fishery:

The Faroese began fishing shrimp in the NAFO Regulatory Area (NRA) during 1993. Then during 1999, Canadian vessels made 4 exploratory trips into Division 3L. Later that year a 6 000-ton quota was established for 2000 and 2001, and fishing was restricted to Div. 3L, at depths greater than 200 m. Canadian vessels may catch 5 000 tons inside the Exclusive Economic Zone (EEZ), while a 1 000-ton quota is set for the NRA. In order to decrease by-catch, all vessels fishing this stock must utilize sorting grates with a maximum bar spacing of 22 mm, and employ toggle chains with a minimum length of 72 cm. If by-catch of all regulated groundfish exceeds 2.5% of the total shrimp catch then the vessel must move 5 Nmi away from the area. Provisional catches for 2000 and 2001 were 4 700 and 6 200 tons, respectively.

Data sources and methods used in 3LNO stock assessments:

1) Canadian autumn and spring multi-species research bottom trawl surveys;
2) Observer databases;
3) Logbook databases, and
4) International catch and effort information.

1) Canadian spring and autumn multi-species research surveys:

Shrimp abundance, biomass, maturity and carapace length data have been collected since autumn 1995, as part of the Canadian multi-species surveys conducted using the CCG Wilfred Templeman, CCG Alfred Needler and CCG Teleost. Fishing sets of 15 minute duration and a towing speed of 3 knots are randomly allocated to strata covering the Grand Banks and slope waters to a depth of 1500 m (Fig. 1). All vessels use a Campelen 1800 shrimp trawl with a codend mesh size of 40 mm and a 12.7-mm liner. SCANMAR sensors estimated that the mean wingspread was 16.8 m. Details of the survey design and fishing protocols are outlined in (Brodie, 1996; McCallum and Walsh, 1996).

Modal analysis using Mix 3.1A (MacDonald and Pitcher, 1979) is conducted on research length frequencies, in an effort to identify year-classes. For instances in which there are no clear modes, cohort slicing (Orr *et al.*, 2002) and the deviation method (Skúladóttir, 1981) are employed. Spawning stock biomass is plotted against abundances of age 2 males to determine whether a stock – recruitment relationship exists. Such a relationship could be used to predict stock prospects.

Since the spring of 2000, a juvenile shrimp net (Fig. 2) has been sewn into the belly of the Campelen approximately 1 m ahead of the codend. The net was developed by Nilssen *et al.* (1986) but modified to account for the 12.7 mm liner material rather than 20 mm material. It is being used to provide an indication of escapement through the 44 mm mesh ahead of the codend.

Shrimp are frozen and returned to the Northwest Atlantic Fisheries Centre where identification to species and maturity stage is made. The maturity of the shrimp is defined by four stages:

males;
transitionals;
primiparous females;
and multiparous females

as defined by Ramussen (1953), Allen (1959) and McCrary (1971).

Oblique carapace lengths (0.1 mm) are recorded while number and weight per set is estimated. Stratified abundance and biomass indices are estimated via areal expansion using programs based upon Cochran (1997) and

written in SAS (D. Orr unpublished). Inshore strata were not sampled during 1999, therefore, the analysis was restricted to data collected from offshore strata only (Fig. 1).

Preliminary instantaneous total mortality (Z) rates are determined for:

1) the change in abundance between age 4 + (males, transitionals and females) in one autumn survey $_{(t1)}$ and the abundance of age 5+ females in the next $_{(t2)}$;
2) the change in abundance between multiparous and ovigerous females from the autumn survey data one year $_{(t1)}$ and spring survey data during the next $_{(t2)}$; and finally
3) the change in abundance between total females (transitionals, primiparous, multiparous and ovigerous) during one spring survey $_{(t1)}$ and the abundance of multiparous females during the succeeding spring $_{(t2)}$.

Instantaneous total mortalities are determined using the following formula:

$$Z = -\log_e(N_{t2}/N_{t1}) \text{ (Ricker, 1975).}$$

Exploitation indices are derived by dividing total catch by each of the following estimates: biomass, spawning stock biomass (SSB), and fishable biomass. The fishable component of the population was defined as being all animals greater than 17 mm CL. The fishable component of the male biomass is determined by converting abundances to biomass using the autumn length weight regression:

$$\text{Wt.} = 0.000838\text{Lt}^{2.929} \text{ (Skúladóttir, 1997).}$$

Female biomass is determined by areal expansion. Female and male biomasses are then added together to obtain total fishable biomass.

Distribution maps of adult and juvenile Atlantic cod (*Gadus morhua*), American plaice (*Hippoglossoides platessoides*), Greenland halibut (*Reinhardtius hippoglossoides*) and redfish (*Sebastes mentella*) are overlain with plots of survey shrimp catches to determine the degree of overlap. The term juvenile refers to the modal length of a species (LC_{50}) passing through a 22 mm Nordmore Grate. The respective LC_{50} values for Atlantic cod, Greenland halibut, redfish and American plaice were: 19 cm (Orr *et al.*, 2000 and Hickey *et al.*, 1993), 24 cm (Nicolajsen, 1997), 14-18 cm (Hickey *et al.*,1993; Kulka and Power, 1996; Kulka, 1998; Nicolajsen, 1997; Skúladóttir, 1997) and 23 cm (Orr *et al.*, 2000). Amounts of by-catch are assessed in relation to total shrimp catch.

The research datasets also include environmental data (water depth, bottom temperature, salinity and sometimes bottom type (Roxanne data)) which may be included in precautionary approaches to fisheries.

2) Observer database:

Approximately 12 large (=>500 ton) fishing vessels and more than 300 smaller (<500 ton; <100') vessels fish shrimp within Davis Strait, along the coast of Labrador and off the East Coast of Newfoundland. Two thousand five hundred tonnes of the Canadian quota are fished by each fleet. There is 100% mandatory observer coverage of the large vessels, but only 10% coverage of the small vessels.

Observers working on large vessels collect detailed maturity stage length frequency information from random sets. Those working on small vessels collect ovigerous/ non-ovigerous length frequencies from random sets and one detailed maturity stage length frequency per trip. Observers on both types of vessels record: shrimp catches, effort, amount of discarding, approximate amounts of by-catch on a species by species basis and randomly collect length frequencies of by-caught species. Length frequencies are collected for all by-caught Atlantic cod.

The Observer database is used to determine the Catch-Per-Unit-Effort (CPUE) of each fleet, catch at size and maturity, as well as, the impact of shrimp fishing upon groundfish species.

3) Logbook database:

There is a mandatory 100% logbook coverage of all fishing activities. Logbook data are compared with observer data when estimating the percent of total catch that was observed. This percentage is used in estimating the number of shrimp – at - length caught and the total groundfish by-catch on a species by species basis.

Logbook and observer catches are plotted using ACON (Black, 2001). The area fished each year is divided into 10 min. X 10 min. cells, catches are aggregated by cells, aggregated catches are organized into a cumulative percent frequency (cpf). The cpf is used to determine the number of cells accounting for 75% of the catch each year (Swain and Morin, 1996). The plots and quantification of spatial coverage are used to describe changes in fishing patterns and practices that might affect CPUE interpretations.

Both the observer and logbook data sets complement the research trawl survey data sets. Research data are collected during the spring and autumn using stratified random set allocations that cover the Grand Banks. Conversely, the observer and logbook data sets are representative of the commercial fishery. They focus upon fishing areas and cover a much broader seasonal scale than the research data. All three are used in determining an exploitation index (catch/biomass) which is a proxy for fishing mortality, and provide insight into the impact of shrimp fishing upon groundfish.

4) International catch and effort information:

These data are made available by Contracting Parties that fish for shrimp in Div. 3L. They are added to the Canadian catches when determining a total catch. Where no information is provided by a Contracting Party, information is augmented through the use of Canadian aerial surveillance data.

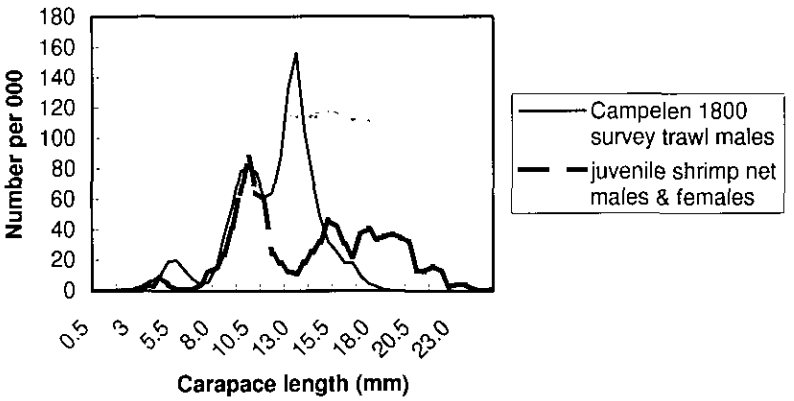
Results and Discussion of Analyses:

Biology:

This species is a protandric hermaphrodite, maturing first as males followed by sex inversion at approximately 4 years of age. Modal analysis indicates that Div. 3LNO shrimp have a 7-8 year life span. Preliminary instantaneous total mortality estimates vary from –1.02 to 1.11. However, the only realistic values were derived by determining the number of age 4+ animals surviving from one autumn until the next (these values ranged between 0.62 and 0.75). The implications of these life history characteristics should account for when developing a Precautionary Approach to this fishery.

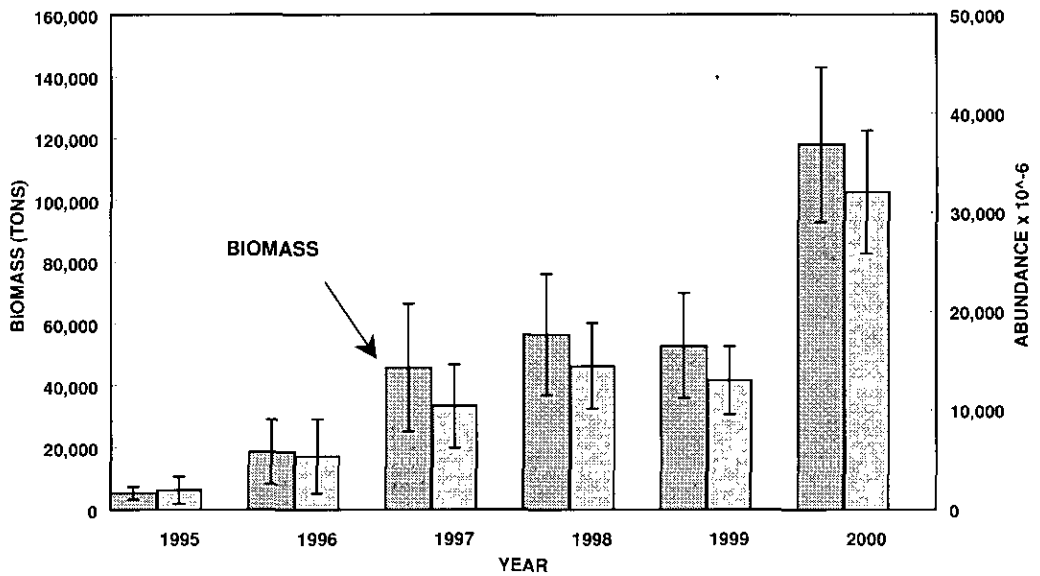
Research data:

Length frequencies produced from collections made using the Campelen 1800 research trawl overlap the entire size range and have similar modes to collections made using the juvenile shrimp net. This indicates that the length frequency data collected using the Campelen 1800 research trawl are representative of the shrimp passing through the research trawl. Similar findings were noted during the spring of 2000 (Orr *et al.*, 2000). These findings are in agreement with Diaz (2001) who made comparisons between a Campelen shrimp trawl and a juvenile net.

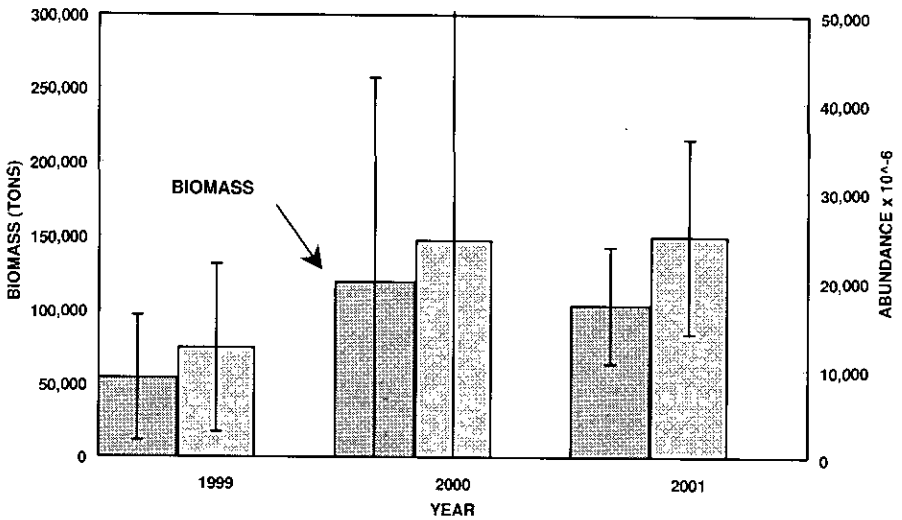


This figure also indicates that the Campelen 1800 research trawl may be able to provide a signal of 0-group (<8.5 mm CL) and one year old animals (8.5-12 mm CL).

Results of the autumn 1995-spring 2001 Canadian multi-species surveys indicate that shrimp have been widely distributed along the edge of Div. 3L. The biomass index increased from 5 921 tons in autumn of 1995 to 59 914 tons during autumn of 1998, remained stable until spring of 2000, at which time it increased to 121 815 tons. The index then decreased to 103 451 tons during spring 2001.



Autumn multispecies survey biomass and abundances of 3LNO *P. borealis*

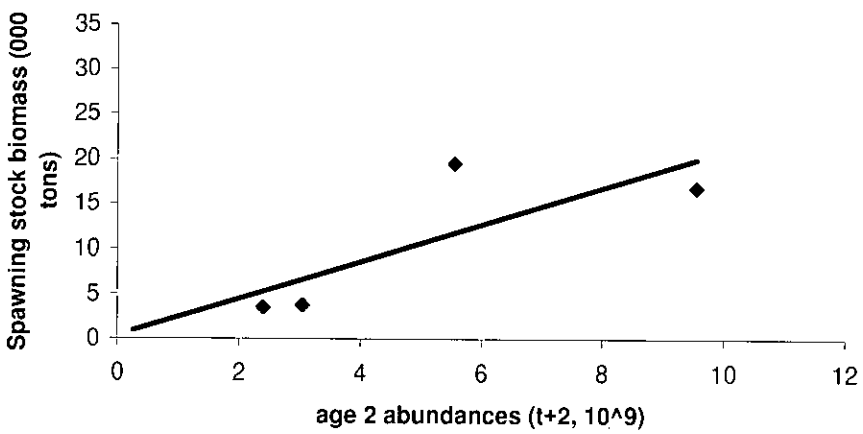


Spring multispecies survey biomass and abundances of 3LNO *P. borealis*

These charts indicate that the biomass and abundance estimates for the autumn surveys have tight confidence limits relative to spring survey results. The lower confidence limits for the spring of 2000 are negative. The differences between spring and autumn confidence limits indicate that there may be a seasonal influence upon shrimp catchability. For this reason, data from the autumn surveys should be treated separately from the spring survey data.

Within the autumn estimates, the ratio of confidence limit width to point estimate appears inversely proportional to the point estimate. This indicates that catches (weight and count) are less variable when population size is high.

As indicated in the above charts, research datasets have a sort history and do not demonstrate a dynamic range therefore there no attempts have been made to complete an analytical assessment of the stock. There appears to be a positive relationship between spawning stock biomass the recruitment index (age 2 shrimp) (advanced by 2 years to be consistent with the fact that many of these animals change sex at 4 years of age). Therefore the recruitment index may have predictive value, but the time series is too short to draw conclusions from these findings.



Commercial data:

Catch, effort and unstandardized CPUE are available for the 8 years during which northern shrimp have been fished in Div. 3L. The data are considered representative of all fleet operations and it is hoped that in the future it will be possible to derive modelled CPUE.

Exploitation rates within the 3L shrimp fishery

Year	Catch/total biomass	Catch/ SSB	Catch/fishable biomass
1996	0.015	0.021	0.016
1997	0.026	0.138	0.076
1998	0.011	0.026	0.019
1999	0.015	0.049	0.026
2000	0.089	0.255	0.163
2001	0.053	0.191	0.107

Exploitation levels produced from ratios of catch/ total biomass, catch/SSB and catch/fishable biomass track the same trend. Overall, exploitation has been low, with increased values in 2000 and 2001 reflecting the start of the fishery under TAC regulation.

Observer datasets:

An attempt is being made to sample 100% of catches for length, sex, maturity and groundfish by-catch on large Canadian fishing vessels. Analyses indicate that at least 90% of the fishing sets are being observed and therefore, it is believed that the data are to be representative of the Canadian large vessel catch composition.

Even though there has been an attempt to observe 10% of the small vessel catches, analyses indicate that as few as 2% of the catches are being observed. Thus relatively few shrimp and groundfish length frequencies have been collected, resulting in length frequencies that are often jagged and may not be representative of the Canadian small vessel catch composition.

Selection of Reference Points:

Due to the problems associated with the short time series and lack of dynamic range, no precautionary reference points could be derived to date. The qualitative "traffic light" checklist proposed by Caddy (SCR Doc. 98/8) and modified by Halliday *et al.* (2001) is viewed as a first step in applying the Precautionary Approach to Div. 3LNO shrimp. The method has the potential for incorporating data on stock composition, distribution, environment, predators, etc.

Harvest Control Rules:

This is a relatively new fishery. Harvest Control Rules consist of the NAFO regulated TAC and rules pertaining to groundfish by-catch (NAFO/FC Doc. 02/9).

Future Research Needs:

It is anticipated that direction for the types of research that should be conducted and the overall framework for a Precautionary Approach to the Div. 3LNO shrimp fishery will be determined during:

1. A DFO sponsored "Invertebrate Reference Point" workshop will be held in Halifax, Dec. 2-5, 2002; and
2. The upcoming NAFO Precautionary Approach Workshop.

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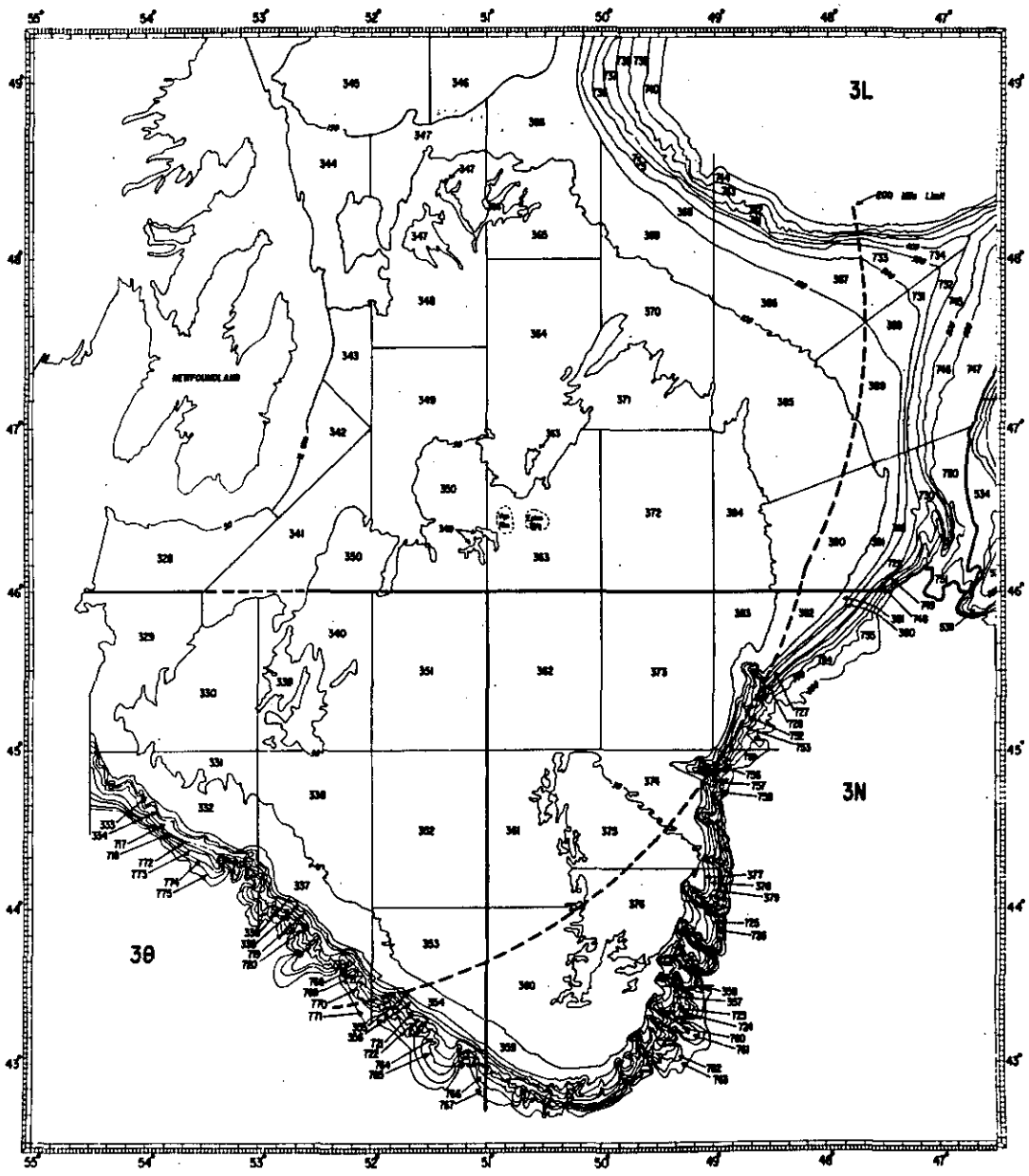

Fig. 1. Stratified area for Canadian research trawl surveys in NAFO Div. 3LNO.

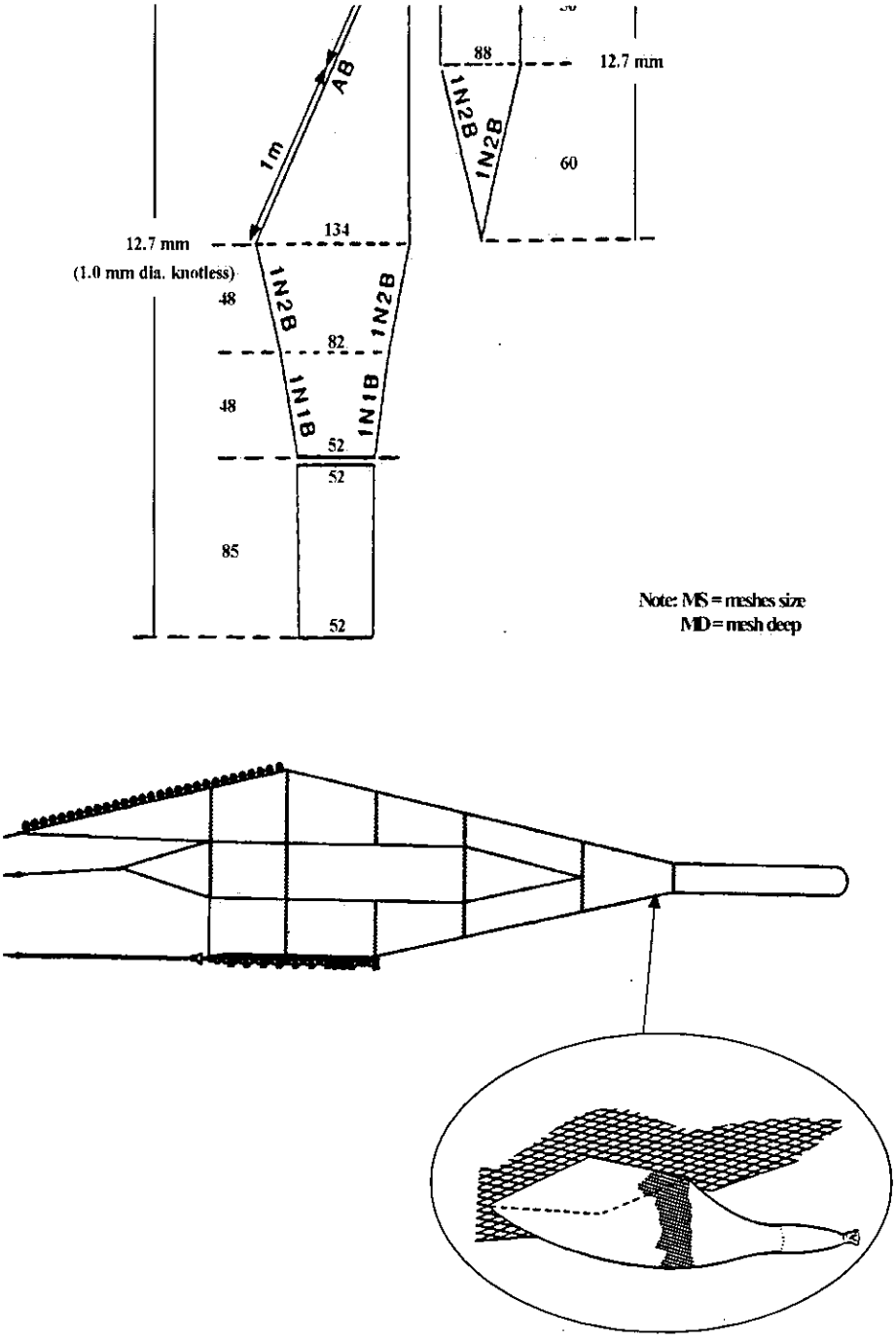

Fig. 2. Campelen 1800 shrimp trawl fitted with a juvenile shrimp net attached 1.0 m forward of the join between the codend and the extension (modified from Nilssen *et al.*, 1986).

Canadian multi-species bottom trawl surveys

Index	History	Utility in terms of PA
Biomass	1995 – present (autumn) 1998 – present (spring)	Very important but due to limited history there is no dynamic range
Abundance	" "	" "
Length frequencies by maturity stage	" "	Very important – provides a recruitment signal; shrimp ages (modal analysis); age of sex inversion; relative year-class strength; Population demographics; instantaneous total mortality estimates derived from this time series
Environment	" "	Very important - includes salinity at bottom, sigma t, bottom temperature, depth, usually includes Roxanne data that may be used in determining bottom type.
Environment	Environment Canada ice charts	– thus far have demonstrated that, for Hopedale and Cartwright Channel (2HJ) shrimp CPUE (lagged by 6 years) increases with increasing areal ice cover.
Predators	1971 – 1982 (spring) used a Yankee 41.5 otter trawl 1982 – 1996 (spring) used an Engel 145 otter trawl 1977 – 1996 (autumn) used an Engel 145 otter trawl 1996 – present (spring) used a Campelen 1800 shrimp trawl 1996 – present (autumn)use a Campelen 1800 shrimp trawl	Very important – decline in cod (*Gadus morhua*) and cool water temperatures have been linked with the present increase in northern shrimp biomass

Observer datasets

Data set	History	Utility in terms of PA
Large vessel (=>500 t)	2000 – present	Very important – almost 100% observer coverage; provides catch, effort, fishing location, gear types, detailed length frequencies, total by-catch of all species as well as length frequencies of economically important groundfish in by-catch
Small vessel (<500 t; <100 ' LOA)	2000 – present	Very important – but not nearly as well covered (as low as 2% of the catch is observed); provides catch, effort, fishing location, gear types, ovigerous/ non-ovigerous length frequencies, total by-catch of all species as well as length frequencies of economically important groundfish in by-catch.

Canadian Logbook dataset

Data	History	Utility
Logbooks	2000 – present	- All vessels must fill out logbooks - Provides catch, effort from which unstandardized CPUE is derived; - In the future standardized CPUE will be modelled; - Catch/ fishable biomass = exploitation rate which is used as a proxy for fishing mortality; - Can make use of fishing location to provide an index of fishery expansion/ contraction (spatial).

International catch and effort

Data	History	Utility
Statlant 21A and B	2000 – present	- Catch and effort from the international fleet fishing in the NRA portion of 3L; - If this data is missing then it may be replaced by estimates made by Canadian surveillance flight data. - International and Canadian catch data are combined in the exploitation rate calculations (catch/ fishable biomass); - In the future, may be able to develop a standardized CPUE model.

Available Data for a PA Framework for the Cod Stock in Division 3M

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Commercial Data

Reported catches were available since 1959, but Scientific Council expressed concern of the reliability of such reports. An independent estimation of commercial catches is available since 1988. Also since then, an appropriate catch sampling is available which provides adequate length distribution and catch at age figures. However, catches decline to less than 1 000 tons in 1998 and became residual since 1999, when a moratorium for fishing take place. Consequently, sampling has been poor since 1998.

Survey Data

Stratified random bottom trawl surveys available are:

1977 – 1985 – Canadian survey
1983 – 1996 (1994 missing) and since 2001 – Russian survey
since 1988 – EU survey

Biological Data

To calculate spawning stock biomass, annual maturity ogives are available from the Canadian surveys in years 1978-1985 and from EU survey in the years 1989-1998 (data for years since 1999 will be soon available).

Stock Estimates

Estimates for recruitment, total biomass and spawning stock biomass are available as results of a SPA for the years 1988-2001 (Vázquez and Cerviño, 2002). However, it was noted that these results are strongly dependent of survey results used to tuning due to the low catch level of the last years.

PA Points Already Estimated

A preliminary estimate for B_{lim} as 14 000 tons was presented (Cerviño and Vázquez, 2000; Vázquez and Cerviño, 2002).

References:

Cerviño, S., and A. Vázquez. 2000. An assessment of the cod stock in NAFO Division 3M. *NAFO SCR Doc.*, No 40.
Vázquez, A., and S. Cerviño. 2002. An Assessment of the Cod Stock in NAFO Division 3M. *NAFO SCR Doc.*, No. 58.