Fisheries and Oceans Science | Pêches et Océans Sciences

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Canadian Stock Assessment Secretariat | **Secrétariat canadien pour l'évaluation des stocks**

Research Document 2000/106 | **Document de recherche 2000/106**

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The northern Gulf of St. Lawrence cod stock – background information on recruitment

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ISSN 1480-4883
Ottawa, 2000

Canada

Abstract

As part of a Workshop on cod recruitment, the FOC (Fisheries Oceanography Committee) reviewed recent trends in recruitment for all Canadian cod stocks to determine if poor recruitment could account for the slow recovery of stocks. Spawning stock biomass of northern Gulf of St. Lawrence cod (3Pn4RS) gradually declined to a minimum in 1994 and has slowly recovered since. Recruitment has been weak through the 1990s. There appears to be a fairly good stock/recruitment relationship in this stock. Recruitment rate (i.e., recruitment given the observed level of spawning stock biomass) has risen in the 1990s, which could indicate a compensatory response of the stock to low abundance levels. Hence the slow recovery of the stock cannot be accounted for by low recruitment given the observed level of spawning stock biomass. Total mortality of adult cod calculated from survey data has been around 0.5 from 1994 to 1997. Taking fishing mortality into account suggests that natural mortality has been between 0.3 and 0.4, which supports the current natural mortality value of 0.4 assumed for the stock in sequential population analysis. There has been a pronounced decline in size-at-age of cod in the late 1980s, early 1990s, indicative of a decline in surplus production.

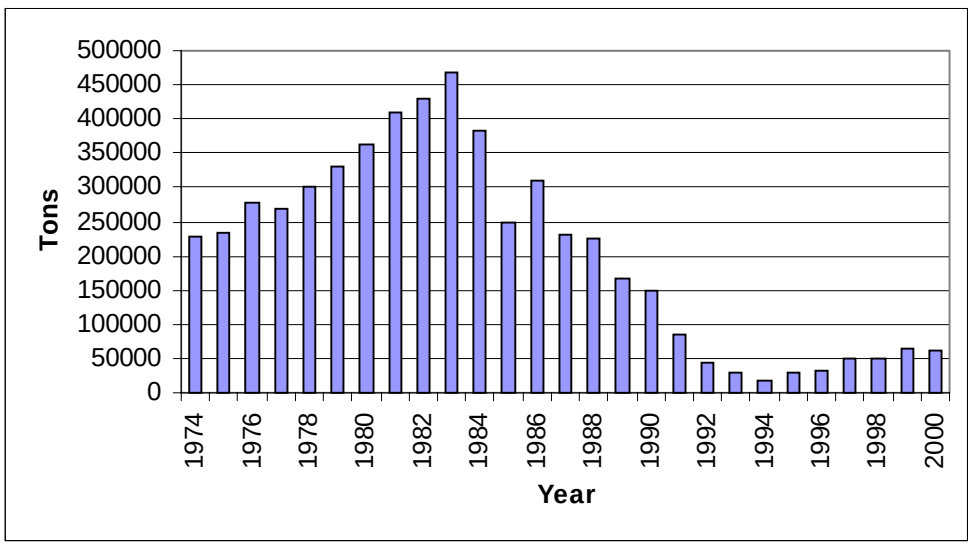
Résumé

Pendant l'atelier de travail sur le recrutement de la morue, le comité d'océanographie des pêches (FOC) a révisé les récentes tendances de recrutement chez les stocks de morue pour déterminer si un faible recrutement pouvait expliquer la faiblesse de la récupération des stocks. La biomasse du stock reproducteur de la morue du nord du Golfe du St-Laurent (3Pn4RS) a diminué graduellement pour atteindre un minimum en 1994, puis remonte lentement depuis. Le recrutement a été faible durant les années 1990. Il semble exister une assez bonne relation stock/recrutement pour ce stock. Le taux de recrutement (i.e., le recrutement étant donné le niveau de biomasse reproductrice) a augmenté durant les années 1990, ce qui pourrait indiquer une réponse compensatoire du stock à de faibles niveaux d'abondance. Il semble donc que la lenteur de la reprise du stock ne puisse pas être due à un faible recrutement compte tenu du niveau de biomasse reproductrice. La mortalité totale des morues adultes calculée à partir des données de relevés a été d'environ 0.5 de 1994 à 1997. En tenant compte de la mortalité par pêche, ceci suggère que la mortalité naturelle était entre 0.3 et 0.4, ce qui supporte la valeur de mortalité naturelle de 0.4 utilisée présentement dans les analyses séquentielles de population calculées pour ce stock. Il y a eu une baisse prononcée de la taille à l'âge à la fin des années 1980 et le début des années 1990 qui indiquent une diminution de la production de surplus.

Introduction

A moratorium on fishing was imposed on most Atlantic cod (*Gadus morhua*) stocks following a period of intensive exploitation in the 1980s and early 1990s. As fishery closures are prolonged, there is increasing frustration in the fishing industry who wonders why are stocks not coming back faster. DFO's Fisheries Oceanography Committee was asked to conduct a workshop on the cod recruitment dilemma and to write a report on the workshop. The first session of the workshop, called "Is there a dilemma?", started with a presentation of hypotheses to account for current levels of recruitment. Following this, DFO scientists from the four regions of eastern Canada presented background information on recruitment rate (i.e., level of recruitment given the observed levels of spawning stock biomass) and on total mortality of adult cod for the seven stocks under consideration (2J3KL, 3NO, 3Ps, 3Pn4RS, 4T, 4VsW, and 4X). Information on total mortality is especially informative when fisheries are closed since it represents natural mortality. This research document presents such background information for the northern Gulf of St. Lawrence cod stock, the 3Pn4RS stock.

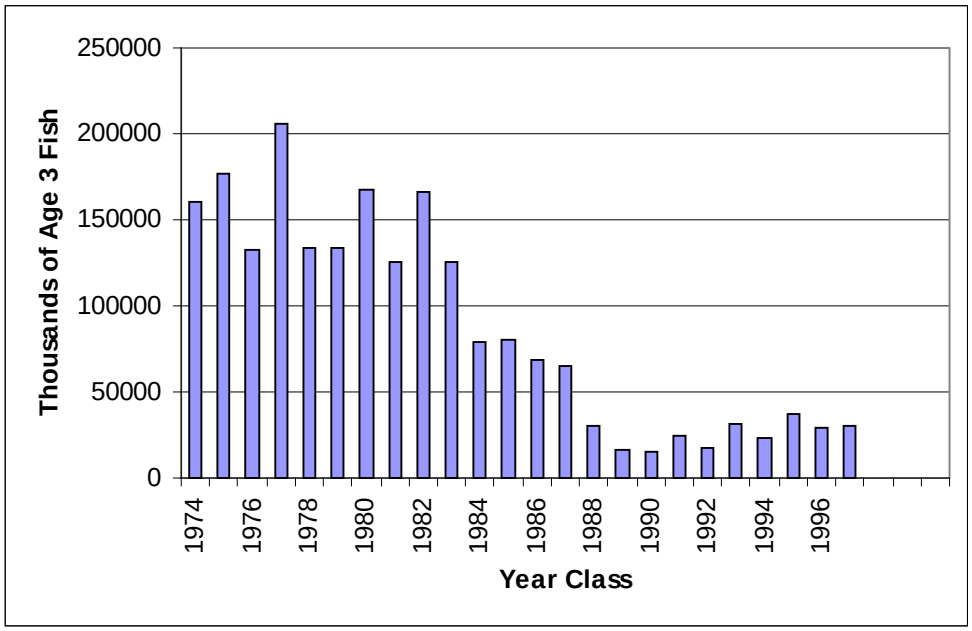
1. Trends in Spawning Stock Biomass (SSB)



- Method: $SSB_i = \sum_{j=4}^{14} N_{ij} W_{ij} P_j$

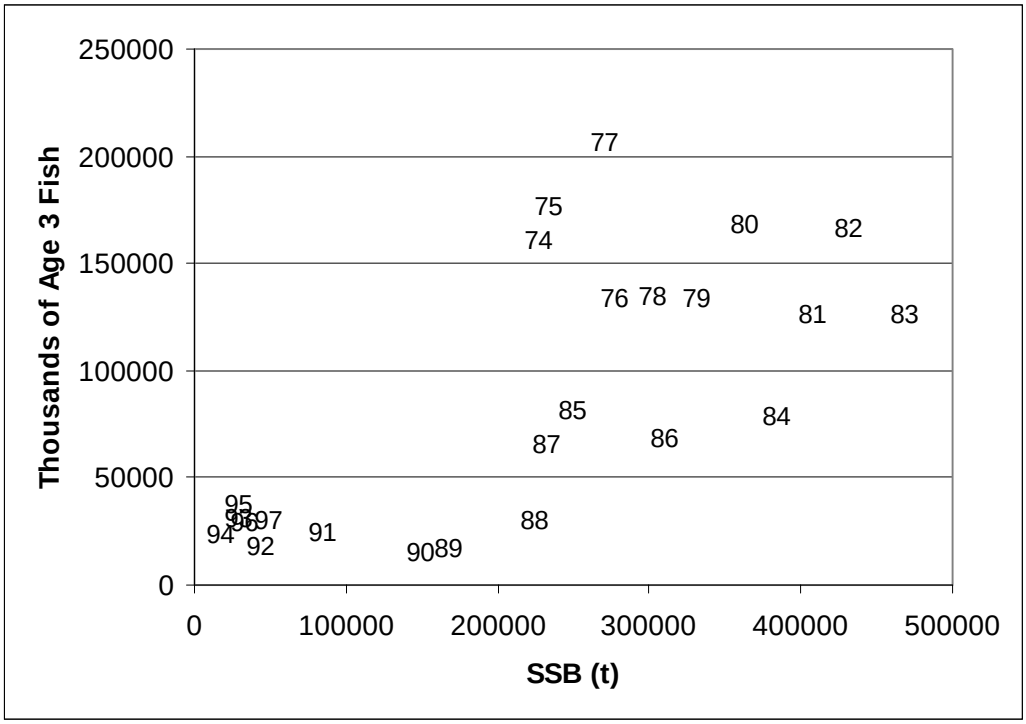
  where N_{ij} is the abundance at age j in year i estimated by SPA, W_{ij} is the mean weight at age j in year i and P_j is the proportion of females mature at age j.
- Increase to a biomass maximum in 1983, followed by a gradual decline to a minimum in 1994.
- Moratorium on directed cod fishing in January 1994 with small-scale reopenings in 1997 (4 400 t), 1998 (3 000 t), and 1999 (6 700 t).
- Slow recovery since 1994 moratorium.

2. Trends in Recruitment



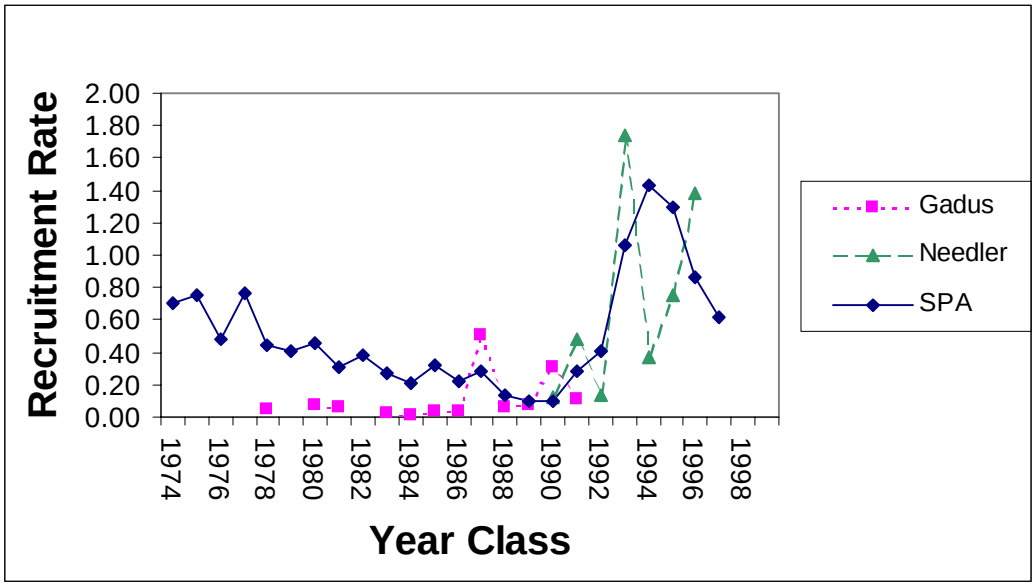
- Maximum recruitment in the late 1970s, early 1980s.
- Gradual recruitment decline since 1983 and relative stability to a reduced level in the 1990s.

3. Stock / Recruitment relationship



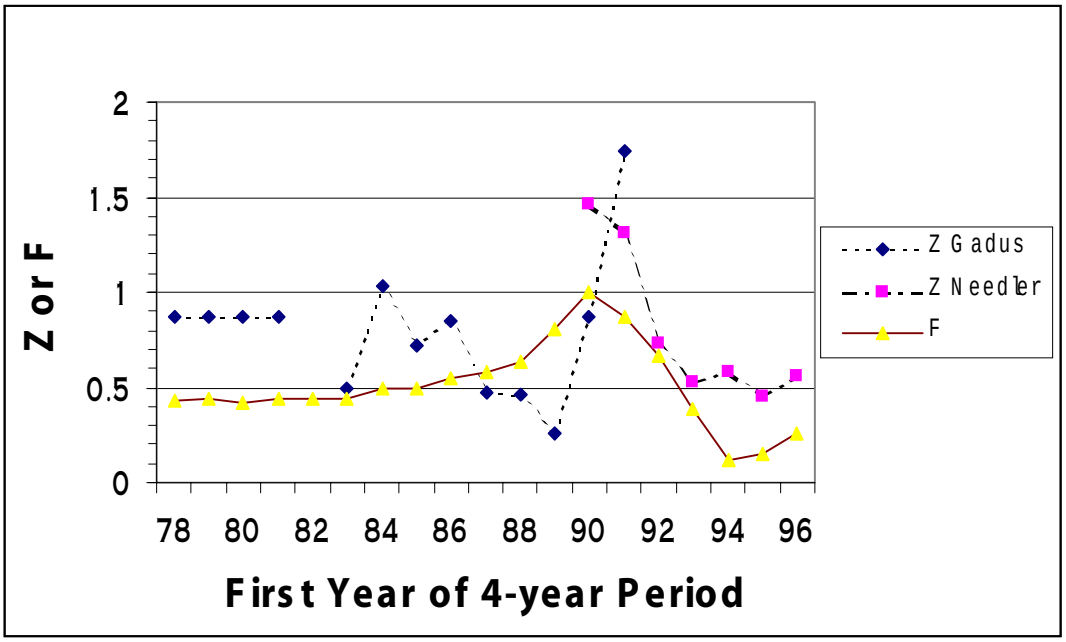
- Number of age 3 fish estimated in the population by SPA against spawning stock biomass in the year fish were spawned (3 years before). The year label indicates the year that fish were spawned.
- Reasonably well defined stock-recruitment relationship indicating that spawning stock size has a strong influence on the strength of recruitment in this stock.
- No occurrence of strong recruitment below a 200 000 t SSB level.
- The 1990s (1991 to 1997) stands out as a period of small stock size and weak recruitment.

4. Recruitment Rate



- Recruitment rate is defined as abundance (numbers) of 3-year old cod estimated by SPA, or mean number of 3-yr old cod per standard tow in the Needler and Gadus research surveys, divided by the spawning stock biomass in the year those fish were spawned. In other words, recruitment rate is the level of recruitment given the observed level of spawning stock biomass.
- Recruitment rate does not appear to have been low in the 1990s. Hence this cannot explain the slow recovery of the stock.
- Recruitment rate calculated from SPA gradually declined from about 0.6 in the late 1970s to 0.1 in 1990, then rose steeply to 1.43 in 1994, and then dropped to 0.6 by 1997, the last year for which estimates are available.
- Recruitment rate calculated from the Needler survey also went up in the 1990s, although with a difference in timing compared to the SPA derived rate.
- Higher recruitment rates in the 1990s may represent a compensatory feedback response to low population abundance.

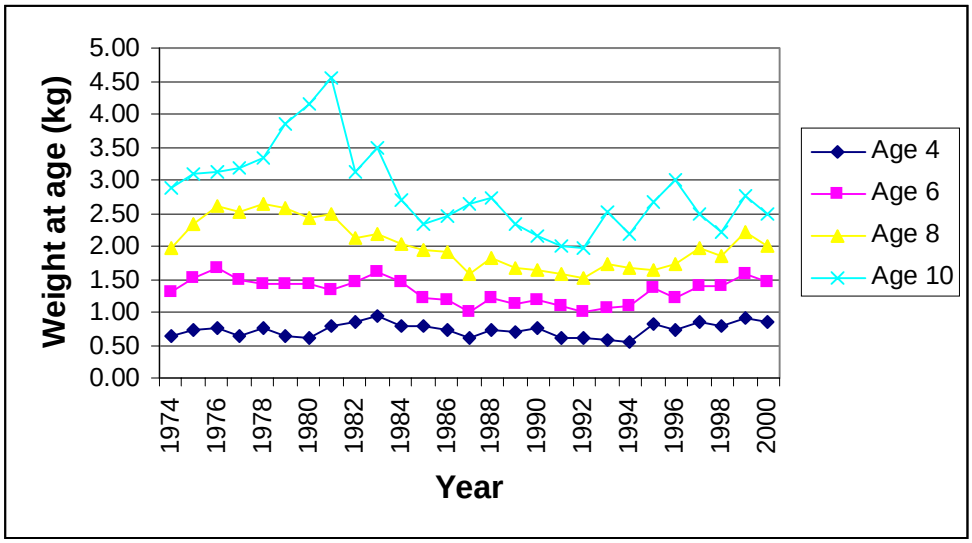
5. Z, the instantaneous rate of total mortality of adults



- The method used here to estimate total mortality of adults (Z) was developed by Chouinard et al. (1999). It consists in estimating Z for moving 4-yr averages using a modified catch curve analysis. An analysis of covariance is calculated with *ln* survey catch rate as the dependent variable, year-class as the class variable and age (ages 6-11 for the Gadus and 5-10 for the Needler) as a covariate which represents Z.
- SPA estimates of F, averaged over ages 6-11 for the same 4-yr blocks, are also included to provide an indication of variation in fishing mortality.
- F estimates from 1987 to 1990 are larger than the Z estimates from the Gadus, which likely reflects a bias in the Gadus winter sampling (part of the population was likely outside the survey area into 3Ps).
- Total mortality increased rapidly in the late 1980s as the fishery intensified, and then declined sharply when the fishery was closed in January 1994. However, even though fishing mortality was reduced to levels near zero from 1994 to 1996, total mortality has remained unexpectedly high in recent years, as indicated by the Needler survey estimates.
- However the $Z_{Needler}$ do not represent only natural mortality since they are 4 year moving averages. The 1994 Z value includes one year with a fishery (1997), the 1995 value includes 2 years of fishery (1997 and 1998), while the 1996 value includes 3 such years (1997, 1998, and 1999). According to the 2000 SPA, F averaged from ages 6 to 11 was 0.32, 0.20, and 0.49 for 1997, 1998, and 1999, respectively.
- Subtracting F moving averages from Z moving averages suggests M values of 0.46 (0.58-0.12), 0.30 (0.45-0.15) and 0.30 (0.56-0.26) from 1994 to 1996, respectively.
- This suggests that natural mortality of adult cod was at a high level when the fishery was shut down in the mid 1990s, above the 0.2 level usually assumed. This could be the result of harsh environmental conditions (Dutil and Lambert 2000), and/or enhanced seal predation and discarding (DFO, 2000).

- The latest assessment (February 2000) for this stock assumes that M has increased from 0.2 to 0.4 since 1986 (DFO, 2000).

6. Size-at-age



- Pronounced decline in weights-at-age from the commercial fishery during the 1980s and early 1990s, with an upward trend since about 1994.
- Another study (Dutil et al. 1999) indicated that declining sizes-at-age resulted from real changes in growth which in turn led to declines in growth production, and hence to declines in surplus production of the stock which made the stock more vulnerable to intensive fishing.

7. Conclusions

- Pre-recruit survival has not been unusually low in the 1990s. Instead, it appears to be high according to both SPA and the Needler survey. This 1990s rise of recruitment rate may represent a compensatory response of the population to low abundance.
- The main factors affecting recovery of this stock are (1) the depleted SSB due to intensive fishing of the late 1980s and early 1990s, (2) a high natural mortality of adults, (3) a slow growth rate of adults in the late 1980s and early 1990s, (4) changes in structure of the spawning stock due to fishing (low mean age of spawners, low age diversity, small size), (6) and possibly the loss of substocks. For a discussion of the latter two points, see the report from the Recruitment Workshop.

Acknowledgments

The author wish to thank Dr. Doug P. Swain for help with Z calculations.

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