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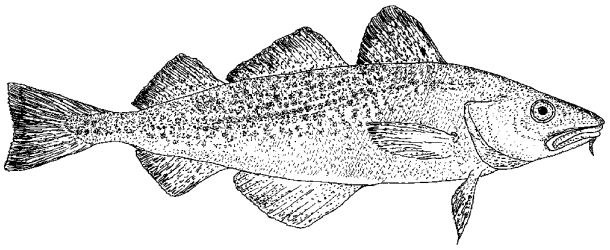
Laurentian Region

Stock Status Report A4-01 (1999)



Cod in the Northern Gulf of St. Lawrence

Background

Cod in the northern Gulf of St. Lawrence (Divisions 3Pn, 4RS) undertake distant annual migrations. In winter, the fish gather southwest of Newfoundland at depths of over 400 m (200 fathoms). During April and May, they move towards the Port au Port Peninsula on the west coast of Newfoundland (Division 4R), where spawning begins. In summer, the cod disperse toward inshore areas, along the west coast of Newfoundland (Division 4R) and the Middle and Lower North Shore of Quebec (Division 4S). This inshore migration is influenced by warmer waters and the presence of capelin, a primary prey species for cod.

Based on the results of numerous tagging experiments, this stock is fairly isolated from other neighbouring stocks (those in 4TVn, 2J, 3KL and 3Ps). Mixing may occasionally occur in the northwestern Gulf (with the 4T,Vn stock), the Strait of Belle Isle (with the 2J, 3KL stock) and on Burgeo Bank (with the 3Ps stock). Recent studies have quantified the magnitude of the mixing around Burgeo Bank during the 1990s.

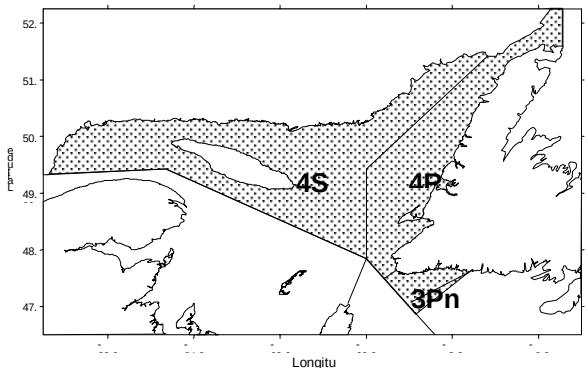


Figure 1. Range of the cod stock in the northern Gulf of St. Lawrence.

Landings (thousands of tonnes)

Year	*1993*	*1994*	*1995*	*1996* [1]	*1997*[1]	*1998*[1]
TAC	*18*	*0*	*0*	*0*	*6*	*3*
Landings	*18*	*0.4*	*0.3*	*0.7*	*4.4*	*3*

[1] *Preliminary data*

Summary

- This assessment is based on eight indices; four bottom trawl research surveys (Gadus, Needler, July mobile sentinel and October mobile sentinel) and four fixed gear time series (Repère and sentinel using hook and line and gill nets).
- The lowest adult biomass was observed in 1994 at 17 Kt, it has slowly increased to reach 55 Kt in 1998. Although there is an improvement, this adult biomass is still much lower than the maximum of 348 Kt observed in 1983.
- The 1993 and 1995 year classes are estimated at 129 million individuals at age 3. This value is close to the historical average. These two year classes are the strongest observed in the 8 last years. The majority of the 1993 year class will spawn for the first time in 1999 and the 1995 year class appears as strong but only a small proportion of them will be mature in 1999 at age 4.
- The directed fishery in 1998 produced landings of 3,000 t with a fishing mortality of 0.11. A harvest of more than 10,000 t in 1999 would be likely to reduce mature biomass.
- Mortality caused by factors other than recorded landings was high in the late 1980s and played a role in the stock's collapse. It is very likely that,

during the 1990s, this mortality remained at least twice as high as assumed in assessments before 1998.

Description of the fishery

The stock was under moratorium from 1994 to 1996. In 1997, a limited fishery was authorized, with a TAC of 6,000 t. Landings totaled 4,400 t. This was brought back to 3,000 t in 1998 and 3,029 t were landed. The directed fishery was restricted to longlines, with fishing effort not exceeding 2,000 hooks per trip. No fishing by foreign vessels was allowed, and the small catches made by trawlers occurred within the context of scientific projects. In Division 4S, 442 t were landed on an initial allocation of 300 t, mainly by gillnets.

The Burgeo Bank area (3Psd) was closed to directed cod fishing during the winter of 1998-1999; this is an area of stock mixing and the purpose of the closure was to minimize the possibility of detrimental effects on the recovery of the neighbouring 3Pn, 4RS (northern Gulf) stock.

Assessment of this stock is complicated by seasonal movement of cod from 3Pn, 4RS into the Burgeo Bank- Hermitage Channel area of 3Ps during winter. Recent analyses of elemental, genetic and meristic markers from cod sampled in the mixing area during January in 1996 and 1997 suggest that the proportion of 3Pn, 4RS cod present in the Burgeo-Hermitage Channel area during the winter can be substantial (more than 50%) declining until April as cod resume their return migration to the Gulf. Information from recent and historical tagging studies, research vessel surveys and commercial catches suggest mixing has occurred in this area for many years. Analyses of changes in length at maturity across the mixing area during winter suggests that the extent of mixing is variable.

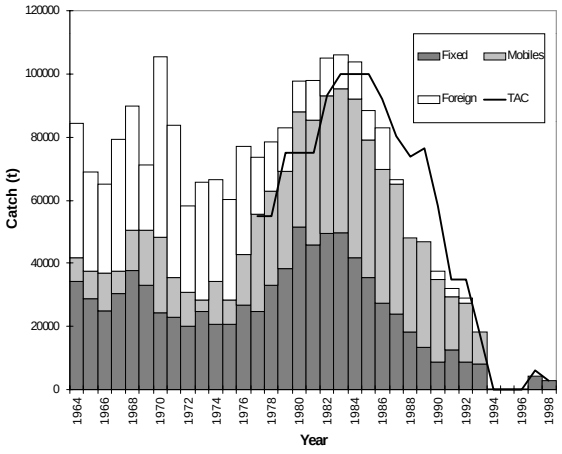


Figure 2. Landings and Total Allowable Catches (TAC).

Results of a telephone survey of fixed gear cod fishers provided a description of their experience and vessel type, fish size, fish condition, timing of migration, fishing depths, occurrence of spawning activity and catch rates for the 1998 cod fishery. Respondents noted improvements in fish size, fish condition and catch rates in 1998 relative to 1992, 1993 and 1997. These improvements were thought to be significant compared to the 1992-93 period (just prior to the northern Gulf cod moratorium) than when comparing 1998 to 1997. The timing of the fish migration into and out of traditional fishing grounds as well as the depth of water in which fish were caught has remained relatively constant since 1992-1993. The majority of fishers did not observe any cod spawning activity during 1998. Similar trends were observed for NAFO divisions 4R, 4S and 3Pn.

The sentinel catches are now included within the TAC. An allocation of 400 t is used to record these landings. Landings from sentinel in 1998 were 350 t.

Biological characteristics

The 1993 year class is moderately strong for the recent time period and the FRCC has recommended not to target this year class. This year class was the only one of importance over the last eight years as indicated in last year's report. The use of hook and line has a large range of selected

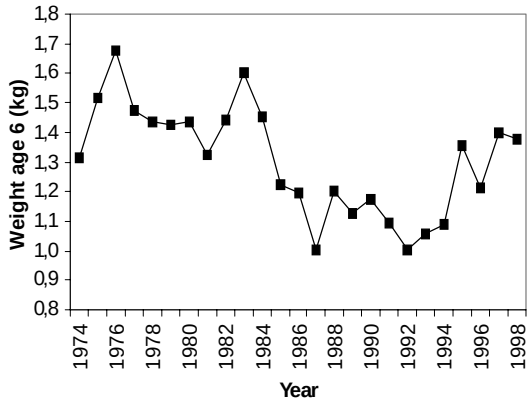


Figure 3. Mean weight of a six-year-old cod caught in the commercial fishery.

fish and only 20% of the 1998 catch at age is comprised by the 1993 year class. The most important age groups from the 1998 fishing season range from 5 to 9 years of age.

The mean weight at age rose in 1996 and 1997 and stabilised in 1998. The average size of the individuals taken by the sentinel fisheries using longlines rose each year during the moratorium. This has shifted to smaller fish somewhat since the commercial reopening in 1997. There are no changes in size composition of the gillnet catches from the "Repère" (1990-1993) and Sentinel programs (1995-1998).

The condition of individual cod reflects their state of health. The condition influences their potential for growth, reproductive success and survival after spawning. It is measured in a variety of ways, by looking at the length weight ratio, the relationship between the liver and the somatic weight (total weight less stomach weight and gonads weight) and finally, the water content of muscle and liver. Since 1995, the condition of the fish has remained good during the summer and fall.

In summer, cod caught by fixed gear near the east coast are in better condition than those caught in deeper waters by mobile gear. This finding may relate to different feeding patterns in the two environments. Inshore cod feed abundantly on prey with a higher energy content (fish), whereas the cod caught offshore eat less food and their diet is less rich (invertebrates). The depletion of oxygen in deep water may also affect digestion rates. These findings are based on the sentinel program and are currently being investigated further.

The condition of cod declined in the late 1980's, reaching a record low in 1991 and 1992, but has improved after that. Condition of cod in the early 90's were very low. Laboratory kept cod with comparable conditions were dying which leads us to believe they could have been mass mortalities in the wild.

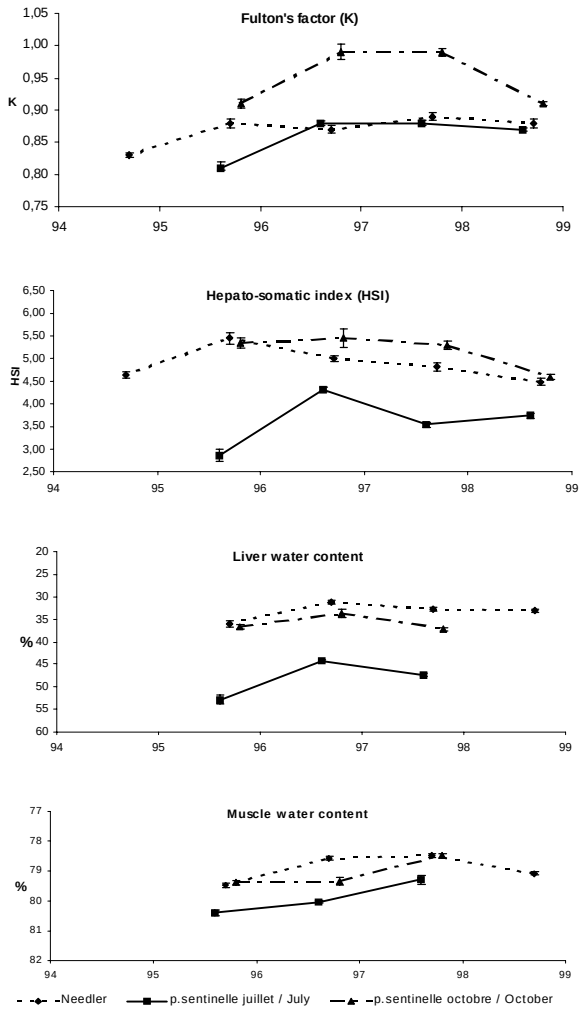


Figure 4. Cod condition from research survey (August) and sentinel survey.

Based on the data from DFO trawl surveys and the sentinel fisheries, **total mortality rate** during the moratorium may have reached 40%. Since no fishing was conducted during the period, that estimate represents natural mortality (M). This high value is incompatible with the value of 18% used in our analyses in the past.

Several factors may explain the increase in natural mortality. They include unfavourable environmental conditions, an increase in unreported catches (discards, misreporting, etc) and higher seal predation. Estimates of the total mortality for the 1995 to 1998 time period remain high (0.46 to 0.62).

The consumption of cod at age by grey and harp seals was calculated for the period 1974 to 1998 based on a constant diet model, and a seal population growth model. For both species, cod at age 1 to 3 make up the majority of ages consumed. Based on ages of otoliths from stomachs of grey and harp seals, they eat cod up to age 11 and up to age 7 respectively. It is estimated that 42 million individuals of age 3 and older were consumed by grey seals in 1998, and 38 million by harps.

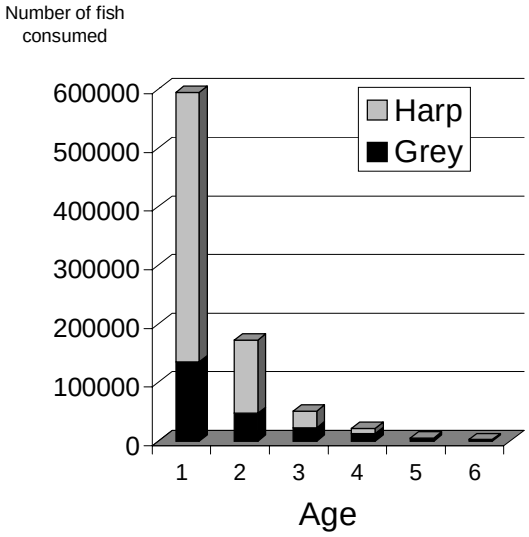


Figure 5. Consumption at age by seals in 1998.

When the seal consumption estimates were included in the sequential population analysis, the historic value of M=0.2 was used from 1993 onwards. Seals were assumed to account for the major part of the increased natural mortality during this period.

For comparison, an additional sequential population analysis not including seals was carried out. For this, the natural mortality is set at 0.4 from 1986 onwards.

During the fall of 1996, approximately 9000 tagged cod were released at sentinel sites in

3Pn, 4RS. A simple Petersen model, applied to returned statistics from 1997 and 1998 estimated biomass in the fall of 1996 to be about 147,000 t.

A comprehensive research program on stock mixing in and around the Gulf of St. Lawrence has demonstrated that in recent years more than 50% of the cod around Burgeo Bank (western part of division 3Ps) in winter are migrants from the northern Gulf of St. Lawrence. Although trawlable biomass in this area has averaged 30,000 t in recent years, management closed the area to fishing during the winter months of 1998. In the absence of a winter fishery on Burgeo Bank, the presence of 3Pn,4RS cod in winter is not expected to impact stock recovery efforts of northern Gulf cod.

Abundance indices

Fixed gears

The "Repère" (1990-1993) and sentinel (1995-1998) sampling protocol and deployment were examined in order to verify if they could be considered as a single index of abundance for the 1990 to 1998 time period. The lack of continuous fishing at individual sites between the the "Repère" (1990-1993) and sentinel (1995-1998) programs and differences in soak time precluded these being considered as one single time series.

The four fixed gear indices used showed similar inter-annual patterns for both gillnets and hook and line (Figure 6). The 1998 catch rates for these gears improved in almost all areas (Figure 7).

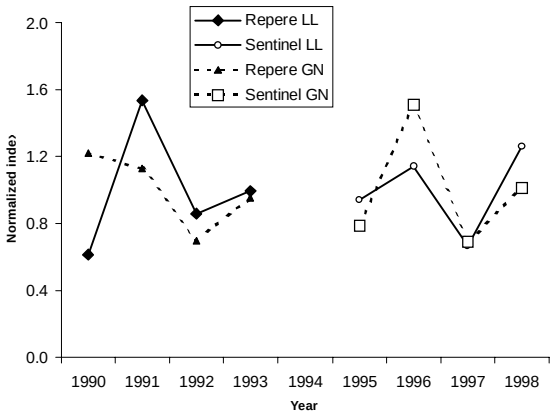


Figure 6. Abundance indices from fixed gears.

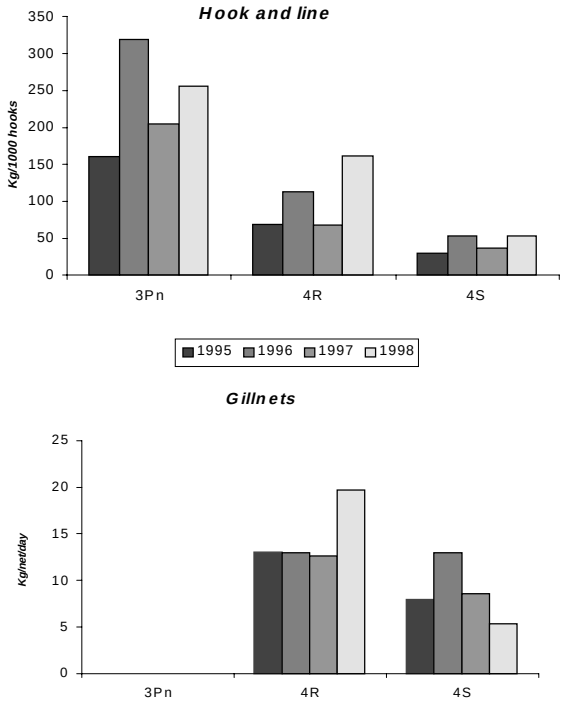


Figure 7. Catch rates of the fixed gear sentinel fisheries.

Bottom trawl surveys

The **sentinel fishery program using mobile gear** began in the northern Gulf in 1994, but it was not until 1995 that the entire offshore stock area was covered. These surveys are conducted twice a year (July and October) using nine trawlers. They carry out stratified random sampling like that done by DFO staff aboard the *Needler*. The gear employed by the nine trawlers was standardized in 1997 by introducing the use of a restrictor cable, which keeps the size of the trawl opening constant throughout fishing operations.

The July abundance index doubled between 1995 and 1997, but remains low in absolute terms. The population abundance estimate declined slightly between 1997 and 1998 for the July surveys. However, the 1995 year-class at age three is the most important in the time series. The October index rose between 1995 and 1996, but declined in 1997. The index of the 1998 October sentinel survey is the highest in the time series exceeding slightly the 1996 and 1997 surveys. The major part of the biomass is located in Division 4R. The distribution of cod does not vary significantly between July and October.

The 1993 year-class dominated catches during the last five surveys, from age two in 1995 to age four in 1997. However, the 1995 year class was the most abundant in both 1998 mobile gear sentinel surveys at age 3.

The *Alfred Needler* (DFO) survey was initiated in 1990 to assess the shrimp and redfish populations in the Gulf. In subsequent years, it was adjusted to enhance coverage of the geographic range of the northern Gulf cod by surveying fishing area 3Pn and waters shallower than 50 fathoms. The number of cod peaked in 1991, fell sharply after that and remained at a low level from 1993 to 1996. The population size rose slightly in 1997. The index from the 1998 survey follows the increasing trend observed since 1993.

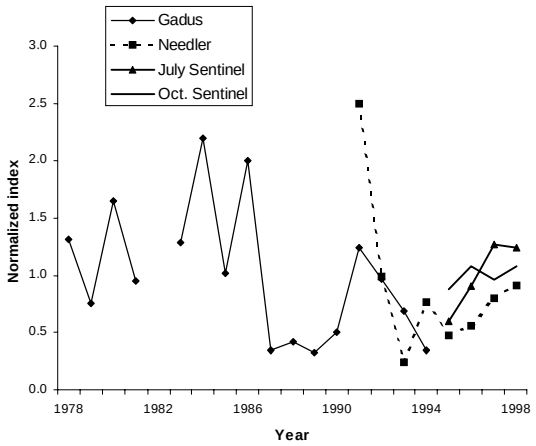


Figure 8. Abundance indices from research surveys.

As in the sentinel fisheries, the 1993 year-class dominated the catches from the 1996 and 1997 surveys. This result attests to the similarity of results from the sentinel operations and the research surveys conducted aboard the *Needler*.

Population analysis

This assessment is based on a calibration that uses eight different indices that encompasses both inshore and offshore gear sectors.

Sequential population analysis, based on combined inshore fixed gear and offshore mobile gear commercial catches together with research vessel survey date, was used in the population analysis. In the last assessment of this stock, the recent increase in natural mortality was reflected indirectly by changing the value used for natural mortality form 0.2 to 0.4 from 1986 onwards. This year, age by age estimates of the number of cod consumed by grey and harp seals were available and were incorporated directly into the population analysis in order to better reflect their contribution to the status of the cod stock.

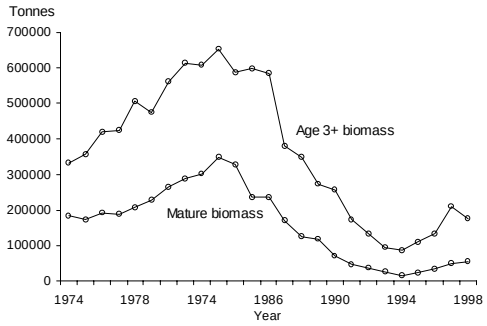


Figure 9. Total 3+ biomass and mature biomass estimated by sequential population analysis.

The abundance of fish three years old and over declined from 613 million in 1985 to 159 million in 1993 but subsequently increased to 232 million in 1998. The spawning biomass was 55 Kt in 1998 which corresponds to only 16% of the historic peak observed in 1983. The minimum mature biomass of 16 Kt was reached in 1994.

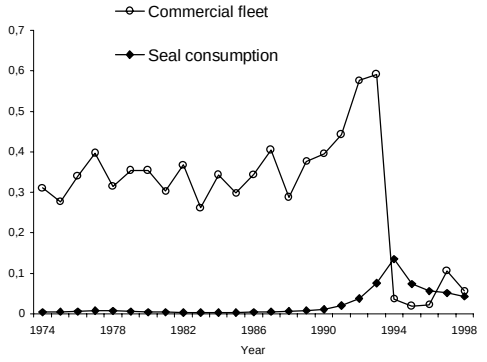


Figure 10. Yearly mortality estimates on fish age 5 to 9 from commercial fleet and seals.

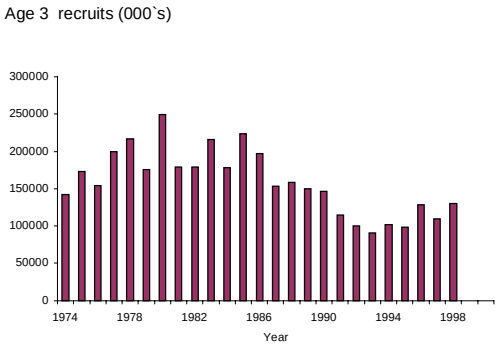


Figure 11. Estimate of recruitment at age three.

The 3 000 t of cod caught by the directed fishery in 1998 resulted in a fishing mortality rate of 0.11.

Sources of uncertainty

The potential impact of the incursions of 3Pn, 4RS cod on Burgeo Bank during the winter was examined by reallocating 75% of the landings taken in 3Psa and 3Psd between January to March and adjusting the catch at age for the Northern Gulf stock accordingly. Landings ranged between 1,200 t to a maximum of 4,144 t in the 1974 to 1993 time period. Yearly landings since 1994 were less than 42 t. These represented only a marginal increase to the northern Gulf cod catch at age.

A population analysis including the Burgeo Bank catch data had a negligible impact on the view of the northern Gulf cod. The 1998 beginning of year 3+ population numbers increased by only 7%. The current approach of limiting the winter fisheries on Burgeo Bank will help keep fishing mortality on the northern Gulf stock to a minimum.

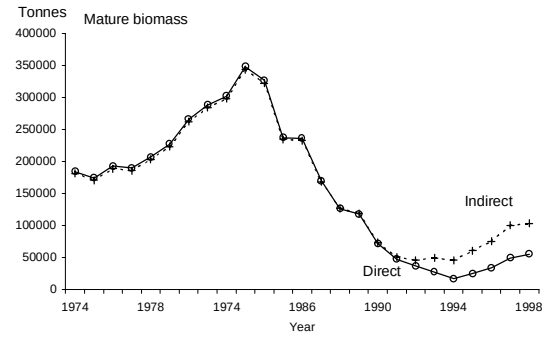


Figure 12. Impact of selecting the seal diet at age (direct) and the change in natural mortality (indirect).

The estimate of the quantity of cod consumed by seals, based on average occurrence of cod otoliths across all years and adjusted to the growth of both seal herds has a number of assumptions. The impact of this formulation is quite high with respect to

the estimate of the recent mature biomass (Figure 12). In addition, there is uncertainty about the number of cod consumed by belly-feeding.

An examination of distribution of catches from the *Needler* survey suggests a recent concentration of cod along the west coast of Newfoundland. The highest concentrations are found in the shallowest strata (30-50 fathoms). It is likely that a variable proportion of cod is found in unsampled inshore areas where the fixed gear fishery takes place.

Any difference in trends of the inshore to the offshore biomass should be picked up by the inshore and offshore indices and will result in large year residuals of the population reconstruction model.

The estimate of the 4+ biomass (147Kt) from the tagging experiment lies half way between the preferred analysis including seal predation estimate (112Kt) and the other analysis in which seal predation on cod was indirectly addressed by assuming a natural mortality of 0.4. The latter produced a biomass in 1997 of 186 Kt.

Under the circumstances of having a relatively high and age-dependent natural mortality, the interpretation of $F_{0.1}$ as a reference point in unclear. In a yield per recruit analysis, high natural mortality generally implies that a higher rate of fishing mortality is required. This is to avoid foregoing catch which would be lost to other sources of mortality. This is questionable in the case, as exists here, that the greater part of the natural mortality will be on age groups younger than those in the fishery i.e. the fishery is targeting age groups that have already survived most of the age-dependent natural mortality. For this reason, no risk analyses in terms of exploitation rate with respect to $F_{0.1}$ are provided.

Outlook

Risk analyses have been done to evaluate the effect of various catch levels in 1999 on the spawning biomass. The results indicate that the productivity of the stock should increase marginally in the short term due to faster individual growth and new recruitment. A ban on fishing in 1999 would allow the adult segment of the stock to grow by 7%, whereas a fishery with a TAC of 10,000 t would prevent any population growth. A catch in the order of 7,000 t would cause fishing mortality of 20% and would allow a marginal increase in the spawning stock.

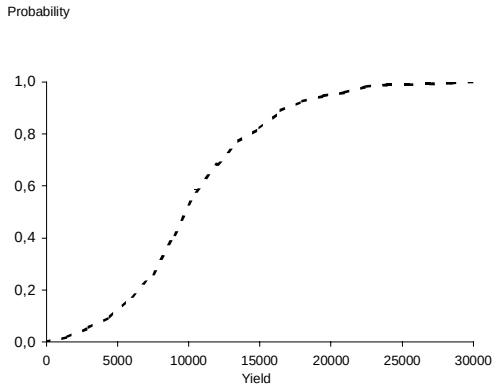


Figure 13. Probality of a decline in mature biomass in relation of various catch levels for 1999.

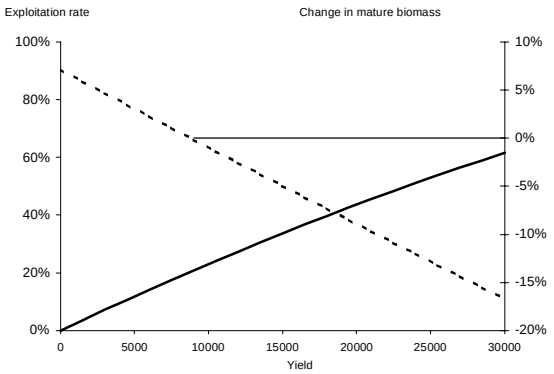


Figure 14. Projected exploitation rate and change in mature biomass relative to various catch levels in 1999.

For more information.

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Prepared by:

Alain Fréchet
Tel: (418) 775-0628
Fax: (418) 775-0679
E-mail: Frecheta@dfo-mpo.gc.ca

Correct citation for this publication

DFO, 1999. Cod in the Northern Gulf of St. Lawrence. DFO Science Stock Status Report A4-01(1999).

Published by

Regional Stock Assessment Office,
Department of Fisheries and Oceans,
Maurice-Lamontagne Institute,
P.O. Box. 1000, Mont-Joli,
Quebec, Canada
G5H 3Z4

Email: Stocksrl@dfo-mpo.gc.ca

ISSN 1480-4913

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