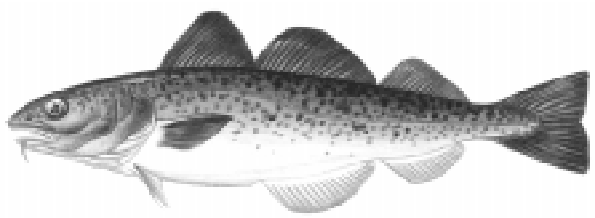
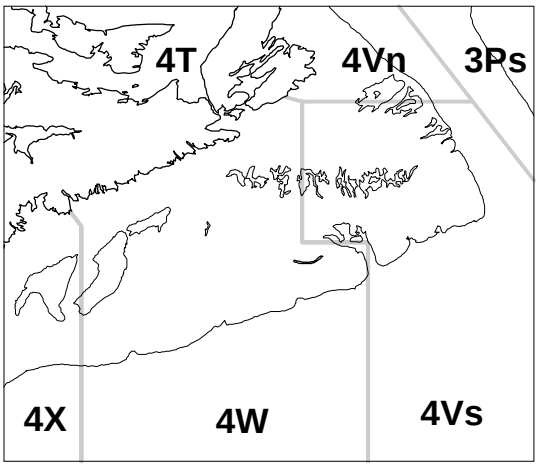


Eastern Scotian Shelf Cod



Background

The cod resource on the Eastern Scotian Shelf is a complex of spawning components including at least two major offshore groups (Western/Sable and Banquereau), smaller offshore groups (Middle Bank, Canso Bank) and a chain of smaller coastal spawning groups. The situation is complicated by the presence of both spring and fall spawning in several of the spawning components (Sable/Western offshore and various inshore areas).

Growth rates differ between 4Vs and 4W so that in the 1970s fish at age 7 in 4Vs reached 68cm while those in 4W reached 72cm. In the mid-1980s growth declined in both areas and the respective average lengths at age 7 dropped to 59 and 54 cm for the period 1985 to 1995. They are fully mature from age 5.

The fishery for 4VsW cod was prosecuted primarily by foreign vessels until the extension of jurisdiction in 1977. Since that time, the Canadian offshore trawler fleet accounted for 70-75% of the landings and longliners most of the rest. Catches from 1958-79 were about 40-50% from 4Vs, however, as the stocks rebuilt in the early 1980s, the fishery shifted more to the east each year and 4Vs accounted for 60-80% of the landings from 1980-93.

Sable Island is a major breeding ground of the grey seal which is an important predator of cod. Seal consumption of cod may be a significant factor inhibiting recovery of this stock.

Summary

- There was no cod-directed fishery in 1997 and the total landings were limited to 231 t of bycatch and Sentinel Program Commercial Index catch.
- Average weight at age has shown some improvement in the last few years from the historic minimum in 1992.
- Surveys indicate that, since the mid-1980s, there has been an increase in the mortality of cod, other than that attributable to fishing, and which has persisted even after the closure of the fishery.
- The scientific evidence indicates that the increase in mortality from sources other than reported landings included discarding, direct and indirect effects of harsh environmental conditions, and predation by seals.
- A population model incorporating most of the plausible range of options for dealing with seal and other mortality in 4VsW cod was examined. These included increasing

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mortality due to seals, to environmental effects and both.

- The spawning stock biomass is at or near the lowest seen, between 5% to 16% of the average from 1979-89. Making plausible assumptions about seal consumption and other natural mortality, the biomass is projected to decline 5% to 20%, even in the absence of any fishery.

- There are inconsistent indicators of recent year-class strength however the weight of evidence suggests that recruitment has been poor.

- The models of cod consumption by grey seals imply a range from 5,400 to 22,000 t of cod being removed by seals. These are relative to estimated biomass of 32,000 to 37,000 t respectively. It is not possible with the available data to choose among these models.

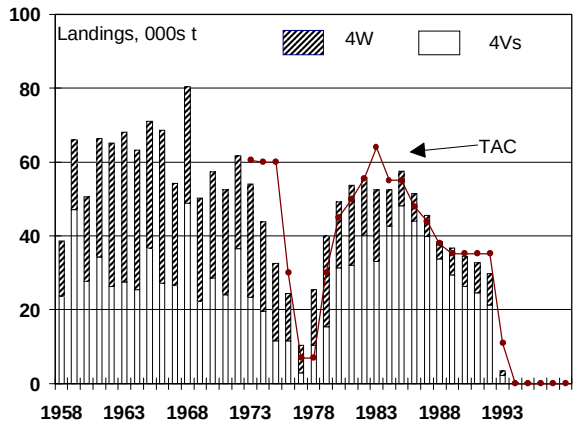
The Fishery

Landings (thousands of tonnes)

Year	58-73 Avg.	73-79 Avg.	80-89 Avg.	1990	1991	1992	1993	94-97 Avg.
TAC	0	43.5	43.9	35.2	35.2	35.2	11.0	0*
4Vs	30.9	13.8	33.3	26.3	24.6	21.3	2.3	0.2
4W	30.1	19.2	13.2	8.1	8.2	8.5	1.2	0.1
TOTAL	60.9	33.0	46.6	34.4	32.8	29.8	3.5	0.3

* = by-catch only

The fishery for cod has been closed since September of 1993 and strict by-catch restrictions have been in place on those fisheries which have continued operating in the area. Since the closure, the **landings** have averaged about 300 t with 1997, at 231 t, the lowest on record. In recent years, the landings from 4Vs have been adjusted downwards to account for the presence of 4T cod in the winter migrating out of 4Vn into 4Vs. This has not been needed since 1994 as there have been negligible winter landings from that boundary area.



Resource Status

Sampling and Surveys

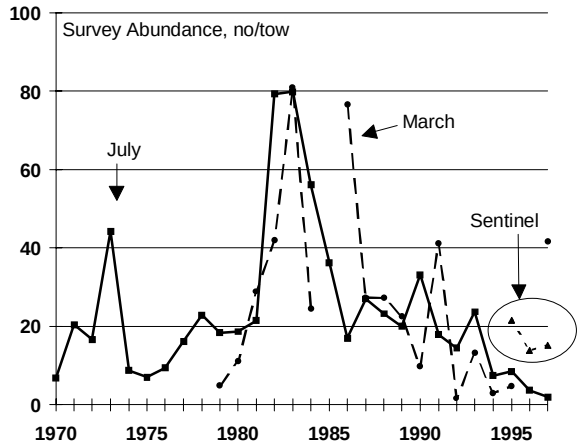
Samples of the commercial catch were again difficult to collect in 1996 and 1997 because landings were limited to by-catch throughout the year. Consequently, the small commercial catch at age has not been well estimated since the closure of the fishery. The numbers at age in the catch indicate that the 1992 year-class was predominant in both 1996 and 1997 and small numbers of fish over age ten were observed. The mean weights at age for ages three to ten show some increases over the last few years. Weights at ages greater than seven are still low relative to long term means but the small number of fish at those ages makes these estimates unreliable.

No commercial catch rate data is available since 1993 as the fishery was closed and no cod-directed effort was recorded.

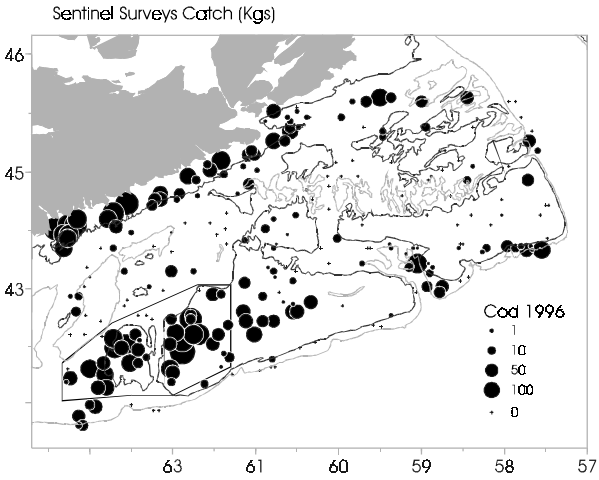
There are two **research survey series (RV)** available for this stock, a July series which started in 1970 and a March series from 1979 to 1997 (except 1985 and 1996). Both series have revealed substantial declines in abundance since

the late 1980s and the July index is at a record low. The March survey index 1997 is the fourth highest in the series. This has been given relatively little weight as the increase was due to two large sets. The abundance index, excluding those two sets, is well below average.

The newest survey series is the **4VsW Sentinel Survey** which has been conducted in Sept.-Oct. for 1995-1997. This survey uses standardized longline gear to sample 250 stratified random stations each year.

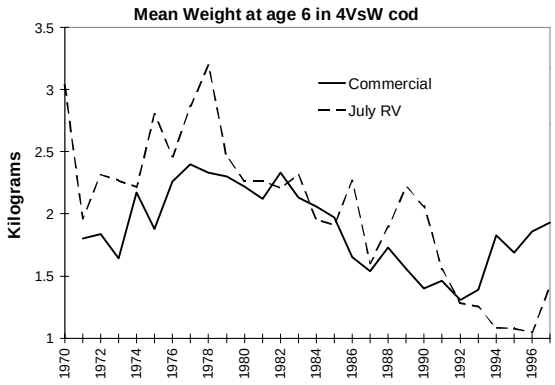


The distribution of catches in the surveys show most of the cod are found on the 4W banks (Western, Sable, Emerald) throughout the year. The **Sentinel survey distribution** also indicates that, at least during the fall, there are concentrations of cod in the nearshore areas. Although the results of the Sentinel surveys to date have not been incorporated into the assessment analysis, it is expected that they will be when the time series is long enough.



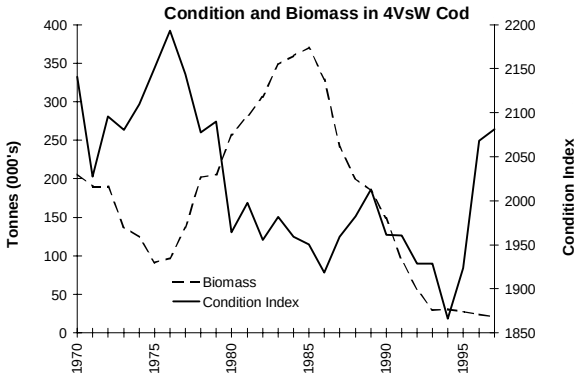
Stock Biology

Size at age has declined in this stock since the mid-1980s, both in the survey and commercial catch data. Since about 1992, the consistent decline in size at age for all ages seems to have levelled off and some improvements seen.



Condition is the relative weight of the fish for their length, i.e. their plumpness. Up to 1989, there was a highly significant negative relationship between population biomass (age 3+) and the condition of the fish in July. This suggested that in periods of high abundance the condition of the fish was reduced. As the population biomass declined in the early 1990s however, the condition index continued to fall and remained low until 1995. Although higher, there is greater uncertainty in the 1996 and 1997 estimates due to relatively small sample sizes. These condition observations are consistent with

the widely reported loss of weight seen by the industry and the presence of "slinky" fish in the catch. Investigations into the cause and significance of low condition in fish have suggested that low temperatures can induce poor condition and that reduced survivorship and reproductive sucess can result. This is also consistent with the appearance of colder waters on the eastern Scotian shelf since 1986.

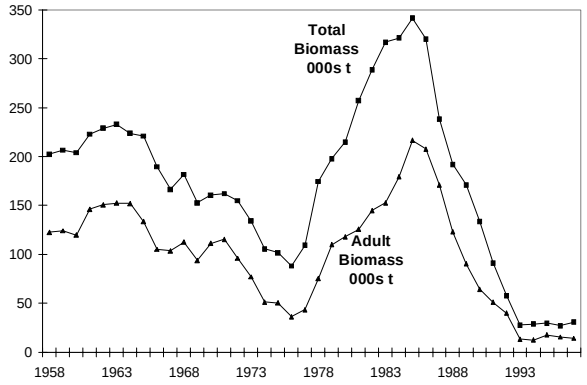


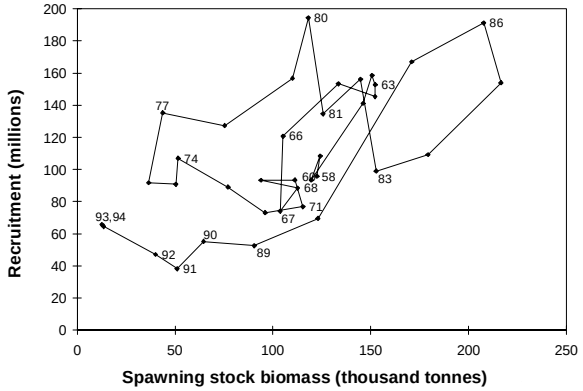
Estimates of **grey seal predation** were first presented in 1993 using information on the composition of grey seal diets collected between 1989 and early 1993. The proportion of cod (mostly less than 4 years old) in these samples did not indicate a trend over the sampling period. Given the low and declining biomass of cod, it was possible that grey seal would reduce their predation on cod in favour of more abundant prey. However, samples collected from Sable Island between the summer of 1993 and the fall of 1997 show that the proportion of cod in the diet, although variable among samples, has shown no trend over eight years of sampling on Sable Island. The mean percentage of cod in the grey seal diet has remained at about 12%. Given that the grey seal population has apparently continued to increase at the same rate as previously measured, the estimate of consumption of 4VsW cod by grey seal is 22,000 t in 1997. Alternatively, if seal consumption of cod varies in proportion to cod abundance, i.e. declines when cod are scarce, the estimated consumption in 1997 would be about 5,400 t. Because of uncertainties in the diet data, neither of these possibilities, constant proportion consumption nor variable proportion consumption, can be ruled out. The subsequent population analysis is based on a modified variable proportion diet model which lies between the bounds of the two options above.

Population Analysis

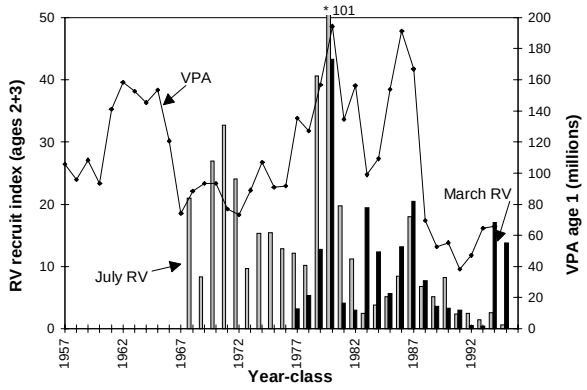
The standard age-based population analysis used in previous assessments was revised substantially to incorporate additional information about non-fishery mortality. Sources considered include discarding, seal predation and increased natural mortality due to unfavourable environmental conditions. The population analysis presented here includes modified proportional consumption by grey seals. All other factors are included as a single increase in natural mortality from 0.2 to 0.4 in 1986 and constant afterward. Although this was deemed the most plausible model overall, there are numerous uncertainties, some of which can have an important impact on the assessment of stock status. The impact of important changes in the assumptions made in this assessment is considered separately in the section on sources of uncertainty.

Spawning stock biomass and **total biomass** are both near the lowest in the time series. The biomass had recovered rapidly from the previous low period in the mid-1970s and reached its highest point in 1985 when the very large year-classes of 1979, 1980 and 1982 were present in large numbers. Since the closure of the fishery in 1993, the decline has halted; however, little or no recovery of spawning stock biomass has followed.



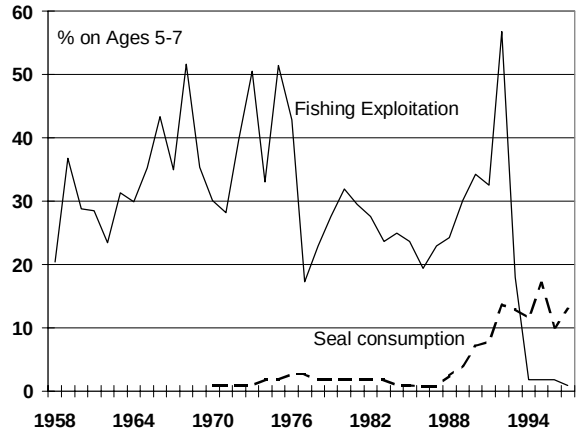


Recruitment since the mid-1980s has been below average however this is one point of uncertainty which is heavily dependent on the assumed pattern of seal predation on cod. The March RV index of recruitment did detect some relatively large numbers of young fish in 1997 however they were not widespread and the estimate is not considered reliable.

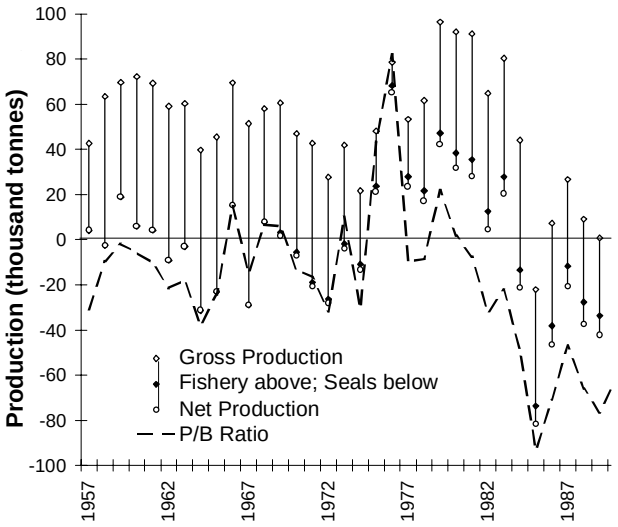


The long-term relationship between **stock and recruitment** showed little correlation until about 1986. Since that time, the relationship has been positively correlated, with both stock and recruitment declining simultaneously.

Both the **exploitation rate** from the fishery and the seal consumption have been estimated for this stock. Uncertainty about the assumed pattern of seal predation on cod has considerable effect on the apparent total rate of removals in the period since the closure of the fishery.



Gross production, the total biomass added to the population in a year without regard to its fate, declined drastically between 1985 and 1986 and has remained very low since. On the figure below, the vertical lines connect the gross production to the **net production**, the year to year growth in the biomass after the fishery and other removals have been deducted. The vertical line is partitioned into the fishery removals above the horizontal tick mark and the seal removals below it. In spite of no increase in gross production, since the closure of the fishery, the net production has been near or

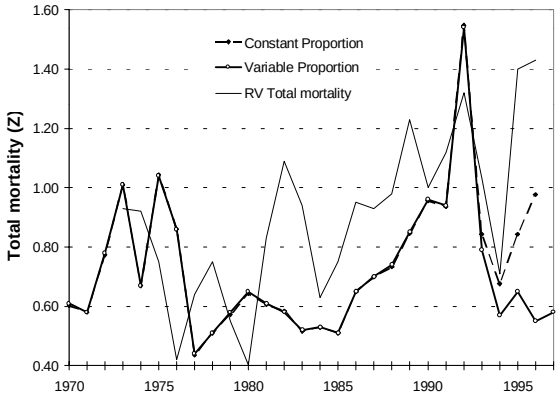


slightly above zero, i.e. the biomass decline has been checked.

The **production to biomass ratio** (P/B), a measure of production adjusted for the current size of the population, had declined from its peak in 1977 to its lowest point in 1986 and has generally increased until it is now above the historical average of 0.26.

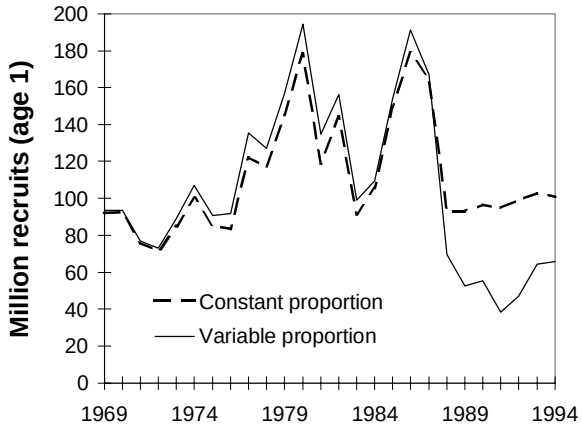
Sources of Uncertainty

Because the perceptions of this stock's history are dependent on various assumptions, particularly about sources of mortality, a number of important alternative assumptions are considered. The single most important assumption concerns the pattern of seal predation on cod. In the analysis presented, it has been assumed that seals would consume up to 20% of their diet as cod and that when cod abundance varies the proportion of cod in the diet will vary as well. As an alternative, the data on seal diet are also consistent with cod being a constant proportion of about 12% of the diet. These two assumptions are considered bounds on the range of likely predation by seals on cod. They have important differences in perceptions of mortality and recruitment. The **total mortalities** estimated under the two diet assumptions are indistinguishable up to and including 1992.



However, the assumption of constant proportion diet is more consistent, since 1992, with the total mortality estimated from the surveys alone than is the variable proportion alternative.

The **recruitment** estimated under the constant proportion of diet assumption for the 1988 and all subsequent year-classes is much higher that that under the variable proportion assumption. In fact, the estimates are near the longterm geometric mean for this stock. This is inconsistent with the recent RV survey indices of recruitment. Except for the March 1997 survey point, even the estimates from the variable proportion diet assumption are very high relative to the survey indices (see figure in population analysis section).



Thus the constant proportion model of seal consumption implies high recruitment at age 1 and high total mortality, especially on the youngest ages. While such total mortalities are consistent with those calculated from the RV surveys alone, there is no evidence from surveys or elsewhere that there are large numbers of juvenile cod which are being consumed before age 3 or 4.

The variable proportion models of seal consumption of cod imply that recruitment has been relatively low but that the total mortalities are also relatively low. In this case the recruitment prediction is consistent with the survey observations but the total mortality is much lower than the survey data indicates.

The March 1997 survey point has not been used for calibration of the population analyses because the value was anomalously large, the age composition was inconsistent with previous surveys and the large abundance estimate was driven by two large catches out of 126 sets made. All of these points challenge the reliability of the overall abundance estimate from March 1997. If these data are included in the population analysis it creates a much more optimistic view of the current resource status.

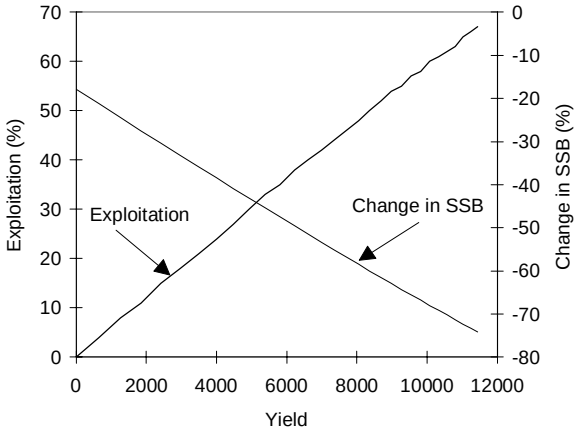
Although many scenarios were considered, there is little uncertainty about the status of the spawning stock biomass. The estimates of spawning stock biomass for recent years are very low in all cases.

Outlook

The short-term prospects for this fishery remain dismal. The productivity of the stock is very low, there are several factors causing increased mortality overall as well as seal predation on the younger age groups. The spawning stock biomass, while not declining, has not rebuilt since the closure of the fishery.

The most optimistic prognosis for this stock is based on including the March 1997 survey data. Although considered unreliable, the March 1997 survey suggests that there are more cod in the stock area than detected by the July survey. If the March 1997 survey were included in the population analysis, then the prospects for improvements in the spawning stock biomass would be much better. The spawning stock biomass could increase by 15% in the absence of any fishery and catches up to 4,000 t would not cause any decline in biomass.

The most likely population analysis, presented in the preceding sections, is much less optimistic. Based on one year **projections,** the exploitation rate and change in biomass associated with a range of yields indicate that, even with no fishery, the spawning stock biomass is projected to decline by about 18%. Although this can be cast in terms of risk, there is little point as there is a very high probability that the biomass will decline in 1999 without any fishing. Thus even by-catch in other fisheries may pose a serious threat to the recovery of this stock.



It is not possible to distinguish between the two models given the existing data, however the two different models of seal consumption of cod lead to different conclusions about the impact of seal predation on the rebuilding of

the cod stock. If cod is a constant proportion of the seal diet it suggests that cod recruitment at age 1 has been good in recent years but that survival of those recruits to age 3 or 4 has been very poor. This leads to the conclusion that cod stock rebuilding will not likely occur while this degree of predation continues. The variable proportion model of cod in the seal diet suggests that recruitment, even at age 1, has been poor and that subsequent survivorship to age 3 or 4 has been much less of a factor in the failure to rebuild than it is in the constant proportion model. Thus, in the variable proportion model the recruitment to the fishery will be less affected by seal predation than in the constant proportion model. Regardless of which model of seal consumption of cod is closer to reality, the recruitment and subsequent survivorship must both improve before it is likely that the stock will rebuild strongly.

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