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Elements of a Non-parametric Precautionary Framework

by

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Introduction

The results of scientific assessments are often communicated to non-scientific audiences with the assumption that the terminology and the relevance of quantitative results will be fully appreciated. However, the subtleties of technical details are most often not fully understood and, worst, contribute to the weakening of the ultimate message. As a result, the overall message is often lost.

For non-technical audiences, the quantitative information could be transformed in various ways with the aim of drawing attention on the main characteristics of the data under consideration. In recent years, there has been considerable advancements in the field of communicating complex and technical information in simple and efficient ways to public audiences. For instance, the computer literature provides numerous examples of how complex technical information on computer systems could be presented so as to provide an index of performance. Similarly, the literature aiming at providing information to "consumers" provides a number of examples on how to reduce massive amounts of information on various products so as to arrive at a single measurement of quality or value.

From the standpoint of the consumers of fisheries-related information, there would be immediate benefits to being able to obtain, at a glance, a global view providing full appreciation of the status of a given stock or the performance of a given fishery. Often, the major characteristics of the information is lost in the mass of unnecessary details and it remains difficult to fully appreciate how the stock performs with respect to the past, in comparison to neighbouring ones or in the overall context of Atlantic fisheries.

The aim of this paper is to illustrate, using the major cod stocks of the Northwest Atlantic, how the results of annual assessments could be displayed so as to improve the ability of the readers (i.e. the consumers of information) to fully appreciate the message. In an attempt to further simplify the material, an overall index of stock health based on the performance of the fisheries and the characteristics of key biological stock parameters is proposed. The proposed framework has a statistical foundation, being based on simple non-parametric statistics. The approach does not imply the loss of scientific content but put emphasis on the main characteristics of each observations rather than its actual value.

Material and Methods

The results of stock assessments are generally cast in terms of trends in recruitment (R), total biomass (B), spawning biomass (S), and fishing mortality (F). The performance of the fisheries is often expressed in terms of catch levels (C) and catch rates (U). In addition, information on fish growth or weight (W) is often used to provide an indication of fish condition.

For each of the principal cod stocks of the Northwest Atlantic, the time series of observations on the above measurements (i.e. R, B, S, F, C, U, and W) were obtained from the most recent assessments as follows: as per Bishop et al. (1994) for the southern Labrador and northern Grand Banks stock; as per Davis et al. (1994(1) and 1994(2)) for cod in southern Grand Banks; as per Bishop et al. (1994) for the Saint-Pierre Bank stock; as per Fréchet et al. (1994) and Sinclair et al. (1994) for the two stock in the Gulf of St. Lawrence; as per Mohn and MacEachern (1994) for cod on Banquereau and around Sable Island; as per Gavaris et al. (1994) for the Browns Bank stock; and as per Hunt and Buzeta (1994) for the Georges Bank stock. The basic data used in this analysis have been compiled with the assistance of these autors and documented in Rivard (1994). Whenever possible, the measurements (denoted below by the subscript y) were obtained from 1960 to 1993. Indices of abundance were also obtained for each stock.

The observations in each time series have been classified into one of four categories representing the quartiles and labelled as:

Much below average
Below average
Above average
Much above average

Each value of the time series were replaced by a symbol selected to identify its quartile. While more complex schemes could be developed, a classification into four categories has the advantage of simplicity while preserving information content. Depending upon the purpose being pursued, classification into three or five categories could also be considered.

In order to maintain consistency of interpretation of these results, it is desirable to give a direction to the classification scheme. For instance, we will want to classify the time series from "good" to "bad". Consequently, we want to be able to identify the four categories as:

Much worse than average
Worse than average
Better than average
Much better than average

This reclassification is necessary as for some measurements, "much above average" may correspond to a desirable property (e.g. for total biomass) while it corresponds to an undesirable property for another (e.g. fishing mortality).

In order to permit a comparison of results for different stocks, the initial categories were defined from the 1970-1993 time period whenever possible (there are a few stocks for which the time series started after 1970). The resulting categories were then applied to the entire time series.

An overall index of stock status, of the fisheries performance or simply of the health of a stock could be defined for each stock through a weighted or unweighted average of the basic information. The overall index could be based upon a number of measurements describing the stock performance: total biomass, spawning biomass, recruitment, growth, etc. The definition must take into account the peculiarities of a given stock, including the lack of information on certain measurements. As conventional analyses do not permit averaging information having different units as a matter of principle, they do not easily lead to the exploration of virtual or conceptual quantities such as "usability", "overall performance", or "overall stock health".

In order to calculate an overall index, each measurement was given a value of 1 to 4 corresponding to its category:

Category	**Assigned value**
Much worse than average	1
Worse than average	2
Better than average	3
Much better than average	4

Then the value of the overall index in year y, say I_y, was calculated as follows:

$$I_y = (R_y + B_y + S_y + F_y + C_y + U_y + W_y) / 7$$

where R_y, B_y, S_y, F_y, C_y, U_y, and W_y are the categorical representations of the measurements. The resulting index will be referred to hereafter as the "Overall Stock Performance Index". Each value I_y is then replaced by a symbol selected to identify its category as follows:

Much worse than average	$I_y <= 1.5$
Worse than average	$1.5 < I_y <= 2.5$
Better than average	$2.5 < I_y <= 3.5$
Much better than average	$3.5 < I_y$

While simpler or more complex overall indices of "stock health" could be developed, the formulation suggested here performed well for the stocks considered.

Results.

The results of a classification into four categories are presented in Table 1 for the principal cod stocks of the northwest Atlantic. Table 1 also shows the results of the application of the Overall Stock Performance Index. The results are consistent with the general understanding of the status of these cod stocks. In particular, while most stocks were "much better than average" in the sixties, they have declined in recent years to conditions that are "much worse than average". The overall index follows the same patterns. A single look at these tables allows the reader to put recent trends in perspective.

The similarities between the "observed indices" (e.g. research vessel indices) and the measurements taken into consideration in Overall Stock Performance Index suggest that the "observed" indices could themselves be used directly for calculating an Overall Performance Index or for providing information of recruitment, biomass, spawning biomass when these cannot be obtained through traditional methods.

General overviews could also be prepared using the same framework. An overall view comparing the various stocks is presented in Table 2. In this case, only the Overall Stock Performance Index is tabulated. The similarities in the overall performance ot these stocks over time is striking. For instance, the performance has been have been "worse" or "much worse than average" for all stocks since 1990.

Table 3 provides an "Annual View" of the Stock Performance for 1983 and 1993 based on initial measurements. A similar tabulation could be made for other years. The 1993 yearly view suggests that the most measurements of "performance" were "much worse than average" for all cod stocks. There is an exception for fishing mortality which appeared to have been reduced considerably as a result of the application of stringent conservation measures.

A Species Performance Index could also be derived using the same framework. While this has not been done here (as only one species is involved), the outcome would be a performance index caracterizing a given species or species group, thereby providing an "ecosystem" view of the performance index.

Discussion

The Overall Stock Performance Index" used here seem to perform well when the measurements entering in its calculation are consistent but may not be adequate when measurements in a given year belong to "diverging" categories. In the latter case, the values of the index tend to concentrate in the "middle" categories, with little classification into the "extreme" categories. This problem is apparent, for example, for cod in 3NO (Table 2). The problem could be alleviated, however, by defining new categories identifying the quartiles of the Overall Performance Index. The drawback of such an approach (which is equivalent to a rescaling) is that the symbolic representation of the index may not correspond to the "average" derived from the initial measurements.

There are many advantages to the framework being proposed here:

- Because the results are represented by symbols representing the historical performance, abstraction could be made of the scale of each measurements (e.g. there is no need to explain what a value of 1.5 means for fishing mortality). As the

actual values of the measurements are replaced by symbols representing broad categories, there is no room to argue on changes that are irrelevant from a conservation standpoint.

- Because actual values are transposed into symbolic terms representing a relative scale (from good to bad; or from low to high), the emphasis is shifted from the meaning of "absolute quantities" to their relative importance. As stock abundance estimates relate more to virtual quantities than to absolute quantities, the proposed scheme treats the information in a manner that is more consistent with the state of the art in stock assessments.

- The framework could be used for the synthesis of data from a wide variety of sources, such as quantitative (or scientific) assessments, information based on categorical classifications and, with adequate treatment, traditional knowledge which arises from the experience of fishermen. The information on a number of measurements not typically measured in stock assessments could also be represented in such a fashion: e.g. condition factors, environment variables influencing the stock, indices of spatial distribution, measurements on ecosystem diversity, etc.

- The Overall Performance Index could be based upon a wide variety of measurements: numerical, categorical or qualitative. Also, the framework does not necessarily demand analytical assessments through complex, age-structured models. It could accommodate information from simple "global" models, from more complex models, or both. It could also be solely based on measurements and bypass completely intermediate analyses. As a result, the overall index could be useful for stocks for which there is insufficient information to carry out analytical assessments. It could also provide an alternative approach to stock assessment when traditional methods fail in a given year for unforeseen reasons.

Refinements to the definition of the "overall index" could include the use of more measurements (e.g. condition factors), the use of more values per measurements (e.g. recruitment for years y-1, y-2 and y-3 would presage poor conditions in year y) or simpler formulae based on observed indices (e.g. research surveys and catch rates). However, refinements should keep in line with the overall objective of defining an index of performance (not necessarily an index of abundance) that is meaningful for the end user.

There is no unique way to define a global index and to translate its values into categories that are meaningful for management. In many cases, it may be advantageous to define the categories as qualifiers for the impact of the harvest on the resource. For instance, the following categories could be used to describe the state of the resource:

- Underutilized
- Fully utilized
- Overharvested
- Collapsed.

Defining categories that are mutually exclusive may not be straightforward as they could involve many measurements (e.g. catch, biomass, recruitment, etc.) and multi-level criteria for defining the thresholds. For instance, the Northeast Fisheries Science Center, U.S.A. (Research Highlights, July-October 1994, pers. comm.), uses three objective conditions to define the state of a resource as "collapsed": 1) recruitment that is chronically low; 2) greatly reduced proportion of older fish; and 3) prolonged periods when the yields are less than 25% of what would be sustained in a healthy population. If these conditions were the basis for the definition of the "Collapsed" category, then a number of subjective decisions would have to be made to define the boundaries of the other three mutually exclusive categories (i.e. "Overharvested", "Fully utilized", and Underutlized"). As there is no unique and simple way to define those, such an approach should be developed in consultation with stakeholders so that mutually exclusive categories can be agreed upon *a priori*.

Ultimately, the framework would be amenable to a management-testing scheme such as that employed by the International Whaling Commission whereby simple control procedures to be applied for the management of the fishery are developed from performance criteria and simple feedback control rules (or procedures). In essence, what is a framework for communication could become a framework for assessment of performance and evaluation

of management strategies. While the framework would not allow for catch projections in the context of TAC setting, a scheme could be developed to define sets of rules (or procedures) by which adjustments to catch levels would be made.

Estimates based on non-parametric treatments of data are often more robust to anomalies in the data than parametric approaches. Future research in this area would be needed to evaluate the robustness of such an approach and its ability to cope with systematic effects such as the "retrospective patterns" in assessments based on age-structured models.

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Table 1 a) Stock Performance: COD in 2J3KL

	Fishery		Stock Status					Indices					
	Catch	CPUE	Recruitment	Biomass	SSB	Fishing Mortality	Growth	RV Bomass 2J	RV Biomass 3K	RV Biomass 3L	2J3KL Nb/tow 1+	2J3KL Nb/tow 6+	Overall
1960	○												
1961	○												
1962	○		○	○	○	○							○
1963	○		○	○	○	○							○
1964	○		○	○	○	○							○
1965	○		○	○	○	◉							○
1966	○		○	○	○	○							○
1967	○		○	○	○	○							○
1968	○		○	○	○	◉							○
1969	○		○	○	○	◉							○
1970	○		○	○	○	◉							○
1971	○		○	○	○	○							○
1972	○		⊙	○	○	⊙							○
1973	○		◔	⊙	○	⊙							⊙
1974	○		●	◉	○	⊙							⊙
1975	○		◉	◔	◉	◔							◉
1976	◉		○	◔	◉	◔							◉
1977	◉		⊙	◔	●	⊙							◉
1978	●		⊙	◉	●	⊙		◉	◉		◉	◔	◉
1979	●		◔	◉	◔	○		◉	○		⊙	◉	◉
1980	◉		◉	◉	◉	○		○	⊙		⊙	⊙	◉
1981	●		○	⊙	⊙	○	○	⊙	⊙	◉	◉	○	⊙
1982	◉		⊙	⊙	○	○	○	⊙	◉	◉	◔	⊙	⊙
1983	⊙		○	○	⊙	○	○	○	⊙	⊙	○	◉	○
1984	⊙		○	○	◉	⊙	⊙	⊙	⊙	○	○	⊙	⊙
1985	◉		⊙	○	⊙	◉	◉	◉	●	⊙	⊙	◉	⊙
1986	⊙		◉	⊙	◉	⊙	●	○	○	○	○	○	◉
1987	⊙		◔	⊙	⊙	◉	◔	⊙	◉	⊙	◉	⊙	◉
1988	⊙		◉	◉	⊙	◉	◉	○	◔	◉	◉	○	◉
1989	⊙		◉	◉	◉	◔	⊙	◉	○	◔	○	○	◉
1990	◉		◉	◔	◔	◔	⊙	◔	○	○	⊙	◉	◉
1991	◔		◔	◔	◔	◔	◉	◔	◉	◔	◔	◔	◔
1992	◔		◔	◔	◔	◔	◔	◔	◔	◔	◔	◔	◔
1993	◔						◔	◔	◔	◔	◔	◔	◔

Comparison to average conditions

○ Much better ⊙ Better ◉ Worse ◔ Much worse

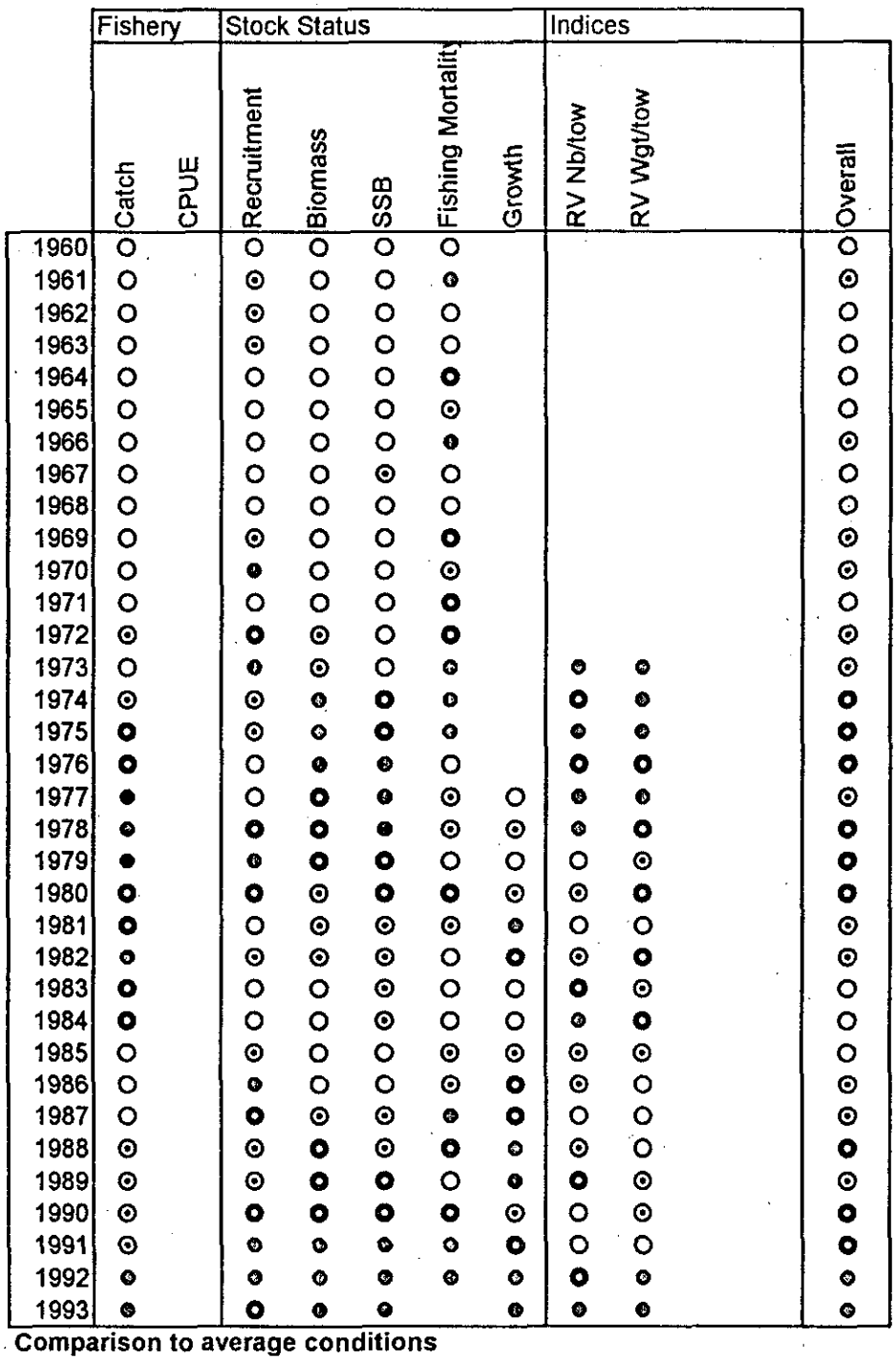
Table 1b) Stock Performance: COD in 3NO

	Fishery		Stock Status					Indices			
	Catch	CPUE	Recruitment	Biomass	SSB	Fishing Mortality	Growth	RV Spring Nb/tow 1+	RV SpringNb/tow 5+	Rus Abun. Spring	Overall
1960	○		○	○	⊙	●					⊙
1961	○		○	○	○	●					○
1962	⊙		○	○	⊙	⊙					⊙
1963	○		○	○	○	◉					⊙
1964	○		○	○	○	●					○
1965	○		○	○	○	◉					⊙
1966	○		○	○	○	◉					⊙
1967	○		○	○	○	◉					⊙
1968	○		○	○	○	◉					⊙
1969	○		○	○	⊙	◉					⊙
1970	○		○	○	⊙	●					⊙
1971	○		○	○	○	◉		○	⊙		⊙
1972	○		○	○	○	◉	●	○	●		⊙
1973	○		⊙	○	⊙	●	○	◉	●		⊙
1974	○		⊙	⊙	⊙	◉	◉	◉	◉		⊙
1975	⊙		●	◉	●	◉	●	●	◉		●
1976	◉		●	◉	◉	⊙	●	●	◉		●
1977	◉	●	○	◉	◉	◉	⊙	⊙	⊙	○	●
1978	◉	◉	⊙	●	◉	○	○	⊙	●	⊙	●
1979	●	⊙	●	●	◉	○	◉	○	○	●	●
1980	◉	◉	●	●	●	○	○	◉	◉	●	●
1981	●	○	●	⊙	⊙	○	⊙	●	⊙	◉	⊙
1982	⊙	○	●	⊙	⊙	⊙	○	⊙	●	⊙	⊙
1983	●	○	⊙	⊙	⊙	○	○			⊙	⊙
1984	●	⊙	○	○	○	⊙	●	○	○	○	⊙
1985	⊙	○	⊙	○	○	⊙	●	⊙	○	○	⊙
1986	○	⊙	◉	⊙	○	⊙	⊙	⊙	○	○	⊙
1987	⊙	●	◉	⊙	○	●	●	○	○	●	●
1988	⊙	⊙	◉	●	●	●	◉	●	○	●	●
1989	⊙	●	◉	●	●	●	⊙	◉	⊙	◉	●
1990	●	●	◉	●	●	●	◉	◉	⊙	◉	●
1991	●	◉	◉	◉	●	◉	○	●	◉	◉	●
1992	◉	◉	○	◉	◉	⊙	◉	◉	◉		●
1993	◉		⊙	◉	◉	○	◉	○	●	⊙	●

Comparison to average conditions

○ Much better ⊙ Better ● Worse ◉ Much worse

Table 1c) Stock Performance: COD in 3Ps



Comparison to average conditions

○ Much better ⊙ Better ● Worse ◉ Much worse

Table 1d) Stock Performance: COD in 3Pn4RS

	Fishery		Stock Status					Indices		
	Catch	CPUE	Recruitment	Biomass	SSB	Fishing Mortality	Growth	RV Biomass - Winte	RV Nb 3+ Winter	Overall
1960	○									
1961	○									
1962	⊙									
1963	⊙									
1964	⊙									
1965	●									
1966	●									
1967	⊙									
1968	○									
1969	●									
1970	○									
1971	⊙									
1972	●									
1973	●									
1974	●		⊙	●	⊙	○	●			⊙
1975	●		○	●	⊙	○	⊙			⊙
1976	⊙		⊙	⊙	⊙	⊙	○			⊙
1977	●		○	⊙	●	●	○			⊙
1978	⊙		○	○	●	○	○	○	⊙	○
1979	⊙		○	⊙	⊙	⊙	⊙	●	●	⊙
1980	○		○	○	○	⊙	○	⊙	○	○
1981	○		⊙	○	○	○	⊙	⊙	●	○
1982	○		⊙	○	○	●	⊙			⊙
1983	○		⊙	○	○	○	○	○	○	⊙
1984	○		●	○	○	●	⊙	○	○	⊙
1985	⊙		●	⊙	○	⊙	●	⊙	⊙	⊙
1986	⊙		●	⊙	⊙	•	●	○	○	●
1987	●		•	●	●	•	•	•	•	•
1988	●		•	●	●	●	●	●	●	●
1989	•		•	●	●	•	●	●	•	•
1990	•		●	•	•	•	•	•	•	•
1991	•		•	•	•	●	•	⊙	⊙	•
1992	•		•	•	•	⊙	•	●	⊙	●
1993	•		•	•	•	•	•	•	●	•

Comparison to average conditions

○ Much better ⊙ Better ● Worse • Much worse

Table 1e) Stock Performance: COD in 4TVn

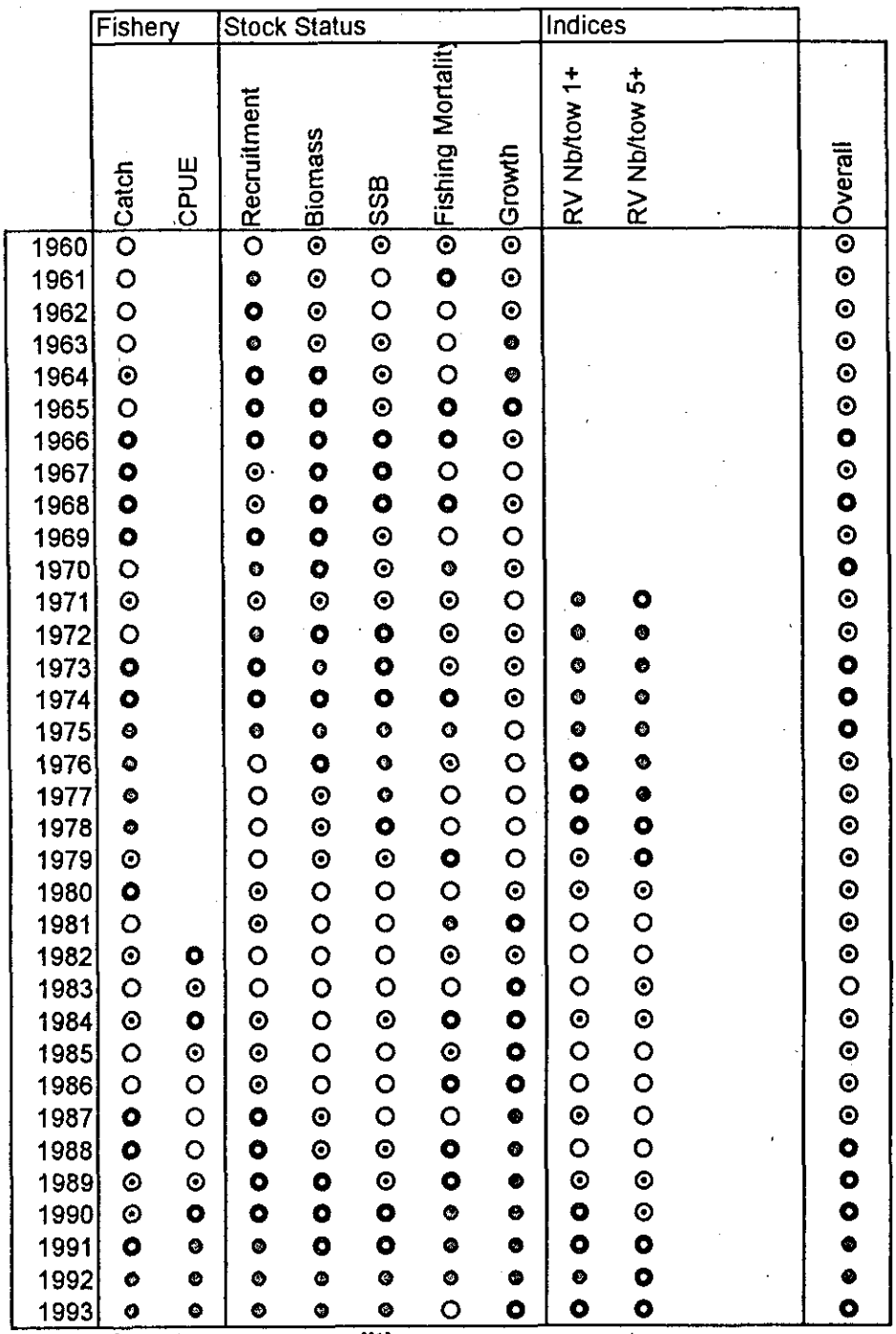


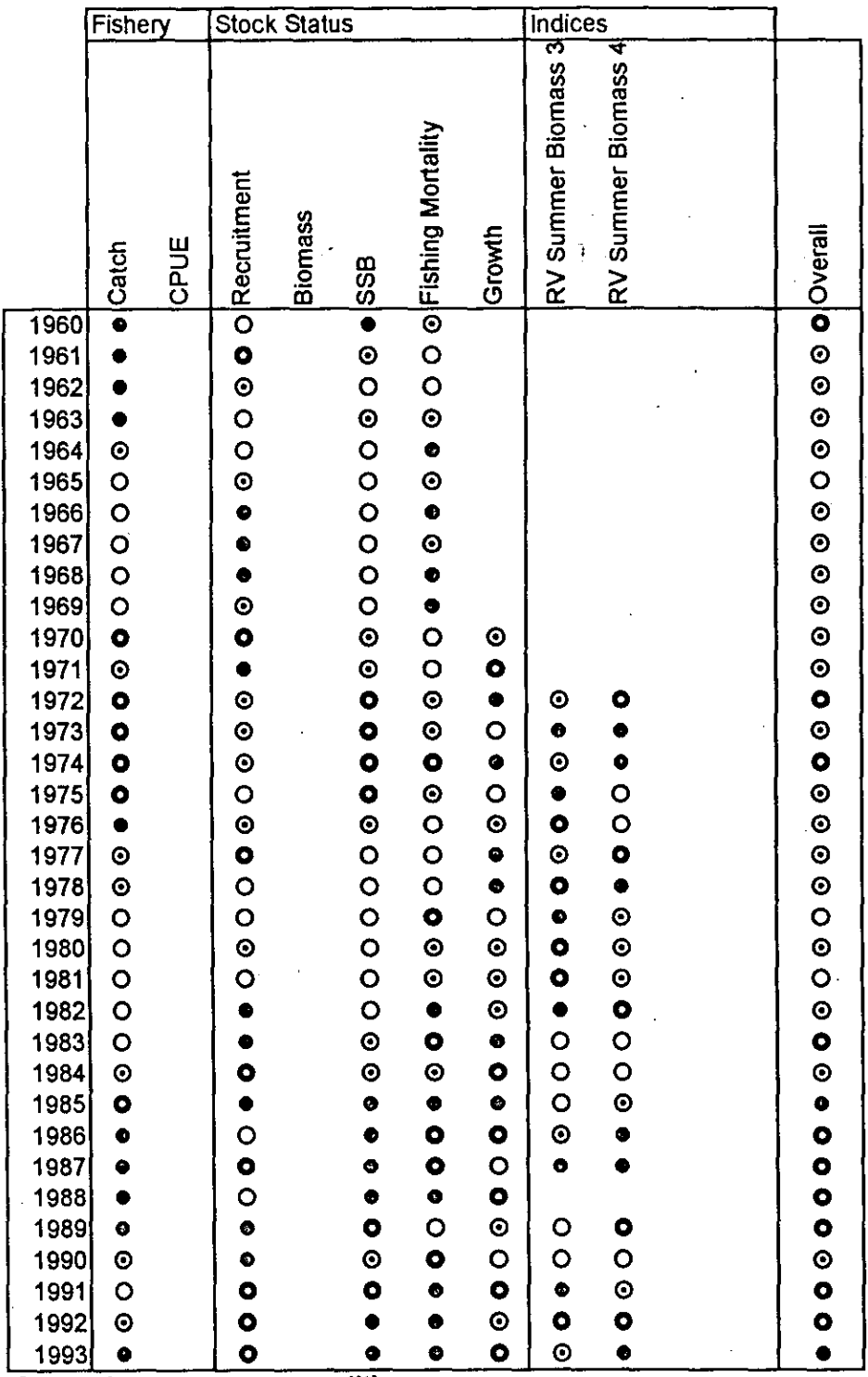
Table 1f) Stock Performance: COD in 4VsW

	Fishery		Stock Status					Indices			
	Catch	CPUE t/hour ZIFF	Recruitment	Biomass	SSB	Fishing Mortality	Growth	RV July Nb/tow 3+	RV Sp^ring Nb/tow 3	CPUE IOP	Overall
1960	⊙		○								○
1961	○		○								○
1962	○		○								○
1963	○		○								○
1964	○		○								○
1965	○		○								○
1966	○		○								○
1967	○		○								○
1968	○		⊙								○
1969	⊙		○								○
1970	○	◉	○	○	⊙	○					○
1971	⊙	●	○	⊙	○	◉	◉	⊙			⊙
1972	○	◉	⊙	⊙	⊙	⊙	◉	◉			⊙
1973	○	●	◉	◉	◉	●	◉	○			◉
1974	⊙	●	⊙	◉	●	⊙	⊙	●			◉
1975	◉	●	⊙	●	◉	●	◉	●			◉
1976	●	●	⊙	●	●	◉	○	●			◉
1977	●	●	⊙	◉	●	○	○	◉			◉
1978	●	⊙	○	⊙	◉	○	○	⊙			⊙
1979	◉	◉	○	⊙	◉	○	○	◉	●		⊙
1980	⊙	◉	○	⊙	⊙	⊙	○	◉	◉		⊙
1981	○	◉	○	○	⊙	⊙	⊙	⊙	⊙		⊙
1982	○	○	◉	○	⊙	◉	⊙	○	○	◉	⊙
1983	⊙	⊙	◉	○	○	○	○	○	○	◉	⊙
1984	⊙	○	●	○	○	⊙	⊙	○	◉	○	⊙
1985	○	○	●	○	○	◉	◉	○		○	⊙
1986	⊙	○	●	⊙	○	⊙	◉	◉	○	⊙	⊙
1987	◉	○	●	◉	○	◉	●	⊙	⊙	⊙	◉
1988	◉	⊙	◉	◉	⊙	●	●	⊙	⊙	⊙	◉
1989	◉	⊙	●	◉	◉	◉	◉	◉	◉	○	◉
1990	◉	○	●	●	◉	●	●	○	●	◉	◉
1991	●	⊙	◉	●	●	●	●	●	○	●	●
1992	●	⊙	●	●	●	●	●	●	●	●	●
1993	●	●	●	●	●	○	●	⊙	◉	●	●

Comparison to average conditions

○ Much better ⊙ Better ◉ Worse ● Much worse

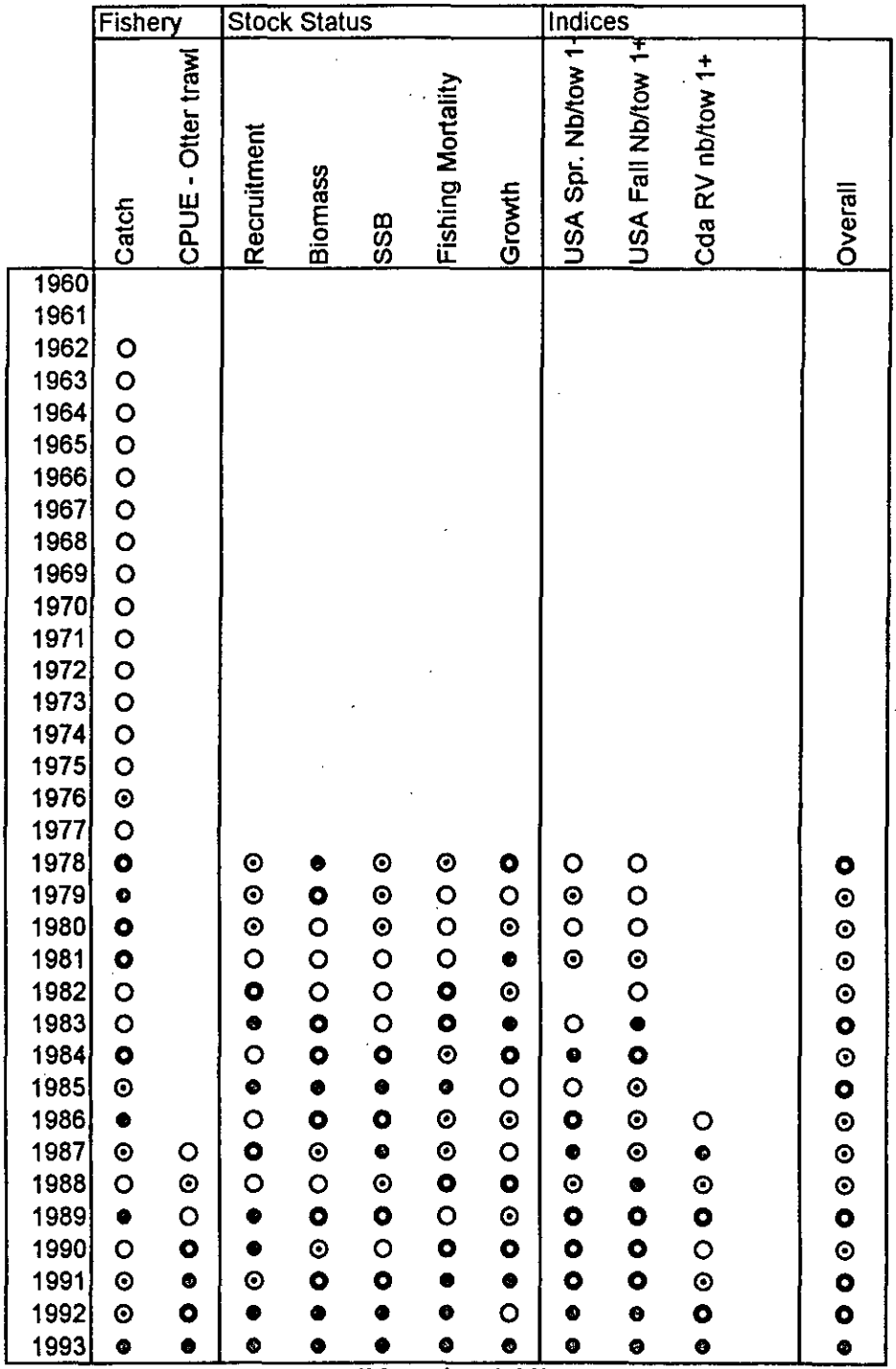
Table 1g) Stock Performance: COD in 4X



Comparison to average conditions

○ Much better ⊙ Better ◎ Worse ● Much worse

Table 1h) Stock Performance: COD in 5Zjm



Comparison to average conditions (1978-93)

○ Much better ⊙ Better ● Worse ◉ Much worse

Table 2. Historical performance for the principal cod stocks of the Northwest Atlantic.

	Cod 2J3KL	Cod 3NO	Cod 3Ps	Cod 3Pn4RS	Cod 4TVn	Cod 4VsW	Cod 4X	Cod 5Zjm
1960		⊙	○		⊙	○	●	
1961		○	⊙		⊙	○	⊙	
1962	○	⊙	○		⊙	○	⊙	
1963	○	⊙	○		⊙	○	⊙	
1964	○	○	○		⊙	○	⊙	
1965	○	⊙	○		⊙	○	○	
1966	○	⊙	⊙		●	○	⊙	
1967	○	⊙	○		⊙	○	⊙	
1968	○	⊙	○		●	○	⊙	
1969	○	⊙	⊙		⊙	○	⊙	
1970	○	⊙	⊙		●	○	⊙	
1971	○	⊙	○		⊙	⊙	⊙	
1972	○	⊙	⊙		⊙	⊙	●	
1973	⊙	⊙	⊙		●	●	⊙	
1974	⊙	⊙	●	⊙	●	●	●	
1975	●	●	●	⊙	●	●	⊙	
1976	●	●	●	⊙	⊙	●	⊙	
1977	●	●	⊙	⊙	⊙	●	⊙	
1978	●	●	●	○	⊙	⊙	⊙	●
1979	●	●	●	⊙	⊙	⊙	○	⊙
1980	●	●	●	○	⊙	⊙	⊙	⊙
1981	⊙	⊙	⊙	○	⊙	⊙	○	⊙
1982	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙
1983	○	⊙	○	⊙	○	⊙	●	●
1984	⊙	⊙	○	⊙	⊙	⊙	⊙	⊙
1985	⊙	⊙	○	⊙	⊙	⊙	●	●
1986	●	⊙	⊙	●	⊙	⊙	●	⊙
1987	●	●	⊙	●	⊙	●	●	⊙
1988	●	●	●	●	●	●	●	⊙
1989	●	●	⊙	●	●	●	●	●
1990	●	●	●	●	●	●	⊙	⊙
1991	●	●	●	●	●	●	●	●
1992	●	●	●	●	●	●	●	●
1993	●	●	●	●	●	●	●	●

Comparison to average performance

○ Much better ⊙ Better

● Worse ● Much worse

Table 3. Stock Performance - Annual view

1983	Fishery		Stock Status					
STOCK	Catch	CPUE	Recruitment	Biomass	SSB	Fishing Mortality	Growth	Overall
COD 2J3KL	⊙		○	○	⊙	○	○	○
COD 3NO	●	○	⊙	⊙	⊙	○	○	⊙
COD 3Ps	●		○	○	⊙	○	○	○
COD 3Pn4RS	○		⊙	○	○	○	○	⊙
COD 4TVn	○	⊙	○	○	○	○	●	○
COD 4VsW	⊙	⊙	●	○	○	○	○	⊙
COD 4X	○		●		⊙	●	●	●
COD 5Zjm	○		●	●	○	●	●	●

1993	Fishery		Stock Status					
STOCK	Catch	CPUE	Recruitment	Biomass	SSB	Fishing Mortality	Growth	Overall
COD 2J3KL	●						●	●
COD 3NO	●		⊙	●	●	○	●	●
COD 3Ps	●		●	●	●		●	●
COD 3Pn4RS	●		●	●	●	●	●	●
COD 4TVn	●	●	●	●	●	○	●	●
COD 4VsW	●	●	●	●	●	○	●	●
COD 4X	●		●		●	●	●	●
COD 5Zjm	●	●	●	●	●	●	●	●

Comparison to average performance

○ Much better ⊙ Better

● Worse ● Much worse