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Proceedings of the Fisheries Management Studies Working Group

15-16 and 31 May 2001

**Bedford Institute of Oceanography
Dartmouth, Nova Scotia**

**R. G. Halliday, Chairman
Bedford Institute of Oceanography
Fisheries and Oceans
P.O. Box 1006, Dartmouth
Nova Scotia, Canada
B2Y 4A2**

August 2001

Canada

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Foreword

The purpose of this proceedings is to archive the activities and discussions of the meeting, including research recommendations, uncertainties, and to provide a place to formally archive official minority opinions. As such, interpretations and opinions presented in this report may be factually incorrect or mis-leading, but are included to record as faithfully as possible what transpired at the meeting. No statements are to be taken as reflecting the consensus of the meeting unless they are clearly identified as such. Moreover, additional information and further review may result in a change of decision where tentative agreement had been reached.

Avant-propos

Le présent compte rendu fait état des activités et des discussions qui ont eu lieu à la réunion, notamment en ce qui concerne les recommandations de recherche et les incertitudes; il sert aussi à consigner en bonne et due forme les opinions minoritaires officielles. Les interprétations et opinions qui y sont présentées peuvent être incorrectes sur le plan des faits ou trompeuses, mais elles sont intégrées au document pour que celui-ci reflète le plus fidèlement possible ce qui s’est dit à la réunion. Aucune déclaration ne doit être considérée comme une expression du consensus des participants, sauf s’il est clairement indiqué qu’elle l’est effectivement. En outre, des renseignements supplémentaires et un plus ample examen peuvent avoir pour effet de modifier une décision qui avait fait l'objet d'un accord préliminaire

Contents

Abstract

The Working Group met on 15-16 and 31 May 2001 to review proposals for indicators to be used in Traffic Light based management decision frameworks. Agreement was reached on nine indicators that were considered suitable for use in Traffic Light analyses. Descriptions of these are appended to this report. The template used for descriptions was again reviewed and minor improvements made to it. Arrangements were made for further work on several aspects of the Traffic Light method, including for preparation of several more indicator descriptions.

Résumé

Le Groupe de travail s'est réuni les 15, 16 et 31 mai 2001 pour examiner les propositions sur les indicateurs à utiliser dans les cadres décisionnels fondés sur la méthode des feux de circulation. On s'est entendu sur neuf indicateurs jugés aptes à servir aux analyses selon les feux de circulation. Ces indicateurs sont décrits en annexe au présent rapport. Le modèle utilisé pour les descriptions a été examiné de nouveau et légèrement modifié. On a pris des dispositions pour effectuer de plus amples travaux sur plusieurs aspects de la méthode des feux de circulation, notamment pour établir plusieurs autres descriptions d'indicateurs.

FISHERIES MANAGEMENT STUDIES WORKING GROUP

REPORT OF MEETINGS of 15-16 and 31 May 2001

The Fisheries Management Studies Working Group (FMSWG) met on 15-16 May and again on the afternoon of 31 May 2001 in the Hayes Boardroom, Bedford Institute of Oceanography, Dartmouth, to review drafts of Traffic Light indicator descriptions. The agenda is in Annex 1. Participants were as listed in Annex 2.

A. 15-16 May 2001 Session

Ways to have Traffic Light indicator descriptions drafted and reviewed were discussed at the January 2001 meeting of the FMSWG. It was noted that a good start had been made in engaging the interest of scientific experts to provide drafts. It was proposed to build on that base by encouraging those that had already made commitments to now produce drafts in conformity with the revised guidelines adopted at the January meeting. Peer review of the indicator descriptions was seen as a necessity. The present meeting was called to implement that recommendation.

1. Description Review

It was clarified that the intention of the meeting was to make available practical work tools that provide an acceptable basis for application of the Traffic Light method now. Most of the indicators proposed are not new and methods for deriving them are well established. In establishing a workbook of indicator descriptions, the intention is to provide a toolbox of methods to analysts that, if followed, will enjoy a wide pre-agreement on their acceptability by peers. This should introduce efficiencies to the stock assessment process, providing the necessary time to be devoted to assessing the implications of results. There is no suggestion that the innovation of analysts be restricted and, indeed, the development of improved and new indicators has been actively encouraged. However, the descriptions document currently acceptable practices, and the onus is on analysts who wish to introduce different methods to demonstrate that these provide improvements over the current benchmarks.

The 10 descriptions tabled on 15-16 May were reviewed and proposals made for revisions. It was decided that the description, Biomass and Abundance, should be amended to include guidance on indicators based on length or age subsets of the data, such as indices of recruitment and spawning stock size. Thus, a separate Index of Recruitment account was viewed as unnecessary. Fishery based distribution indicators were considered to be of potential interest but the conceptual basis for their application has not yet been adequately developed. The remaining eight indicator descriptions were accepted for inclusion in the proposed Traffic Light workbook, contingent on satisfactory revision. It was agreed that revised drafts should be made available no later than 31 May.

ACTION: PRINCIPAL AUTHORS

2. Indicator Template

The indicator template, as revised in accordance with the requests from the January 2001 meeting, was found to be serving well as guidance to description authors. However, a proposal to consolidate material related to indicator estimation in a separate section under Attributes was accepted as worthwhile.

ACTION: FANNING

3. Other Matters

Other Indicators: Several additional indicator descriptions were identified as necessary.

- Total Mortality (Catch Curve Z): most of the work for this indicator description is completed and a write-up will be available soon. It was agreed that a description of the calculation of total mortality from research vessel numbers at age would also be produced.

ACTION: MOHN

- Population Size/Age Structure: a verbal account of work in progress elicited several suggestions for ways to derive a suitable indicator. These will be pursued.

ACTION: SHOWELL

- Biomass and Abundance – Industry Surveys: it was agreed that industry surveys were sufficiently different from research vessel surveys, and from each other, that separate, survey-specific descriptions of the indicators derived from them were required. As production of these necessitates actions by individuals not in attendance at this meeting, an *ad hoc* group was formed to devise ways to have such descriptions produced.

ACTION: CAMPANA, FANNING, FOWLER.

Descriptions of Characteristics: It was proposed at the January 2001 meeting that descriptions of characteristics be developed, as well as descriptions of individual indicators. This was seen as an aid in deciding what indicators should be associated with particular characteristics and it would also establish the basis for interpreting characteristics in the context of decision rules. No arrangements have yet been made to produce these. Paul Fanning agreed to take the lead in having such descriptions prepared.

ACTION: FANNING

Boundary Points: It was decided to accept the previously used arbitrary Boundary Points in indicator descriptions at this time. However, it was the view of the meeting that it is preferable to have boundary points established objectively on some biological basis, as had been agreed also at the January 2001 meeting. Suggestions were made in relation to a few of the indicators described for further investigations on establishing such boundaries. It was clear, however, that the goal of having biologically based boundaries for indicators, with a few possible exceptions such as condition, is likely to be achieved only in the long-term. In the absence of biologically based indicators, this meeting preferred that boundaries be established subjectively based on identification of indicator states during historical periods when the stock status overall was considered to be 'good' and 'bad'. Adoption of the arbitrary defaults used previously (e.g. the mean and a percentile of it) was viewed as acceptable only as a last resort.

4. Adjournment

The meeting was adjourned until 31 May.

B. 31 May 2001 Session

1. Description Review

A newly available description for the indicator 'Total Mortality – Catch Curve Z' was reviewed and revisions proposed. The two case studies presented gave conflicting results and further case studies are necessary to establish the utility of this method.

Revisions of four descriptions previously discussed at the 15-16 May session were also tabled, two of which were again reviewed and further changes were suggested.

An agreement was reached that descriptions on abundance and biomass estimation from industry surveys would be produced as follows:

- 4Vn sentinel ACTION: MOHN
- 4VsW sentinel ACTION: FANNING
- 4X ITQ ACTION: HURLEY and COMEAU
- Halibut ACTION: ZWANENBURG

It was agreed that all new and revised drafts that are made available to the chairman would be included as annexes to the report of this meeting (Annex 3). All further editing issues will be resolved between authors and the chairman.

ACTION: AUTHORS, HALLIDAY

2. Indicator Template

A proposal that the indicator template be further revised to include a statement at the end of the section on Estimation on whether or not standard software is available for calculating the indicator and, if so, where it is located, was accepted.

ACTION: FANNING (see Annex 3)

3. <u>Other Matters</u>

Descriptions of Characteristics: It was agreed that descriptions would be prepared for presentation at the 25-27 June meeting.

ACTION: FANNING, MOHN

Scaling of Survey Abundance Indicators of different Duration: Solutions to this problem, identified during the groundfish RAP in November 2000 and discussed at the January 2001 meeting of the WG, are required prior to the next round of groundfish assessments. It was agreed that some potential solutions would be presented at the 25-27 June meeting.

ACTION: FOWLER

Annex 1.

Agenda

1. Indicator Descriptions for Review

- Fish Condition – Survey Based (K. FRANK, M. FOWLER)
- Fish Growth Rate – Fishery or Survey Based (J. NEILSON)
- Environmental Conditions – Temperature (K. DRINKWATER)
- Relative Fishing Mortality (M. FOWLER)
- Biomass and Abundance – Survey Based (M. FOWLER)
- Index of Recruitment – Survey Based (P. FANNING)
- Distribution – Survey Based (K. ZWANENBURG, J. BLACK, K. MOHN)
- Distribution – Fishery Based (R. BRANTON)
- Length at Maturity (M. SHOWELL)
- Length at Sex Transition (*Pandalus borealis*) (P. KOELLER)
- Total Mortality – Catch Curve Z (R. MOHN)

2. Indicator Template

3. Other Matters

Annex 2.

List of Participants

Black, J.	MFD-BIO, Science, Scotia-Fundy
Branton, R.	MFD-BIO, Science, Scotia-Fundy
Campana, S.	MFD-BIO, Science, Scotia-Fundy
Chaput, G.	GFC, Science, Gulf Region
Drinkwater, K.	OSD-BIO, Science, Maritimes
Fanning, P.	MFD-BIO, Science, Scotia-Fundy
Fowler, M.	MFD-BIO, Science, Scotia-Fundy
Frank, K.	MFD-BIO, Science, Scotia-Fundy
Halliday, R. (Chairman)	MFD-BIO, Science, Scotia-Fundy
Hurley, P.	MFD-BIO, Science, Scotia-Fundy
Koeller, P.	IMPD-BIO, Science, Scotia-Fundy
McRuer, J.	MFD-BIO, Science, Scotia-Fundy
Mohn, R.	MFD-BIO, Science, Scotia-Fundy
Showell, M.	MFD-BIO, Science, Scotia-Fundy
Simon, J.	MFD-BIO, Science, Scotia-Fundy
Zwanenburg, K.	MFD-BIO, Science, Scotia-Fundy

Annex 3. Indicator Template and Descriptions

Template outlining the Sections of a Traffic Light Indicator Account

Indicator: **<u>Descriptive name of indicator, including short form used on Traffic Light output</u>**

Characteristic: Name of the characteristic of stock status the indicator reflects. Current choices include **Abundance**, **Production, Fishing Mortality** and **Ecosystem**.

Description: Describe the attribute being measured by the indicator and the scientific basis underlying its relationship to one or more characteristics. Describe also, if necessary, how the indicator relates to the attribute.

Boundary Point(s): Basis for setting boundary points between colour ranges. Although statistics based on historical data series have been widely used it is preferable that some external basis for determining the ranges be applied, especially in cases where there is a short data series or little dynamic range in the data. Intercalibration of data series may be an option in some cases.

Properties:

Estimation:

- data source(s)
- range selections
- computation including transformations, smoothing etc.
- availability and location of software for calculation of the indicator

Measurability:

- statistical properties of estimator e.g. variability, bias, skewness
- transformations if required
- standard or alternative formulations for estimator, if non-standard, why?
- consistency with other estimators of indicator

Interpretability:

- how does this indicator reflect stock status or the identified characteristic?
- what caveats exist?
- how well are the colour boundaries related to changes in stock status or characteristic?

Sensitivity:

- how rapidly does indicator respond to changes in stock status?
- is there adequate time for management interventions?
- is the natural variability likely mask real changes?

Weight:

The overall value of an indicator, on a scale relative to the other available indicators. This is based on primarily on the strength of the individual attributes and the qualities of the proposed reference points. At least four types of uncertainty have been identified:

1. Statistical uncertainty due to sampling error in the indicator related to measurability
2. Boundary point uncertainty related to interpretability
3. Importance of the indicator, again related to interpretability
4. Structural uncertainty, the sensitivity of the indicator to changes in the formulation of the estimator.

Review of Performance or **Validation of Indicator:**

If data exists, an assessment of the performance of the indicator over a time series of estimates is desirable. An alternative approach would be to validate the indicator and boundary points against external information e.g. $F_{0.1}$ or critical values for fish condition. In either case the review must demonstrate the adequacy of the indicator, its estimator and the selected boundary values.

Indicator: **<u>Fish Growth Rate – Fishery or Survey Based</u>**

Characteristics: This indicator reflects one component of **Production.** It has been suggested that fish growth rate is also negatively correlated with **Abundance**, but the evidence reviewed here indicates that there is little to support this conclusion for Maritime marine fish stocks.

Description: On first principles of competition theory, growth rates of individual fish are expected to decline as the **Abundance** of the population increases, unless the food supply also increases. Thus, growth rate may offer some potential as a measure of stock abundance. A review of the literature, however, suggests that most of the empirical data supporting a negative correlation between growth rate and abundance are from freshwater ecosystems. For marine fish stocks in Canadian Maritimes Region, temperature accounts for a considerably larger fraction of variation in growth rate than does density dependence (Brander, 1997). Other examples of the lack of a negative correlation between abundance and growth rate are provided here for yellowtail flounder on Georges Bank and for pollock on the Scotian Shelf and Bay of Fundy.

As a component of **Production**, consideration of growth and growth rates is obligatory. Unusual recent observations of growth rate must, of course, be included in the assessment and the resulting projections of population growth and potential harvest.

Boundary Point(s): Examination of historic data series and arbitrary division into categories will be required. Such divisions will be stock-specific in most cases.

Properties:

Estimation:

- Long-standing series of annual estimates of length and weight at age are available for many of the stocks of interest to the Maritimes Region, either from the commercial fisheries or the surveys.
- From surveys, growth rate information is collected one or more times per year depending on the geographic area. For instance, on the eastern Scotian Shelf there are two surveys per year (March and July) and on the western Scotian Shelf there is one survey per year (July). On Georges Bank, there are several surveys available conducted by Canada and the USA.
- As long as reliable indicators of age are available, measurement of growth rate is fairly straightforward. Instantaneous measures of growth rate are a convenient metric (the natural logarithm of the ratio of final weight/length to

initial weight/length in a unit of time, usually a year). Such data could be summarized as instantaneous measures of growth rate for a given cohort.
- Alternatively, measures of size of age can be employed as a proxy for growth rate. However, such measures integrate the animal's growth history. If size at age is to be compared with some other parameter such as temperature, appropriate time scales must be chosen for both.
- Some authors have measured observed growth rate versus expected using a von Bertalanffy model (i.e. cod, Swain et al. 1999). Thus, residuals from the model fit can be compared with other characteristics.

Measurability:
- Growth data appear to be subject to high levels of interannual variation, and smoothing may often be required.
- Regardless of whether the source of the growth data is surveys or the commercial fishery, younger (and sometimes older) ages are often incompletely available to the fishing gear, smaller (larger) fish within an age group having a lower probability of being caught, resulting in a bias in size-at-age estimates. Researchers need to be aware of such features, particularly when they are time-trended.

Interpretability:
- For cod stocks in the Maritimes region, growth rate responds more to density-independent factors such as water temperature than to abundance (Swain et al. 1999). The examples that follow demonstrate a similar lack of correspondence between growth rate and population abundance for yellowtail flounder on Georges Bank and pollock.
- Growth rate (when measured in weight) is confounded with condition factor. Other linkages are expected with attributes such as reproductive potential.

Sensitivity:
- While growth rate does not appear to reflect the characteristic of population abundance, it is a sensitive indicator of population productivity.
- The time scale associated with growth rate changes is probably sufficient for timely management interventions (but this is speculative).

Weight: Given the poor performance of this indicator (see Swain et al. (1999) and Brander (1997) for examples pertaining to cod stocks, and other examples presented later, this measure appears to have little or no utility as an indicator of **Abundance** for marine fish populations in the Region.

For the population characteristic of **Production**, however, growth rate is of obvious importance, and should be given high weight. Unusual growth patterns and weights at age should be considered in any projection of future population abundance or harvest.

References:

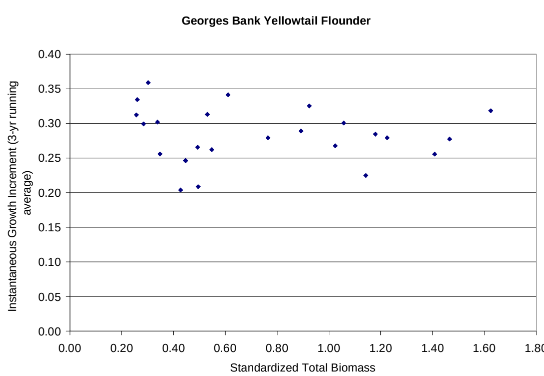
Brander, K. M. 1995. The effect of temperature on growth of Atlantic cod (*Gadus morhua* L.). ICES Journal of Marine Science, 52(10): 1-10.

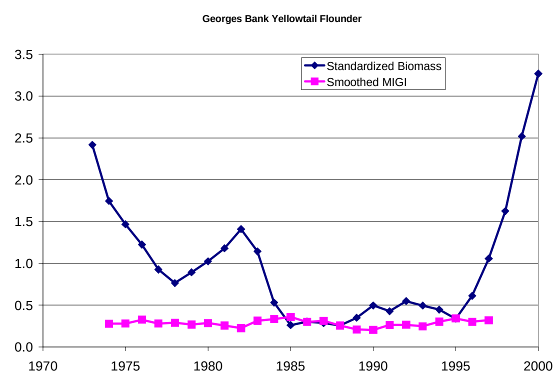
Swain, D. P. A. F. Sinclair, M. Castonguay, G. A. Chouinard, K.F. Drinkwater, L. P. Fanning and D. S. Clark. Submitted. Density- versus temperature-dependent growth of Atlantic cod (*Gadus morhua*) in the Gulf of St. Lawrence and on the Scotian Shelf. Fisheries Research.

Example Application 1: 5Zjmhn Yellowtail Flounder (Georges Bank)

Indicator: A negative relationship between abundance and growth rate.

Review of Performance: Smoothed instantaneous growth rate was computed each year (ages 2 to 3, 3 to 4 and 4 to 5 were averaged each year) and plotted against a standardized measure of population abundance (total biomass from the VPA) from the 2000 assessment. If there were evidence of density dependence, a negative slope would be expected. For this stock, there is no evidence of density-dependence (left hand figure). In the right hand figure, the time series of the measure of population abundance shows a very marked recent increase, but the measure of growth rate (MIGI – mean instantaneous growth increment) shows no concurrent decline. Other Georges Bank stocks (notably haddock) are showing a similar pattern, with no evidence of reduced growth rates with increasing population abundance.

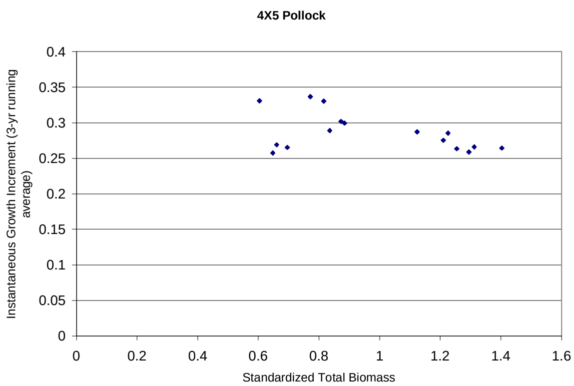


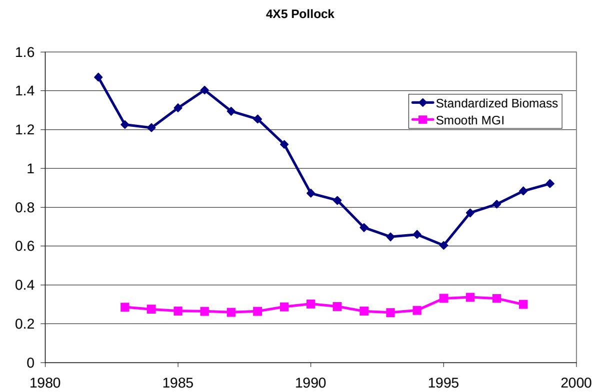


Example Application 2: 4X5 Pollock (SW Scotian Shelf/Bay of Fundy/Georges Bank)

Indicator: A negative relationship between abundance and growth rate.

Review of Performance: In this case, there was an indication of a weak relationship between population density and growth rate (left hand figure, data from 1999 assessment). However, some of the highest growth increments observed in the series have been observed in recent years. The population density during that period was somewhat below the average, but not as low as observed in the early 1990s (right hand figure).





Indicator: **<u>Fish Condition – Survey Based</u>**

Characteristic: **Production**

Description: Change in the individual weight of fish of the same body length over time can reveal positive or negative occurrences in the life of the fish, such as trends in environmental conditions or prey availability, that affect the growth rate of the animal. In addition to implications for future yields, trends in Condition may reflect concurrent trends in survivability and reproductive potential of the stock.

Boundary Point(s): Meaningful boundary points may require controlled feeding experiments. For example, prolonged fasting of laboratory reared cod from the Northern Gulf of St. Lawrence resulted in a condition factor (K) below 0.70 whereas feeding cod typically had K values above 0.85 (Lambert and Dutil 1997). In the interim, default arbitrary thresholds have been established using percentiles, based on the historical time series. The top and bottom of the middle third of all values denote the default green/yellow and yellow/red boundaries, respectively.

Properties:

Estimation:

- Length and weight data from RV surveys are log-transformed to achieve a least-squares linear regression of the relationship between length and weight for each year of the survey. These equations are then used to predict the weight (W_{pred}) for a given length in each year to provide a time series of predicted weights, referred to as the Condition Factor. A single factor can be taken as representative of condition in the population as a whole, while sometimes inferences about immature and/or mature fish separately might be pertinent.
- Where research provides a basis for defining good or poor states of condition, W_{pred} should be re-expressed in terms of Fulton's K ($W_{pred} /L^3 * 100$) to derive meaningful boundary points for W_{pred} (published accounts of fish condition, such as laboratory feeding experiments, typically represent condition as Fulton's K).
- The predicted weight at length should be compared with the observed weight at length. If results are inconsistent, an average of the observed weights from a specified length range may be used as an index of condition.
- See [*Web address*] for computation of this indicator.

Measurability:

- It is a simple procedure to determine the total weight and length of fish from collections made during research vessel surveys. It has been argued that

somatic weight (total weight less gonad and stomach contents) is a better reflection of condition but comparison of condition factors based on somatic and total weights of cod yielded only slight differences (Lambert and Dutil 1997).
- Weight estimates of small fish (< 100-150 g) were less accurate before the implementation of electronic scales that occurred in 1992. Caution should be exercised in the interpretation of condition data for small species or for juvenile stages prior to 1992.
- Smoothing the data with a 3 yr running mean is useful to accentuate trends.
- For groundfish stocks on the Scotian Shelf temporal changes in condition of males and females was highly correlated.
- Seasonal variation in condition associated with maturation, reproduction, over-wintering, and intense feeding is known to occur in most fish. Reliance on a point estimate of condition to develop a time series of annual estimates assumes that there has been no phase shift in the annual condition cycle (Taggart et al 1994).
- In some areas seasonal surveys are conducted and condition indices should be compared to assess their correspondence.
- Estimates of condition based on predictions from length - weight regression can be confounded by changes in the size and/or age structure of the stock over time. A decrease in the representation of larger fish, either through loss of older fish or recruitment of younger fish, can translate into a decline in predicted weight of the larger fish that might not reflect their true condition. This possibility can be both investigated and resolved by reducing or eliminating the potential contribution of size structure on predictions. Some specific methods include comparing or substituting 1) observed condition factor, 2) estimating condition of only the commonest length to avoid the influence of changes in size composition, 3) constraining the size range of the data used in the prediction to exclude fish of sizes not found, or not found in appreciable numbers, in all years, or 4) generating a prediction using only mean weights at length in the regression, such that all lengths are equally weighted in the regression. In the last case, it would be advisable to use only a common length range within which there are abundant observations, or outliers may drive the prediction.

Interpretability:
- Condition is an indicator of population productivity and not necessarily so for population abundance or biomass.
- Condition factor (relative plumpness) of individual fish appears to be an indicator of growth, reproductive success via its influence on fecundity and egg quality (Marshall et al. 1998), and natural mortality (Dutil and Lambert 2000).
- Declining or low condition factors preceded the collapse of several groundfish stocks in the northwest Atlantic. While condition has improved in many of these stocks, recovery has been slow or non-existent.

Sensitivity:

- Condition is relatively sensitive to environmental change and can vary rapidly depending upon the magnitude of such change.
- Condition is measured one or more times per year depending on the geographic area of the RV survey. For instance, on the eastern Scotian Shelf there are two surveys per year (March and July) and on the western Scotian Shelf there is one survey per year (July).

Weight: To be determined.

References:

Dutil, J.-D. and Y. Lambert. 2000. Natural mortality from poor condition in Atlantic cod (Gadus morhua). Can. J. Fish. Aquat. Sci., 57: 826-836.

Lambert, Y. and J.-D. Dutil. 1997. Condition and energy reserves of Atlantic cod (*Gadus morhua*) during the collapse of the northern Gulf of St. Lawrence stock. Can. J. Fish. Aquat. Sci., 54: 2388-2400.

Marshall, C. T. and K. T. Frank. 1999. The effect of interannual variation in growth and condition on haddock recruitment. Can. J. Fish. Aquat. Sci., 56: 347-355.

Marshall, C. T., O. S. Kjesbu, P. Solemdal, O. Ulltang, and N. A. Yaragina. 1998. Is spawner biomass a sensitive measure of the reproductive and recruitment potential of Northeast Arctic cod? Can. J. Fish. Aquat. Sci., 55: 1766-1783.

Taggart, C. T., J. Anderson, C. Bishop, E. Colbourne, J. Hutchings, G. Lilly, J. Morgan, E. Murphy, R. Myers, G. Rose and P. Shelton. 1994. Overview of cod stocks, biology, and environment in the Northwest Atlantic region of Newfoundland, with emphasis on northern cod. ICES mar. Sci. Symp., 198: 140-157.

Individual Traffic Light Indicators in the Precautionary Framework

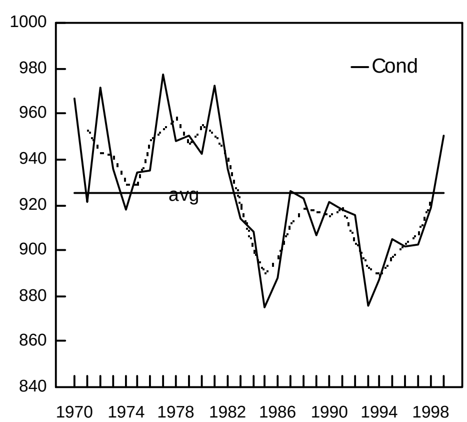
Example Application: 4VW Haddock

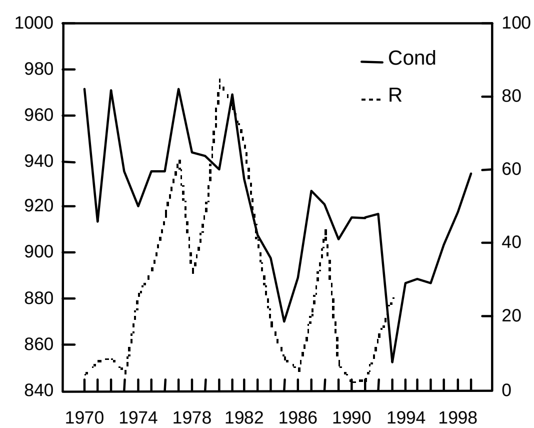
Indicator: Predicted weight, g at 45 cm (female only)

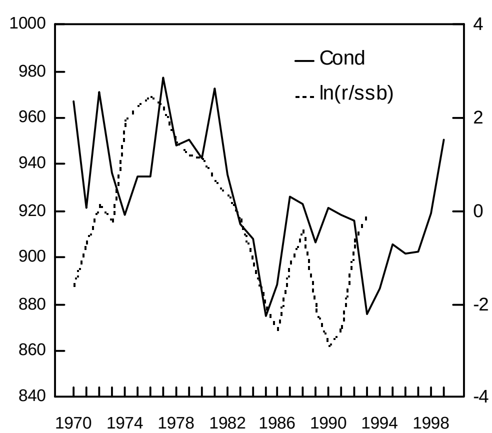
Review of Performance:

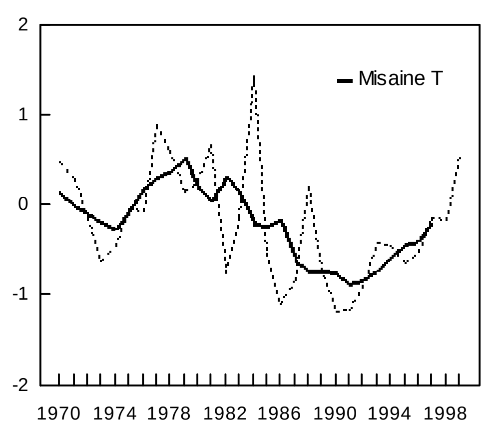
Condition of adult female haddock exhibited a [cascading] pattern. Relatively high levels typified the first part of the data series from 1970 to1982. A minimum was reached in the mid-1980s followed by an increase to a level slightly below the long-term average. Condition reached an historical low in1993 and has slowly increased since that time. Condition and recruitment were positively correlated (r=0.44, n=24) and the strongest year-classes were produced during the late 1970s/early 1980s when both condition and SSB were relatively high. Condition and survival rate (ln(r/ssb)) were also correlated (r=0.50, n =24).

Low condition factors were also generally associated with colder-than-normal water temperatures and vice versa (r=0.44, n=30).

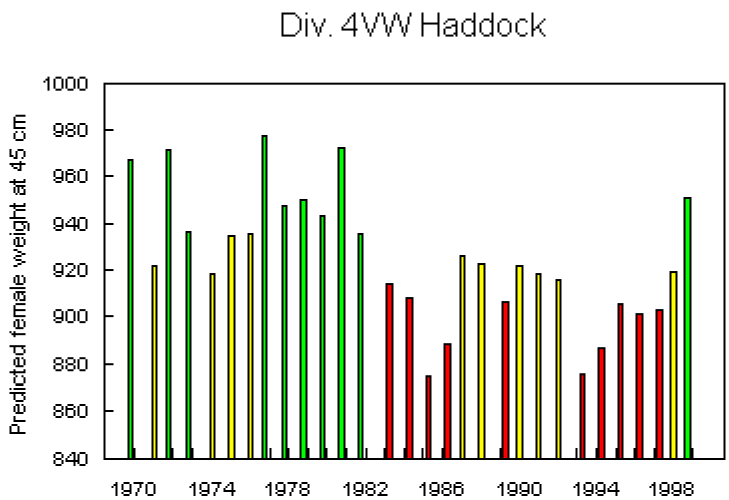








Translation of the condition factor for haddock into a traffic light based on percentile limits



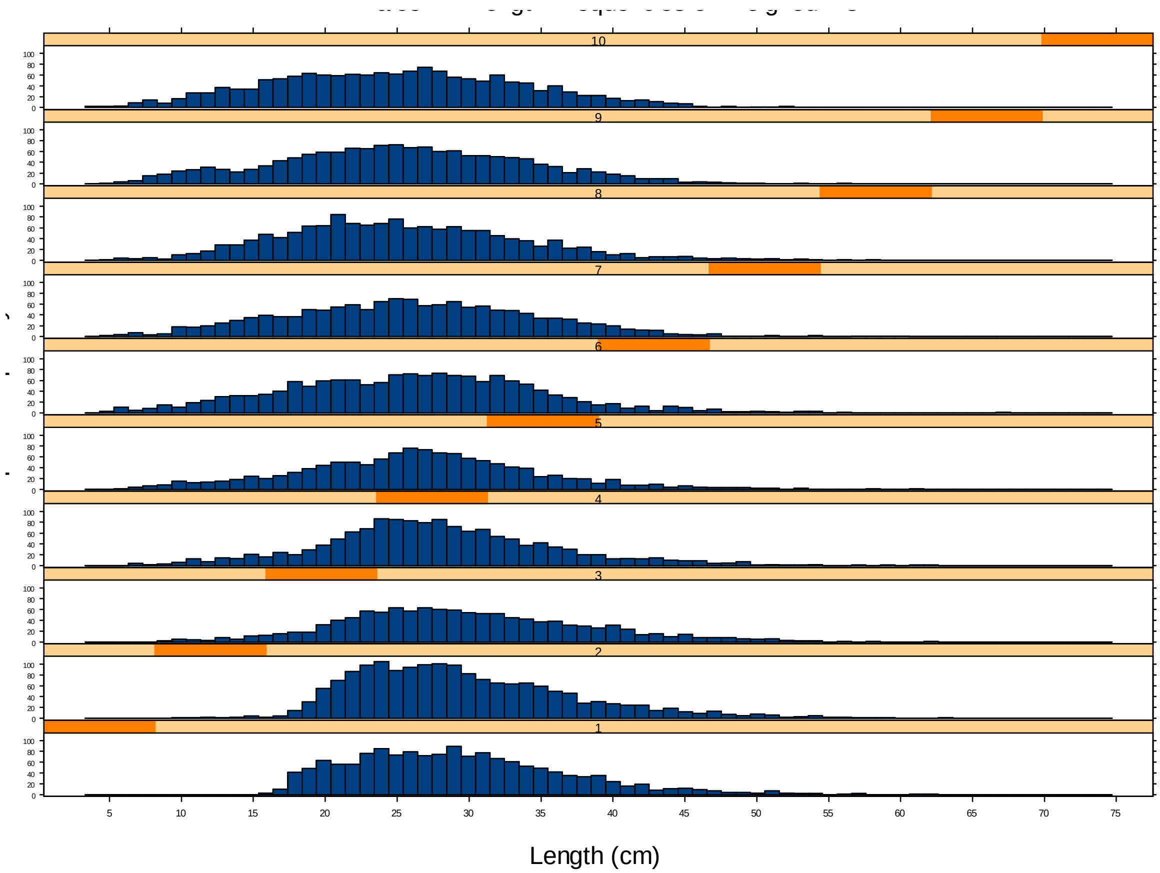
Example Application: 4VW Plaice

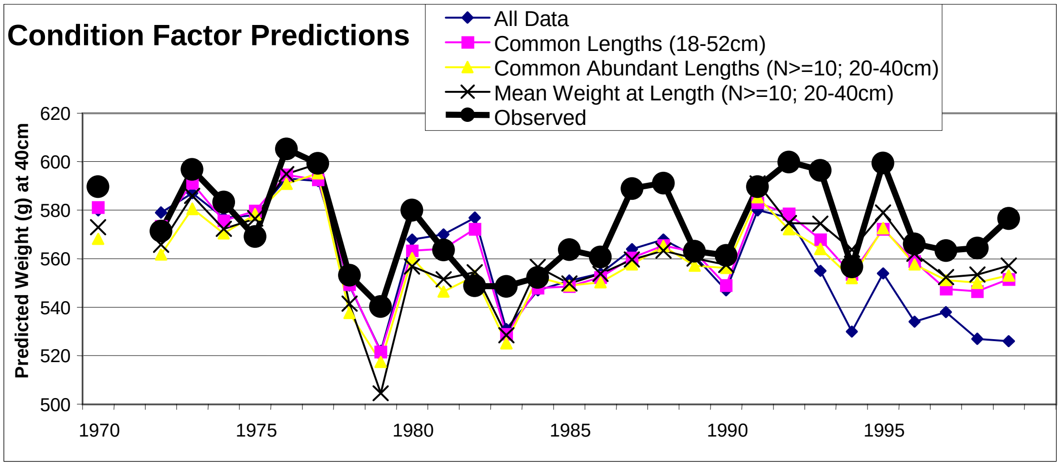
Indicator: Predicted weights at 40 and 28 cm

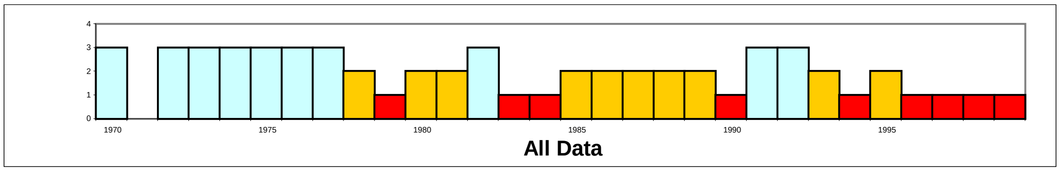
Review of Performance:

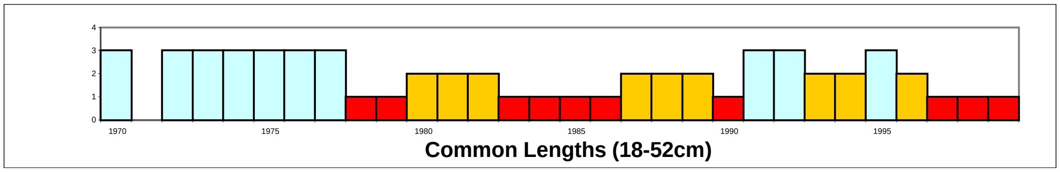
The predicted weight at 40 cm is confounded by changes in the size structure of the population during the 1990's. Constraining the prediction to a length range well represented throughout the time series compensates for the influence of size structure on the regression. In this case any of the predictions constrained to avoid the tails of the length distribution for the time series give a reasonable result, the unweighted regression (using mean weights so every length is equally weighted) giving a prediction closest to the observed data.

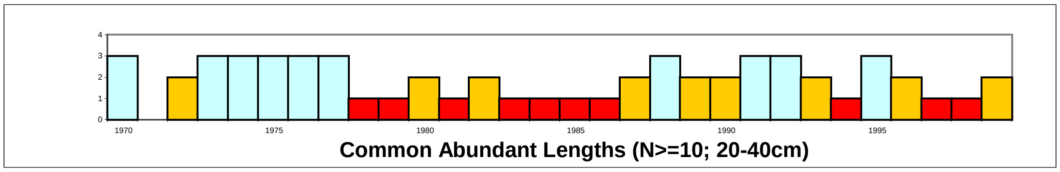
4VW Plaice: Length frequencies of individually weighed fish from summer RV (1999 on top, 1990 on bottom).

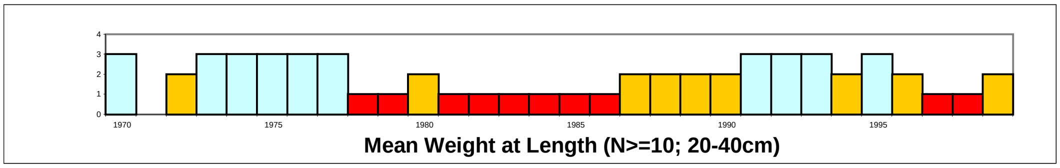






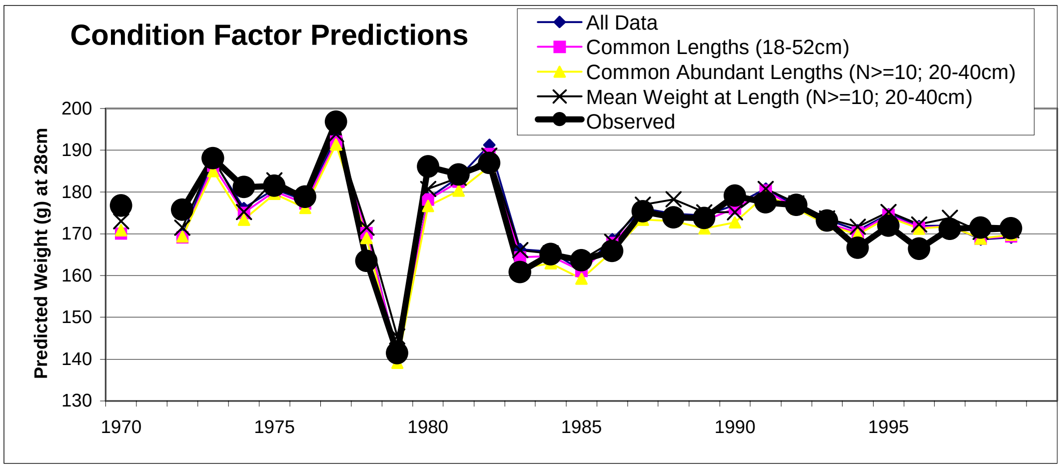






Estimates of condition factor based on predictions from growth equations are sensitive to changes in the size (age) structure of the stock. In this example for 4VW American plaice, pronounced loss of larger fish concurrent with increased abundance of small fish occurred during the 1990's. Progressive removal of the influence of the size structure of the stock on estimates of predicted weight produces a trend in the Traffic Light pattern, with the apparent worst years shifting from the 1990's to the 1980's.

Divergence of predicted and observed trends can also be circumvented by selecting the most frequent length in the data (where such a length remains common in all years) to avoid the influence on regression of changes in size structure. The following example for 28 cm plaice derives from the data set that generated the 40 cm predictions above.



Here we have essentially no difference in results between observed and predicted weights at length, regardless of whether or how we constrain the data.

Indicator: **<u>Biomass and Abundance – Survey Based</u>**

Characteristic: **Abundance** of population or **Production** in case of recruitment estimates.

Description: Estimate of the weight or numbers of a population, or subset of a population (e.g. abundance of pre-recruits, biomass of fishery sizes), obtained by stratified random sampling on multi-species research vessel bottom trawl surveys. Commonly interpreted as a relative index of abundance, it is sometimes used as a minimum estimate of absolute abundance. For a description of these surveys see Doubleday (1981), Halliday and Koeller (1971), Halliday and Koeller (1981), Koeller (1981).

Boundary Point(s): Biological criteria have yet to be determined to establish boundaries for this indicator. In the interim, default arbitrary thresholds have been established, based on the historical time series. Any value at or over the mean is considered good (green), any value under 60% of the mean is considered bad (red), and values in between are considered intermediate (yellow).

Properties:

Estimation:

- For estimation methods see Smith (1988, 1996) and references therein.
- A standard analysis program, STRAP, is available.

Measurability:

- The utility of estimates is dependent on the appropriateness of the survey design, in terms of spatial coverage, timing, stratification, trawl protocols and sampling frequency per strata, for the stock in question. Various aspects the relationships between survey design and resulting estimates are summarized in the 'Estimation Concerns' table.
- Diagnostic tests exist to compare variances between stratified and random estimates to determine if either of the stratification or sample allocation make no contribution to, or detract from, the estimation process for a given stock (see Smith 1996).
- Confidence in the indicator can be expressed in terms of likelihoods, such as bootstrapped confidence intervals (see Smith 1996).

Interpretability:

- Utility of the indicator is highest for those stocks given the most consideration during the survey design process, i.e. haddock and cod. The extent to which a given stock was included in the stratification and sampling allocation rationale will affect the precision and accuracy of estimates in various ways. See 'Estimation Concerns' table for further details.

- Changes in catchability due to changes in the survey vessel or trawl gear used are problematic. They affect not only overall estimates of biomass and abundance, but may vary among components of a stock (e.g. size of the fish). Major vessel/gear changes affecting the July 4VWX survey occurred during 1982-1983 (A T Cameron until 1981, Lady Hammond in 1982, Alfred Needler in 1983 and subsequently). Another major vessel/gear change, coupled with modifications to survey design, affected the March 4VsW cod survey (Lady Hammond until 1983, Alfred Needler in 1984, no survey in 1985, revised survey design in 1986 and subsequently). Minor vessel/gear changes involving brief (usually single year) substitutions of a vessel for a survey occurred in 1983 (fall 4VWX survey; Lady Hammond until 1982, Alfred Needler for 1983-84 after which the survey was discontinued), 1991 (Lady Hammond conducted part of the July 4VWX survey in place of the Alfred Needler), and 1993 (Wilfred Templeman conducted the Georges Bank survey, otherwise conducted by Alfred Needler). A summary of correction factors for differences in catchability between vessels for several species exist for the 1982 and 1983 summer surveys (Fanning, 1985), although in some cases these will no longer be considered appropriate. Refer to the literature documenting the assessments for a given stock to ascertain if correction rules have been determined to apply to RV estimates.

Sensitivity:

- Measured annually.

Weight: Varies with stock and details of estimation methods, but usually a very good indicator of abundance/biomass.

References:

Dahm, E. 2000. Changes in the length compositions of some fish species as a consequence of alterations in the groundgear of the GOV-trawl. Fisheries Research 49: 39-50.

Doubleday, W. G. 1981. Manual on groundfish surveys in the Northwest Atlantic. NAFO Sci. Coun. Studies 2:7-55.

Engas, A. and Godo, O. R. 1989. The effect of different sweep lengths on the length composition of bottom-sampling trawl catches. J. Cons. int. Explor. Mer 45: 263-268.

Engas, A. and Godo, O. R. 1989. Escape of fish under the fishing line of a Norwegian sampling trawl and its influence on survey results. J. Cons. int. Explor. Mer 45: 269-276.

Engås, A. and Godø, O. R. 1986. Influence of trawl geometry and vertical distribution of fish on sampling with bottom trawl. J. Northw. Atl. Fish. Sci. **7**: 35-42.

Engas, A. and West, C. W. 1987. Trawl performance during the Barents Sea cod and haddock survey: potential sources of gear-related sampling bias. Fisheries Research 5: 279-286.

Fanning, L. P. 1985. Intercalibration of research survey results obtained by different vessels. CAFSAC Res. Doc. 85/3: 43p.

Gavaris, S. and S. J. Smith. 1987. Effect of allocation and stratification strategies on precision of survey abundance estimates for Atlantic cod (*Gadus morhua*) on the Eastern Scotian Shelf. J. Northw. Atl. Fish. Sci. 7: 137-144.

Halliday, R. G. and P. A. Koeller. 1981. A history of Canadian groundfish trawling surveys and data usage in ICNAF Division 4TVWX. *In* Doubleday, W.G. and D. Rivard [ed.] Bottom trawl surveys. Can. Spec. Publ. Fish. Aquat. Sci. 58: 27-41.

Halliday, R. G. and A. C. Kohler. 1971. Groundfish survey programmes of the St. Andrews Biological Station, Fisheries Research Board of Canada – objectives and characteristics. ICNAF Res. Doc. 71/35: 10p.

Koeller, P. A. 1981. Manual for groundfish survey personnel – cruise preparation, conduct and standing orders. DFO MFD Lab. Ref. 81/3.

Koeller, P. A. 1991. Approaches to improving groundfish survey abundance estimates by controlling the variability of survey gear geometry and performance. J. Northw. Atl. Fish. Sci. 11: 51-58.

Page, F., R. Losier, S. Smith and K. Hatt. 1994. Associations between cod, and temperature, salinity and depth within the Canadian groundfish bottom trawl surveys (1970-93) conducted within NAFO Divisions 4VWX and 5Z. Can. Tech. Rep. Fish. Aquat. Sci. 1958: vii + 160p.

Perry, R. I. and S. J. Smith. 1994. Identifying habitat associations of marine fishes using survey data: application to the Northwest Atlantic. Can. J. Fish. Aquat. Sci. 51: 589-602.

Smith, S. J. 1988. Abundance indices from research survey data. *In* Rivard, D. [ed.] Collected papers on stock assessment methods. CAFSAC Res Doc 88/39:15p.

Smith, S. J. 1991. Assessing the efficacy of the groundfish survey design for the Scotian Shelf summer trawl surveys – 1980-1990. CAFSAC Res Doc 88/61: 16-43.

Smith, S. J. 1996. Assessment of groundfish stocks based on bottom trawl survey results. NAFO Sci. Coun. Studies 28: 25-53.

Smith, S. J. 1997. Bootstrap confidence limits for groundfish trawl survey estimates of mean abundance. Can. J. Fish. Aquat. Sci. 54(3): 616-630.

Smith, S. J. and S. Gavaris. 1993. Improving the precision of abundance estimates of Eastern Scotian shelf Atlantic cod from bottom trawl surveys. N. Am. J. Fish. Manage. 13: 35-47.

Smith, S. J., R. I. Perry and L. P. Fanning. 1991. Relationships between water mass characteristics and estimates of fish population abundance from trawl surveys. Environmental Monitoring and Assessment 17: 227-245.

Walsh, S.J. 1996. Efficiency of bottom sampling trawls in deriving survey abundance indices. NAFO Sci. Coun. Studies 28: 9-24.

Walsh, S.J. 1992. Size-dependent selection at the footgear of a groundfish survey trawl. North American Journal of Fisheries Management 12: 625-633.

Walsh, S.J. 1991. Diel variation in availability and vulnerability of fish to a survey trawl. J.Appl. Ichthyol. 7: 147-159.

Wardle, C.S. 1983. Fish reactions to towed fishing gears. *In* Experimental biology at sea. *Ed.* A.G. MacDonald and I.G. Priede. Academic Press, London, New York.

ESTIMATION CONCERNS WITH RESEARCH VESSEL BOTTOM TRAWL SURVEYS

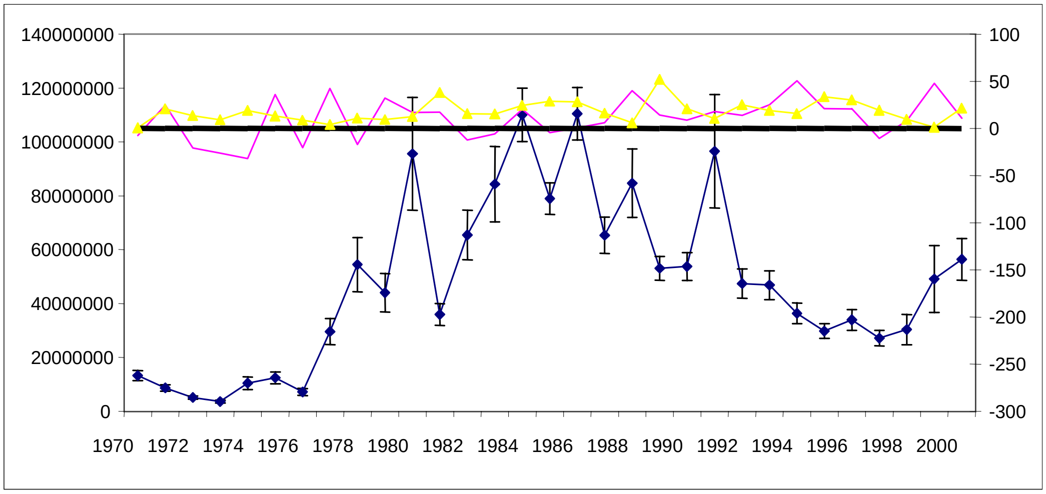
CONCERN	RELATIVE ABUNDANCE ESTIMATION		POSSIBLE POST-HOC FIXES (Relative Abundance Only)	SELECTED REFERENCES
	ACCURACY	PRECISION		
Horizontal stratification does not reflect boundaries of habitat preference.	Y	Y	Restratify.	2
Depth stratification does not reflect boundaries of habitat preference.	Y	Y	Restratify or standardize for depth.	13
Anomalous estimates. E.g. missing the preferred depth zone in a critical stratum.	Y	Y	Weight by variance or use multi-year smoothing.	15,18
Catchability varies diurnally or with depth. E.g. Vertical migrations, light-dependent differences in escape behavior.	Y		Add temporal stratification or standardize for local time or depth.	2,5,15,21,23,24
Within-stratum variation in preferred habitat. E.g. tight association with particular bottom substrates whose distribution is not reflected by the stratification.	Y		Restratify.	2,14
Catchability varies between stock components.	Y		Special study.	2,4,6,14,15,21,22
Catchability varies with time. E.g. vessel changes, loss of older fish changes catchability of younger fish of schooling species, drop in temperature changes escape behaviour or response rate.	Y		Comparative fishing or special study.	1,2,3,7,13,20,21
Insufficient sampling frequency.		Y	Restratify by combining strata to increase sample size per stratum.	8,16,17,18,19
Survey does not cover horizontal dimension of stock distribution.	Y			2
Stock distribution changes during sampling period. E.g. survey period overlaps migration period irregularly from year to year.	Y			2,15
Unrealized differences in relative tow speeds or net spread cause differences in Swept Area. E.g. subsurface currents of different speeds or directions than surface currents.	Y	Y		2,12
Non-uniform distribution of patches of fish. E.g. highly localized schooling.	Y	Y		
Change in catchability with tow duration.		Y		2,15,24
Habitat preference for untrawlable bottom differs from trawlable bottom.	Y			2

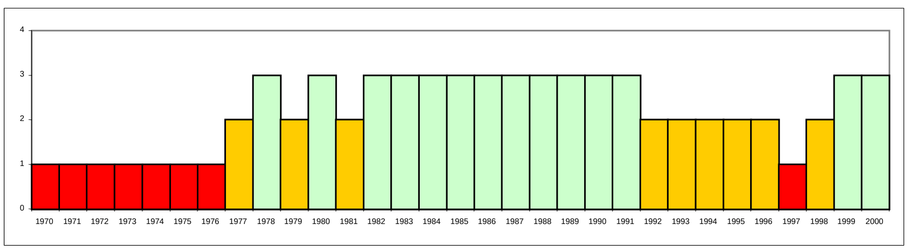
Example Application: 4VW Haddock

Indicator: summer survey biomass of fish over 36 cm

Review of Performance:

Abundance estimates (with standard errors) of fish over 36cm, and associated percent efficiencies of survey set allocation (dark line) and stratification (light line) relative to zero (the horizontal bar). Below is a Traffic Light depiction of stock status based on the abundance indicator.





There are positive efficiencies for both set allocation and stratification in most years, suggesting that the survey design (and implementation) has been appropriate for this stock.

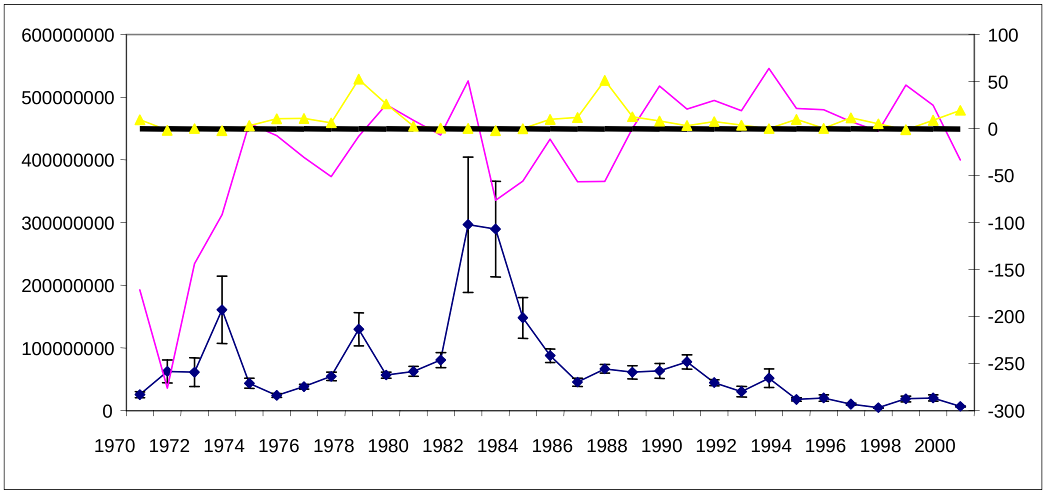
Weight: High

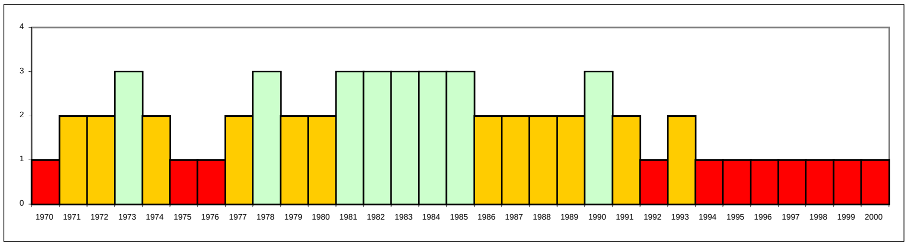
Example Application: 4VsW Cod

Indicator: summer survey biomass of fish over 30 cm

Review of Performance:

Abundance estimates (with standard errors) of fish over 30cm, and associated percent efficiencies of survey set allocation (dark line) and stratification (light line) relative to zero (the horizontal bar). Below is a Traffic Light depiction of stock status based on the abundance indicator.



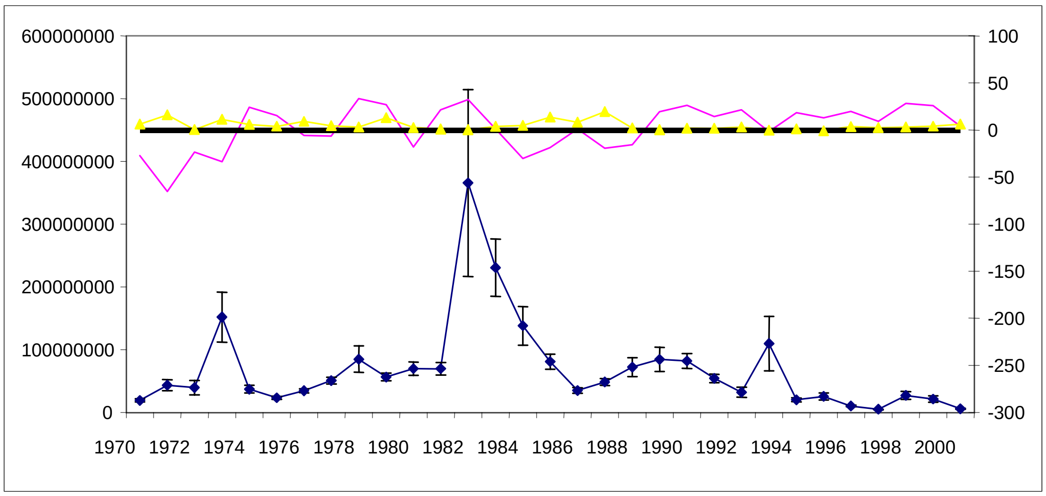


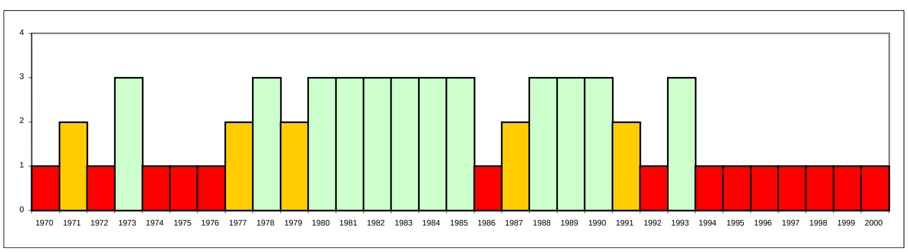
The diagnostics associated with this indicator suggest some extreme instances of poor sampling, while at the same time the stratification is rarely relevant. Gavaris and Smith (1987) contended that the data were over-stratified for this stock, and that precision could be improved by combining the original strata into only 6 larger strata to increase the sampling allocation per stratum.

Weight: Medium

The following example applies a five-strata approximation of the Gavaris and Smith (1987; Figure 3) stratification scheme to this stock (subjective visual assignment of traditional to revised strata):

Abundance estimates (with standard errors) of fish over 30cm, and associated percent efficiencies of survey set allocation (dark line) and stratification (light line) relative to zero (the horizontal bar). Below is a Traffic Light depiction of stock status based on the abundance indicator.





The historical representation of cod abundance remains essentially the same as above, the restratification serving only to increase our confidence in the indicator.

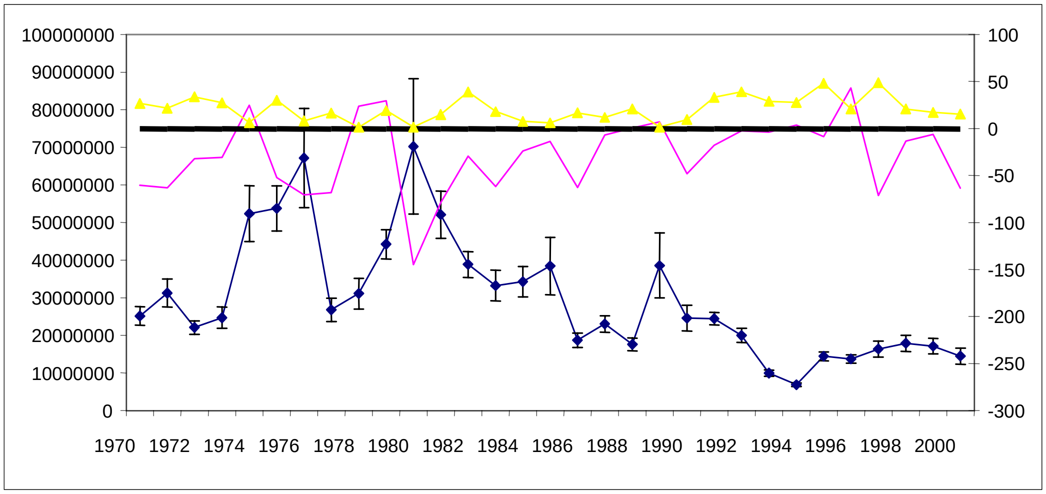
Weight: <u>High</u>

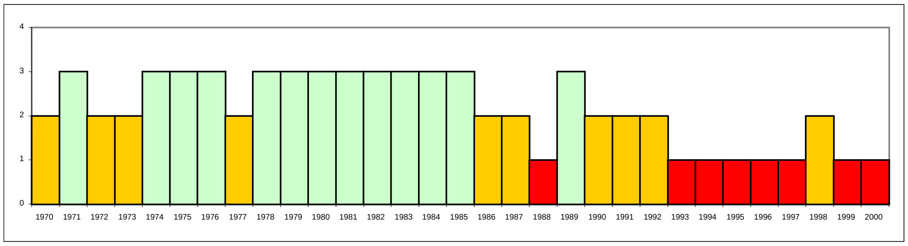
Example Application: 4VW Plaice

Indicator: summer survey biomass of fish over 35 cm

Review of Performance:

Abundance estimates (with standard errors) of fish over 35cm, and associated percent efficiencies of survey set allocation (dark line) and stratification (light line) relative to zero (the horizontal bar). Below is a Traffic Light depiction of stock status based on the abundance indicator.





The diagnostics suggest suboptimal sampling, with the worst sampling year corresponding to the highest abundance estimate (and largest standard error) for this stock. However the stratification is very meaningful for this indicator, so it might not be possible to improve these estimates by simply combining strata as was accomplished for 4VsW cod above.

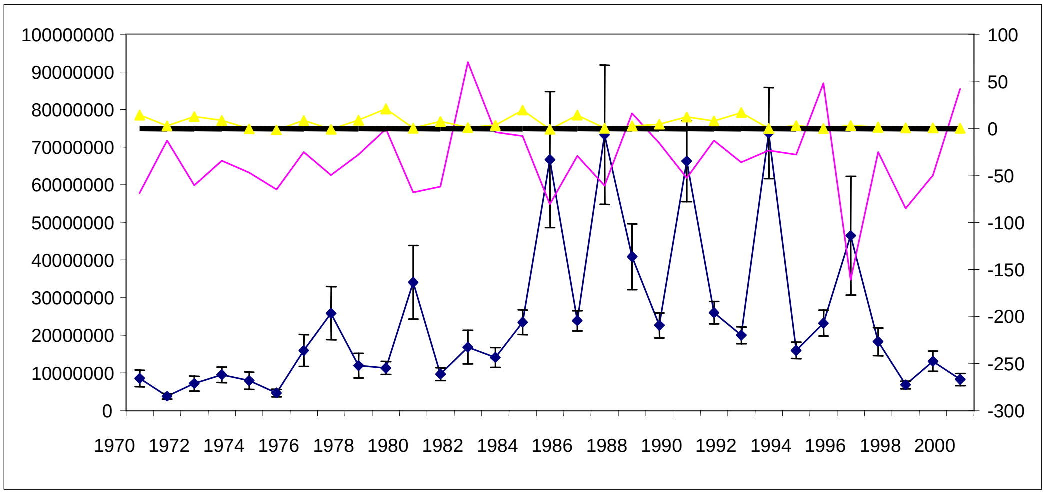
Weight: Medium

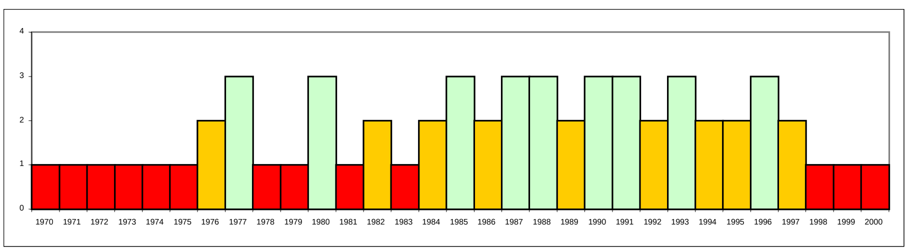
Example Application: Pollock

Indicator: summer survey biomass of fish over 36 cm

Review of Performance:

Abundance estimates (with standard errors) of fish over 36cm, and associated percent efficiencies of survey set allocation (dark line) and stratification (light line) relative to zero (the horizontal bar). Below is a Traffic Light depiction of stock status based on the abundance indicator.





Extreme interannual variation in abundance estimates, consistently suboptimal sampling, and no apparent relationship between the survey stratification and stock distribution, suggest this indicator has limited utility for pollock. Possibly the estimates will be amenable to restratification by combining like strata, as demonstrated above for cod. However the more pelagic tendencies of pollock relative to cod may frustrate attempts to improve estimates.

Weight: Low

Indicator: **<u>Relative Fishing Mortality</u>**

Characteristic: **Fishing Mortality**

Description: Ratio of the commercial catch divided by a research vessel survey index of relative population abundance, providing a measure of fishing mortality for stocks, typically where numbers-at-age data is not available (Fanning et al., 1996; Sinclair, 1998).

Boundary Point(s): Biological criteria have yet to be determined for this indicator. In the interim, default arbitrary thresholds have been established, based on the historical time series. Any value under the mean is considered good (green), any value over 140% of the mean is considered bad (red), and values in between are considered intermediate (yellow).

Properties:

Estimation:

- In the simplest form, the commercial landings are divided by the RV survey biomass estimates for the appropriate stock management area in each year.
- Where biological sampling provides length and weight data for individual fish, estimate the RV biomass of only fished components of the stock as the denominator.
- Usually, individual lengths and weights of fish are only subsampled, but total numbers and weights are recorded. The biomass of fished components may be estimated by applying the length-frequency proportions of the sampled fish to the total number of fish to partition the abundance by size groups. These abundances can then be multiplied by the mean weight of fish in their respective size groups to estimate the biomass of each fished component of the stock.
- The mean weight and abundance might be single values for the entire fished component (mean weight X total abundance of all fishery-sized fish), or a separate biomass might be computed for each length and then summed to produce the total.

Measurability:

- The commercial landings for some stocks may misrepresent the true catch due to discarding or misreporting.
- It is important to ensure that catch data summation is centralized with respect to the timing of the survey. For instance, if using a summer survey to estimate the denominator, simple annual landings are appropriate. If using a spring survey, however, the landings would need to be tabulated for a yearly period more centred on the survey month.
- Any concerns with estimates of biomass (see Biomass and Abundance – Survey Based) apply to Relative F.

Interpretability:

- Trends in relative F should mirror trends in fishing mortality.
- Correspondence in actual magnitudes of relative F versus true fishing mortality will only occur in the unusual circumstance that the survey estimate is a measure of absolute biomass, as opposed to a relative index. Hence the method cannot be extended to provide estimates of population size and production, or to generate catch projections. Nor do we have a suite of associated diagnostic methods, such as provided by SPA, by which to gauge the accuracy or precision of relative F estimates.
- When catches are severely restricted in response to low stock abundance and/or productivity, F will be low, and default boundary rules classify such low values as "green". Under these circumstances, a different interpretation of F in stock status determination may be warranted than when the stock is in a high abundance/productivity state. This could be achieved by making boundary points, indicator weighting, or the influence of F in decision rules, contingent on abundance/productivity characteristics.

Sensitivity:

- Survey biomass is usually measured at least annually. However, inter-annual variability in survey data may require smoothing over several years to obtain stability in estimates of relative F.

Weight: Where we have confidence in the quality of the catch data (landings and discards) and temporal consistency of survey estimation of relative biomass, this can be a fairly reliable indicator of fishing mortality.

References:

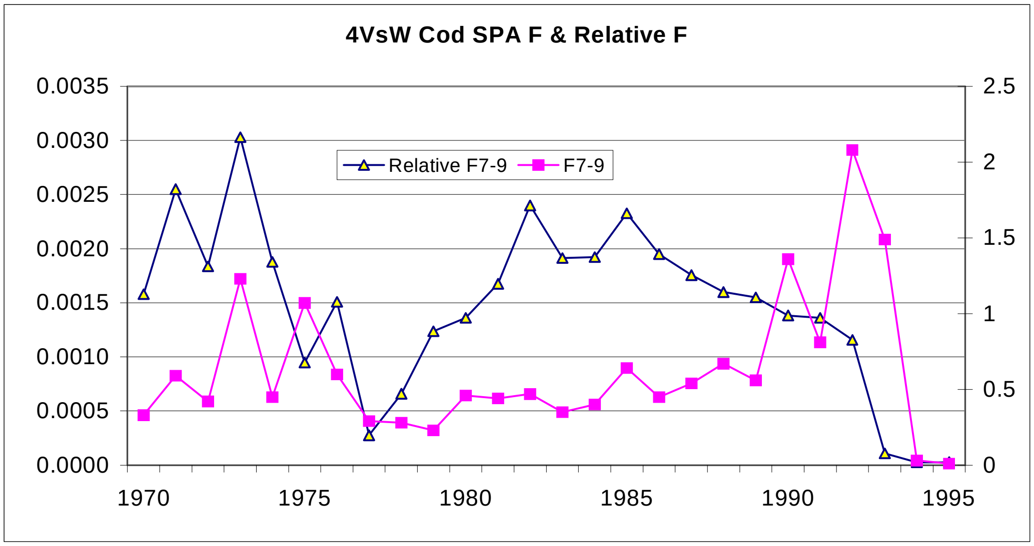
Fanning, L. P., R. K. Mohn and W. J. MacEachern. 1996. Assessment of 4VsW cod in 1995 with consideration of ecological indicators of stock status. DFO Atlantic Fisheries Research Document 96/27.

Sinclair, A. F. 1998. Estimating trends in fishing mortality at age and length directly from research survey and commercial catch data. Can. J. Fish. Aquat. Sci. 55: 1248-1263.

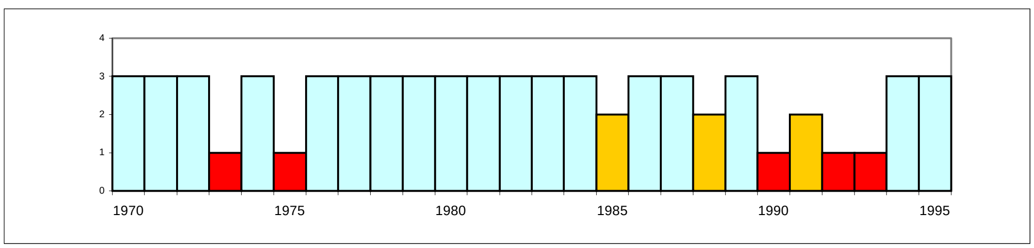
Example Application: 4VsW Cod

Indicator: commercial catch / survey biomass of fish aged 7-9

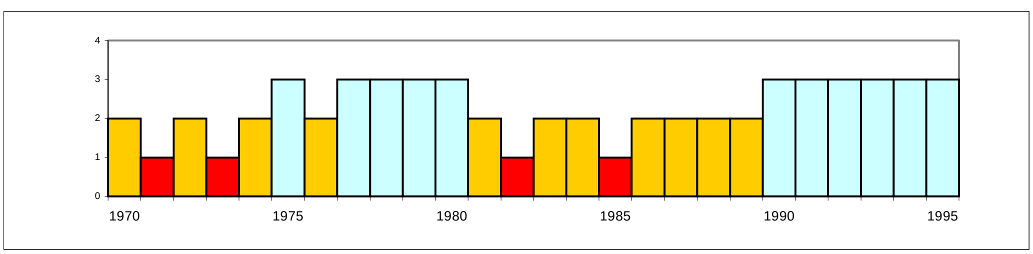
Review of Performance:



F on Ages 7-9



Relative F on Ages 7-9



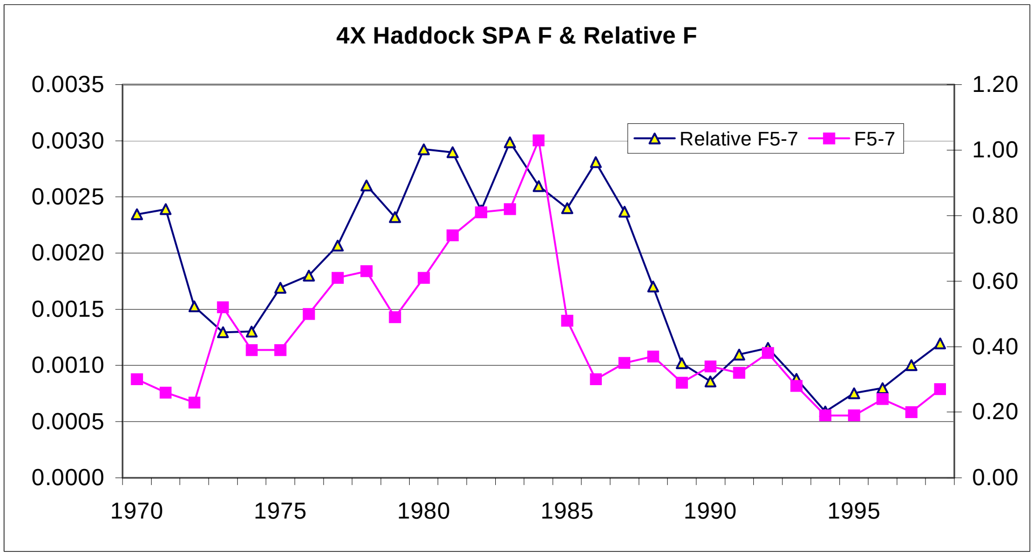
Correspondence between relative F and SPA-F on ages 7-9 is poor. Both depict a reduction in F due to catch restrictions in the later 1970s, and another reduction following the 1993 fishery closure, but the high F prior to the 1993 closure depicted by SPA-F, is not apparent with Relative F.

Weight: Low

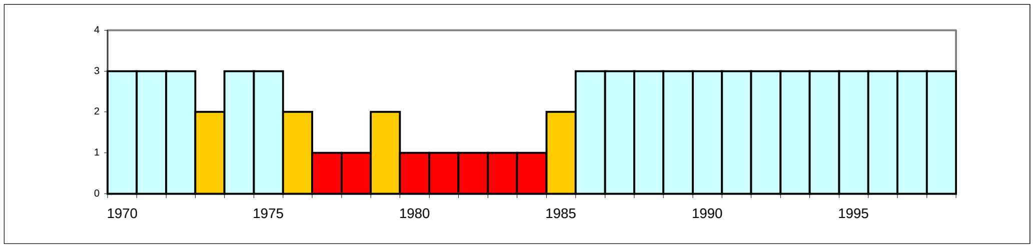
Example Application: 4X Haddock

Indicator: commercial catch / survey biomass of fish aged 5-7

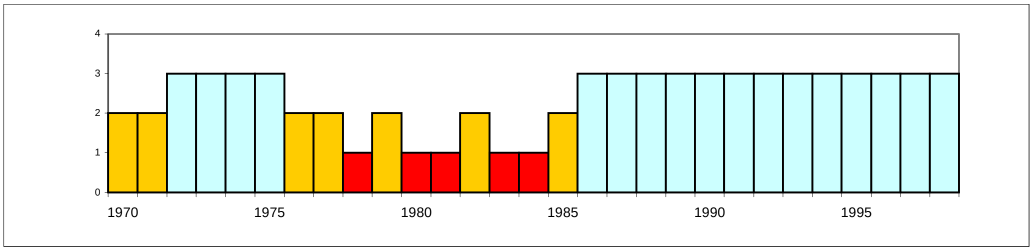
Review of Performance:



F on Ages 5-7



Relative F on Ages 5-7



We see general correspondence in trends between relative F and SPA-based F on ages 5-7 for most of the time series, although they diverge markedly during the later 1980's (not apparent from the Traffic Lights).

Weight: Medium

Indicator: **Z derived from Research Vessel Numbers at Age (RV Z)**

Characteristic: **Production**, perhaps **Fishing Mortality**

Description: This indicator is derived from the log of the ratio of numbers at age in a cohort. The natural log of this ratio is an estimate of the instantaneous mortality rate Z.

Boundary Point(s): Boundary points might be derived from production modelling, some versions of which deal directly with Z. If M were estimable, yield per recruit type limits could also be used. Z limits may also be inferred from age or size composition considerations.

Properties:

Estimation:

- Numbers at age data for a number of years are required. Unless (relative) gear efficiency at age is known, absolute Z can be estimated only for ages fully selected by the survey gear.
- Cohort survivorship ratios are estimated, for age a at time t, ($N_{a+1,t+1}/N_{a,t}$), and then the natural log taken. The ratio has been inverted so the Z will be positive. As a practical measure to remove the effects of zeros in the data, the ratios are constrained to be between 0.001 and 1000.
- Ages are constrained to those for which there are enough observations to make meaningful estimates.
- Data are often noisy so a number of ages may be pooled or running means used.
- In a similar manner a relative Z may be estimated for the age classes that are not fully recruited.
- As well as survey data, aged commercial catch rate (CPUE) data may be used with the usual caveats.

Measurability:

- Although computationally simple, the results are quite noisy and may exhibit 'year' effects.
- Survey design may change over the data period.
- If commercial data are used they may not represent either the population or the same portion of the population throughout the time series.

Interpretability:

- Absolute Z is easily interpreted, although fishing and natural causes of mortality are mixed.
- Relative Z (due to incomplete recruitment of some ages) can be used only to show time trends. They can be converted to estimates of absolute Z if the gear efficiency at age is available.

- If commercial data are used, changes in fishing practice will bias results. Also, full selectivity of commercial gear is likely to occur at older ages than for research gear.

Sensitivity:

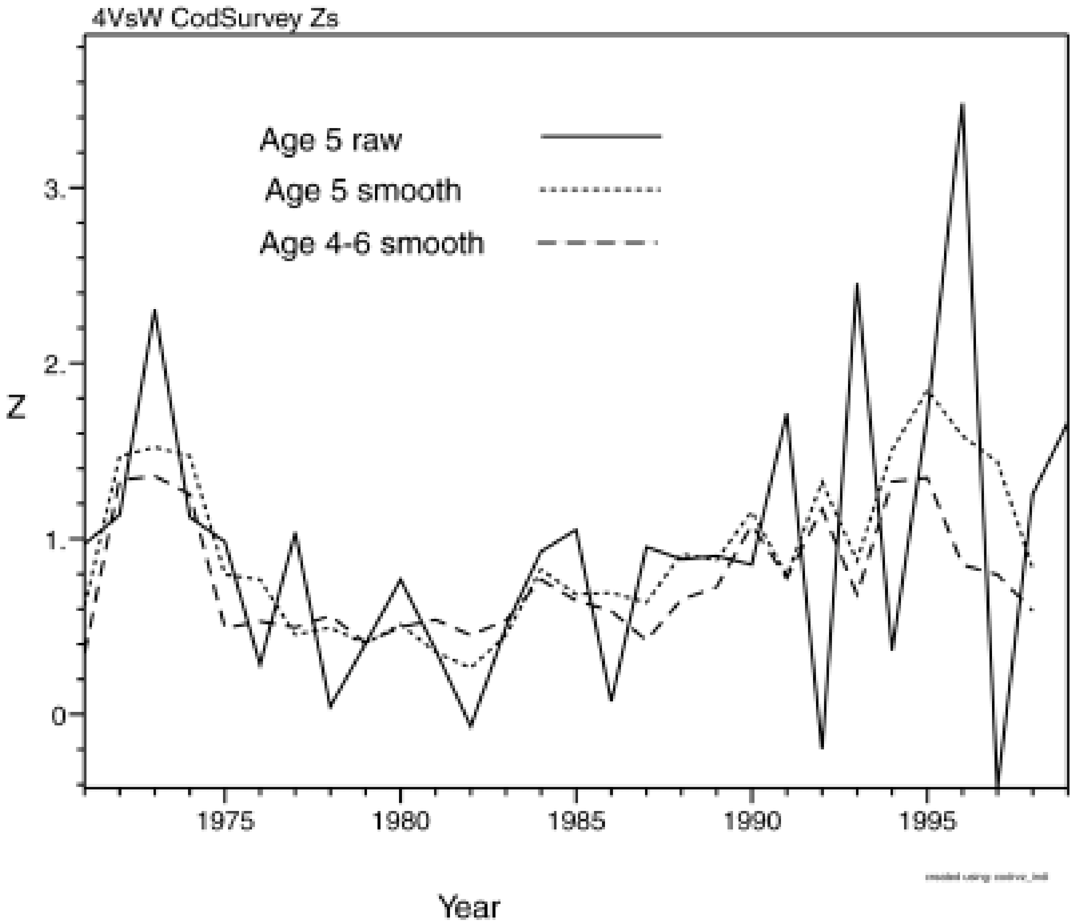
- Aged survey data tend to be noisy, which could mask real events.
- When ages are aggregated or moving averages used, sensitivity will be decreased.

Weight:

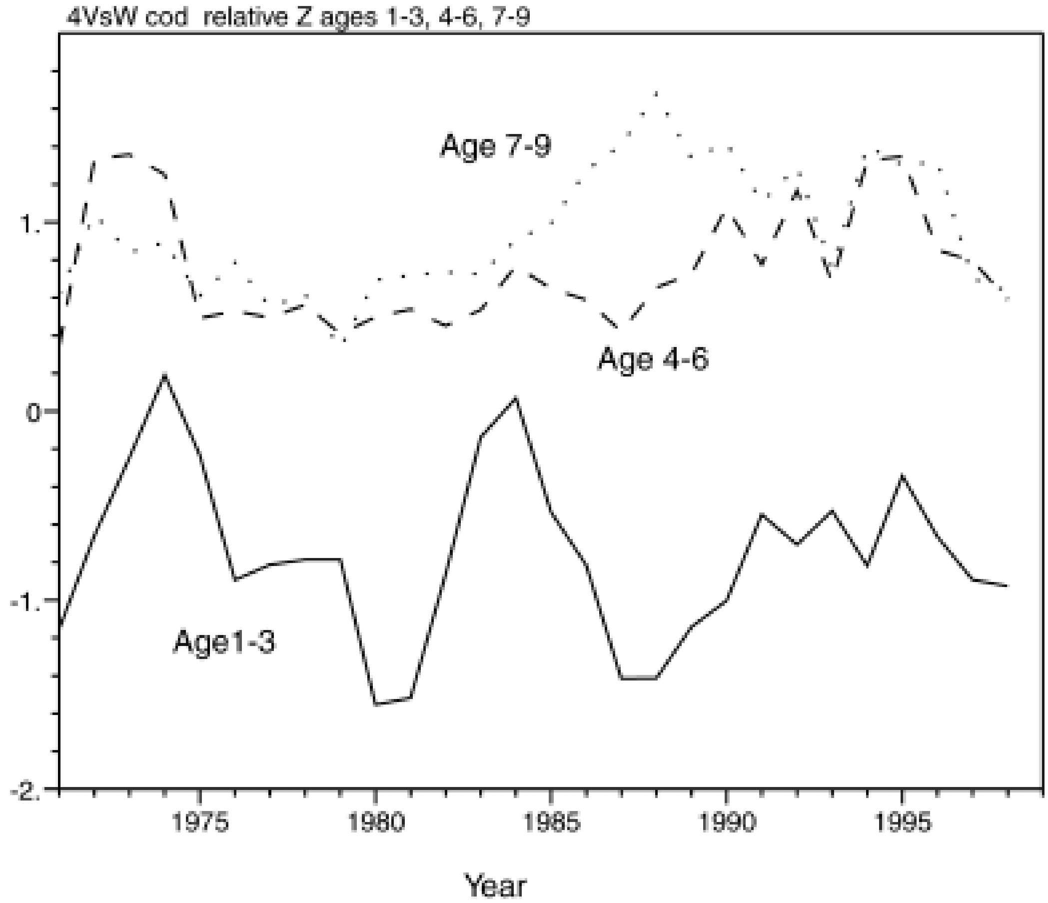
If the species are well sampled in the survey, and the Zs reasonably stable from year to year, these estimates should be given high weight as they are the most direct estimates of survivorship.

Review of Performance or **Validation of Indicator**

4VsW Cod Case Study
Data are from the 4VWX summer survey series. Although ages from 0 to over 15 are seen in the survey, the data are constrained to ages 1-10. The first plot shows the Z estimates for age 5 with and without 3 year moving average smoothing. Also this plot shows the further smoothing by averaging three age classes, 4-6.



The following figure shows the Zs in three age groups, 1-3, 4-6, 7-9. The age group 1-3 has a negative Z because these ages are only partially recruited to the survey gear. Thus age group 1-3 estimates must be considered as relative Zs. The other ages are probably fully recruited to survey gear so there estimates may be thoughtof as absolute Zs.



Haddock Case Studies
See the indicator description **Z derived from Catch Curve Analysis** for 4VW and 4X haddock examples.

Indicator: **Z derived from Catch Curve Analysis (slope of length frequencies)**

Characteristic: **Production**, perhaps **Fishing Mortality**

Description: This indicator is derived from the slope of the descending limb of either catch or survey length frequency data. Two transformations are required. The first is to the y-axis and it is to take the natural log of the frequencies. The second is to convert the x-axis from length to a pseudo age by inverting a growth curve, typically a von Bertalanffy, but any may be used.

Warning: This method requires many assumptions and should not be used if more direct estimates are available. This is especially true when using commercial data.

Boundary Point(s): Boundary points might be derived from production modelling, some versions of which deal directly with Z. If M were estimable, yield per recruit type limits could also be used. Z limits may also be inferred from age or size composition considerations.

Properties:

Estimation:

- Length frequency data for a number of years are required and the descending limb selected.
- A growth curve (length at age) is required.
- A length frequency for a year or the average for a number of years can be used.
- The x-axis is transformed by inverting the growth curve (see example below).
- The y-axis is transformed by taking the natural log.
- A linear regression is fit through the chosen descending limb and its slope is the estimate of Z.
- The frequencies do not have to be absolute, i.e. relative frequencies may be used.

Measurability:

- Although computationally simple, choice of the points that define the descending limb in the regression is subjective.
- Growth rates may vary through time.
- If commercial data are used they may not represent either the population or the same portion of the population throughout the time series.

Interpretability:

- Z is easily interpreted, but the method assumes equilibrium or that the standing stock approximates a cohort.
- Recruitment changes may confound the estimates. For this reason often length frequencies for a number of years are averaged together to damp out recruitment spikes.
- If commercial data are used, changes in fishing practice will bias results.

Sensitivity:

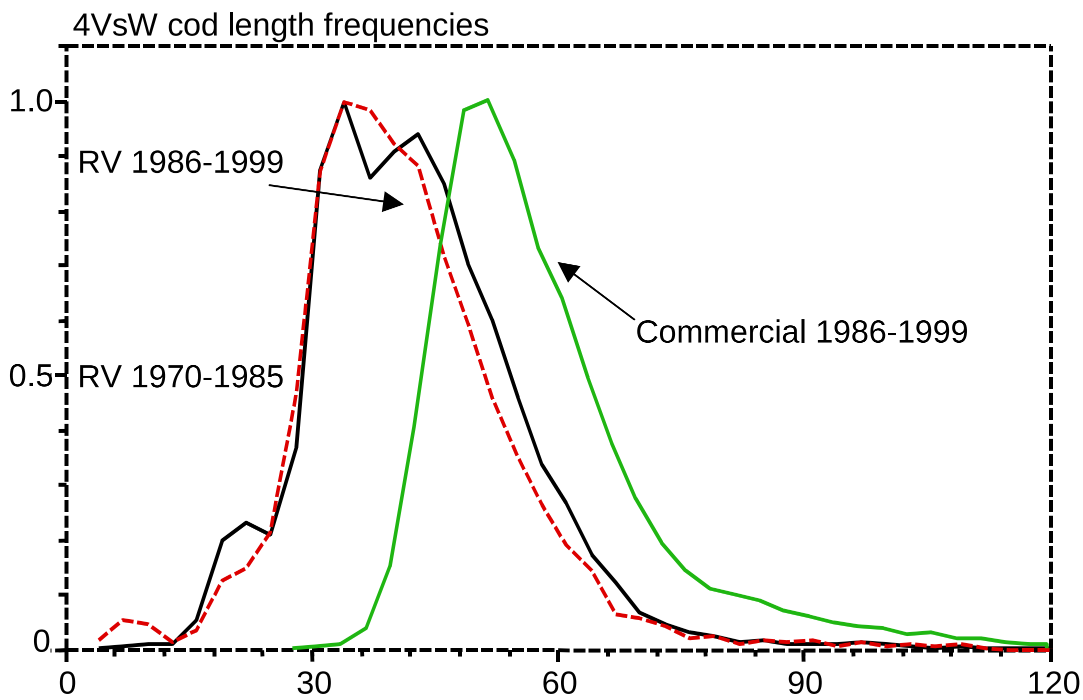
- When moving averages of length frequencies are used, longer time windows will decrease sensitivity.
- A lag is also inherent in this estimate as fishery events may take some time to reach the descending limb of the length frequency data.

Weight:

Because of the restrictive assumptions this method would not be used if more direct indices are available. When they are not, subjective down-weighting or even rejection may be warranted depending on the data and fishery involved.

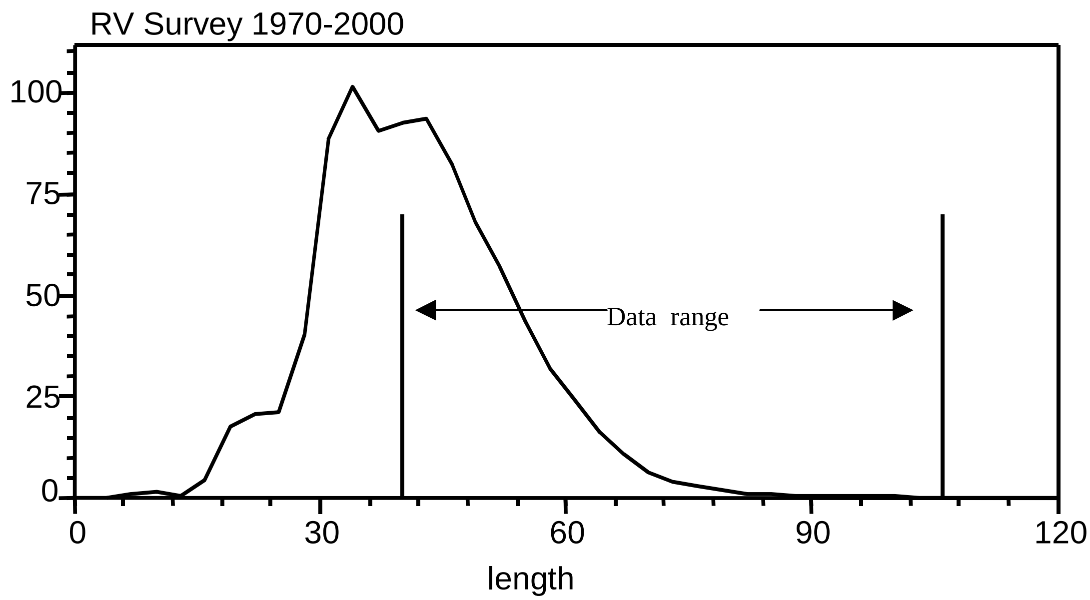
Review of Performance or **Validation of Indicator**

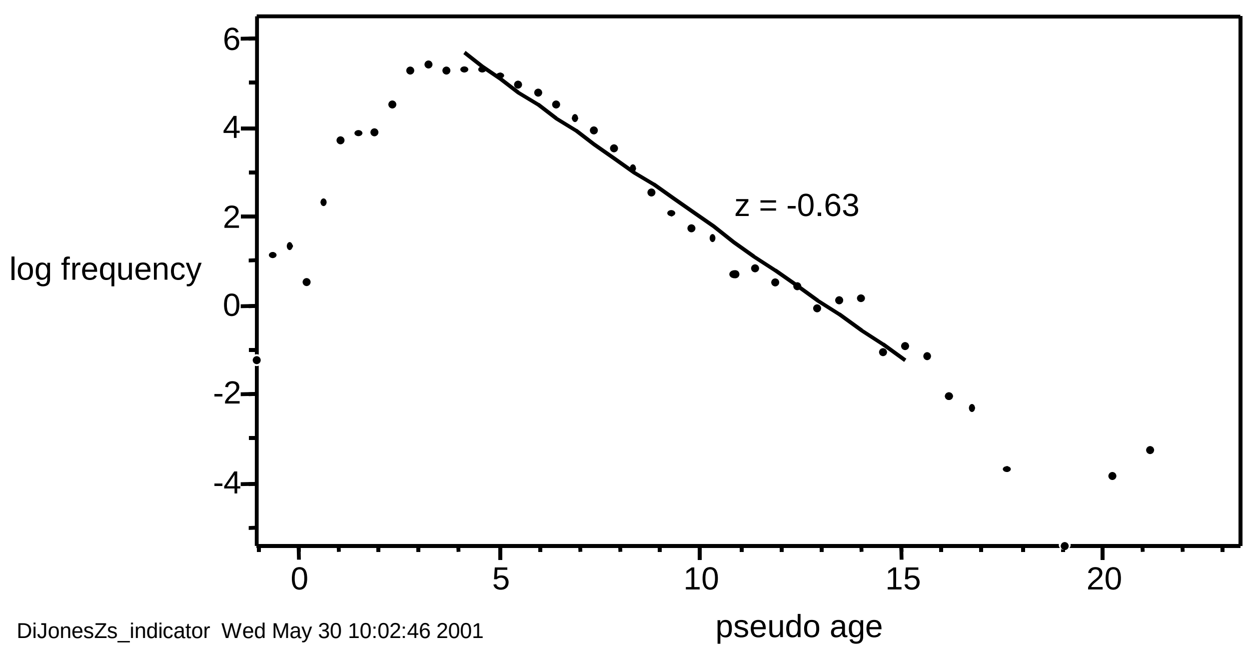
4VsW Cod Case Study
Both survey and commercial data are used. The length frequencies for the summer RV have been broken into two periods so that one will match the commercial length frequencies from 1986-1999. The data have been normalised so the maximum frequency is one.



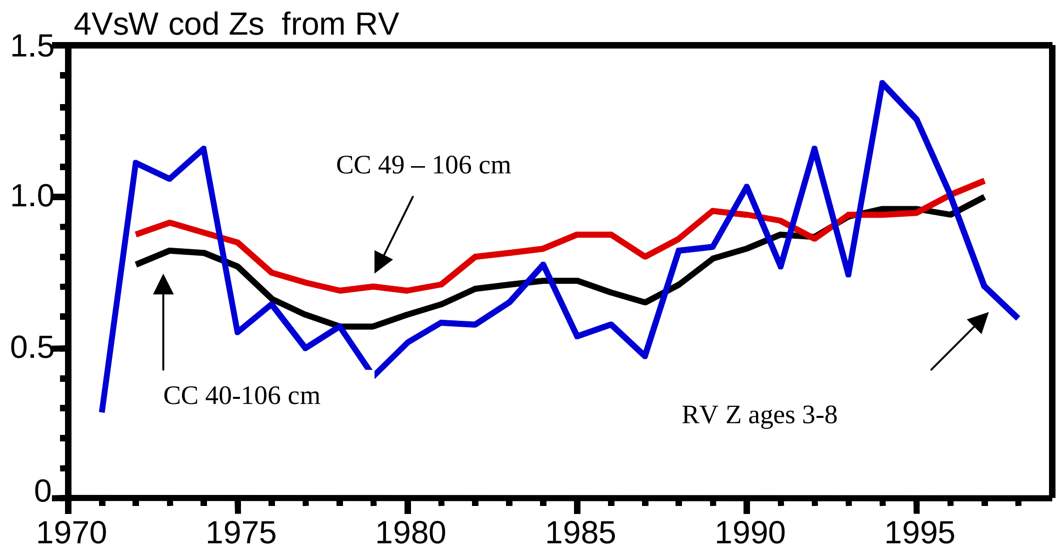
DiJonesZs_indicator Tue May 29 17:13:10 2001

The following figures show the average RV frequency for the entire time period. Also shown is the data range used in the regression and the data after transformation. The regression line only fits the range of lengths chosen and its slope, which is –0.63, is the Z estimate.

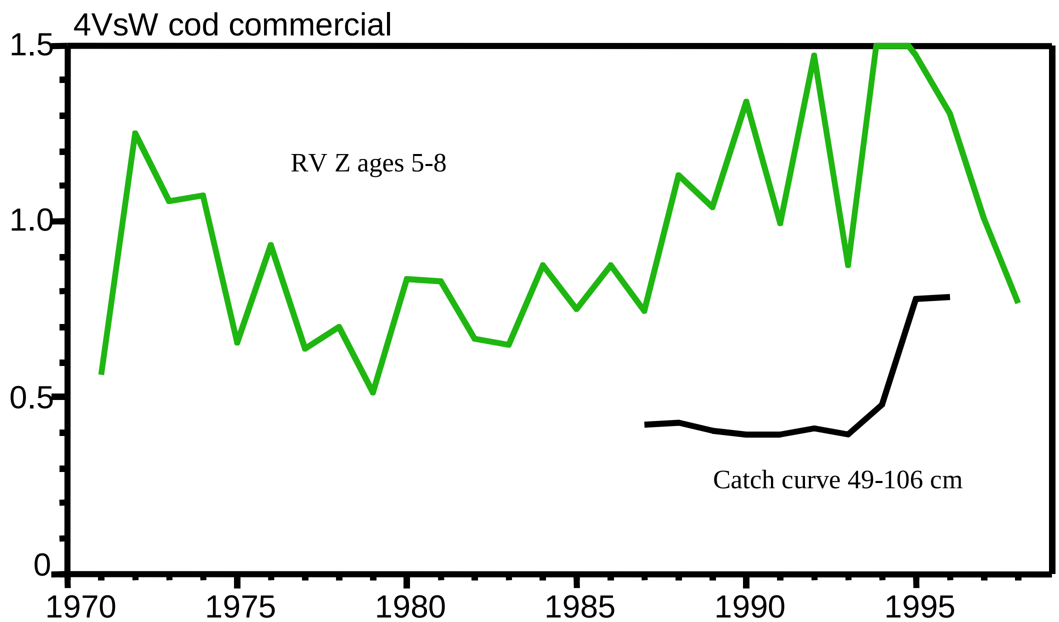




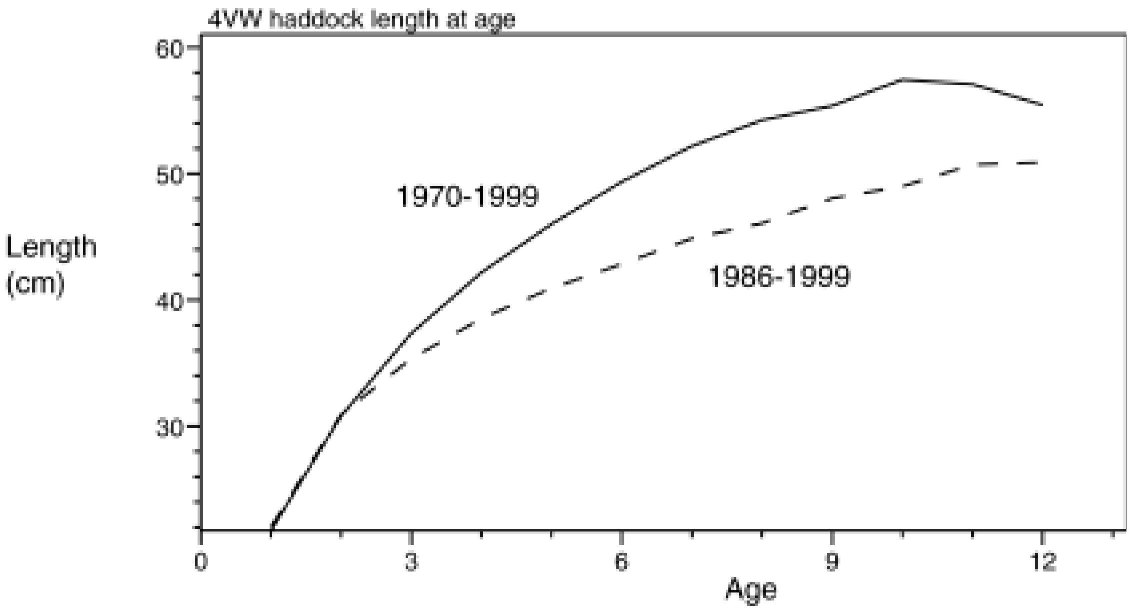
If the data are analysed ina moving window on length frequencies a time series of estimated Zs is produced. In the following example the temporal window is 5 years. Two lengths ranges were chosen, 40 – 106 and 49- 106 cm. For comparison the Z calculated directly from the aged RV is also shown. The catch curve Zs follow the RV Z fairly well but are smoothed by the averaging over years.



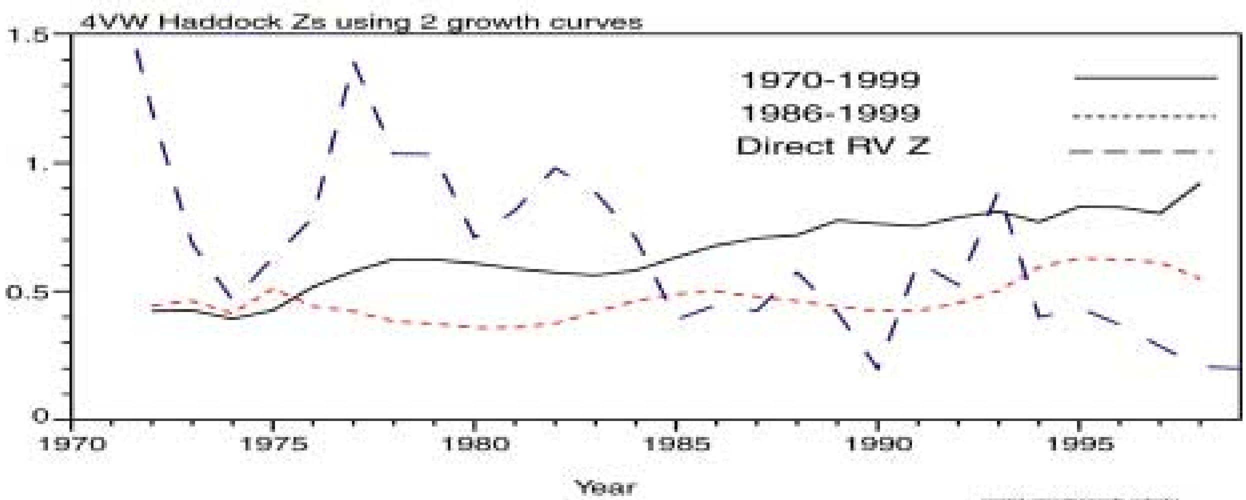
A similar analysis was done using commercial data. For comparison, as above, a direct Z is estimated from the RV, but for ages 5-8 as these are the main ages in the commercial data. The commercial catch curve Z shows a long plateau and then a sudden increase suggesting that the industry could find large fish until the mid-1990s althought the survey did not. Except for general trend, this index is not informative with these data. The change in the commercial based Z coincides with the closure of the fishery in 1993.



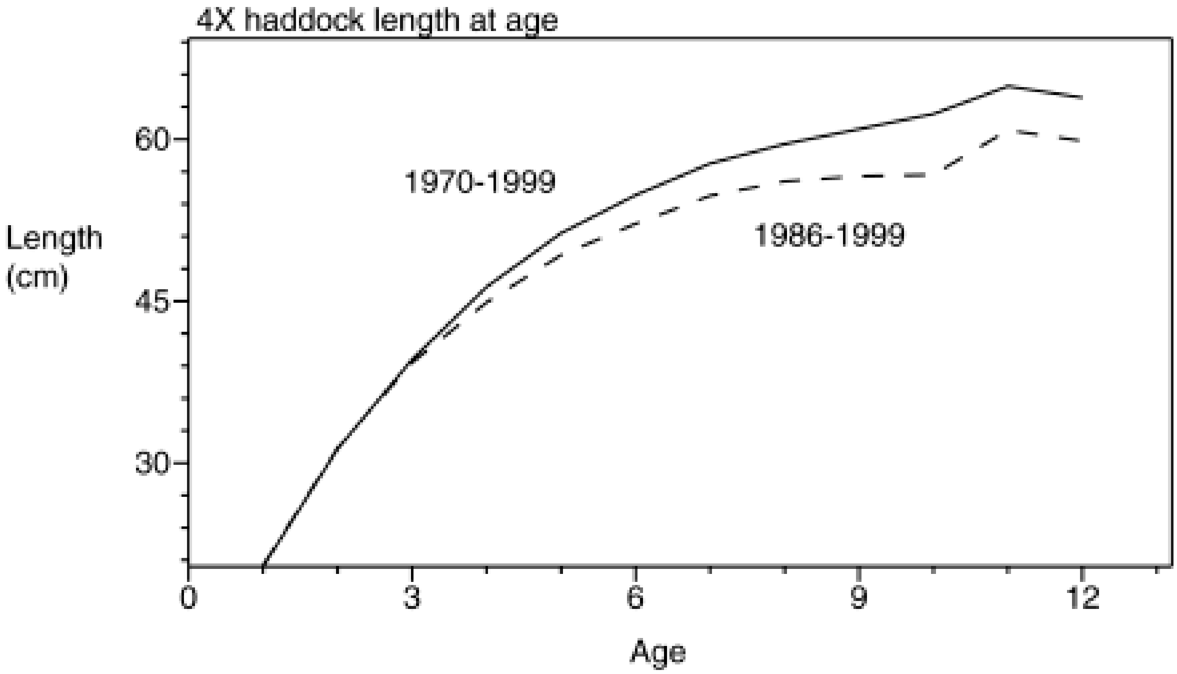
4VW Haddock Case Study
This stock was chosen for two reasons; 1) because of a known change in growth rate and 2) because of the failure of the catch curve to match the direct RV estimates. The following figure shows the length at age from summer survey data for the periods 1970-1999 and 1986-1999.



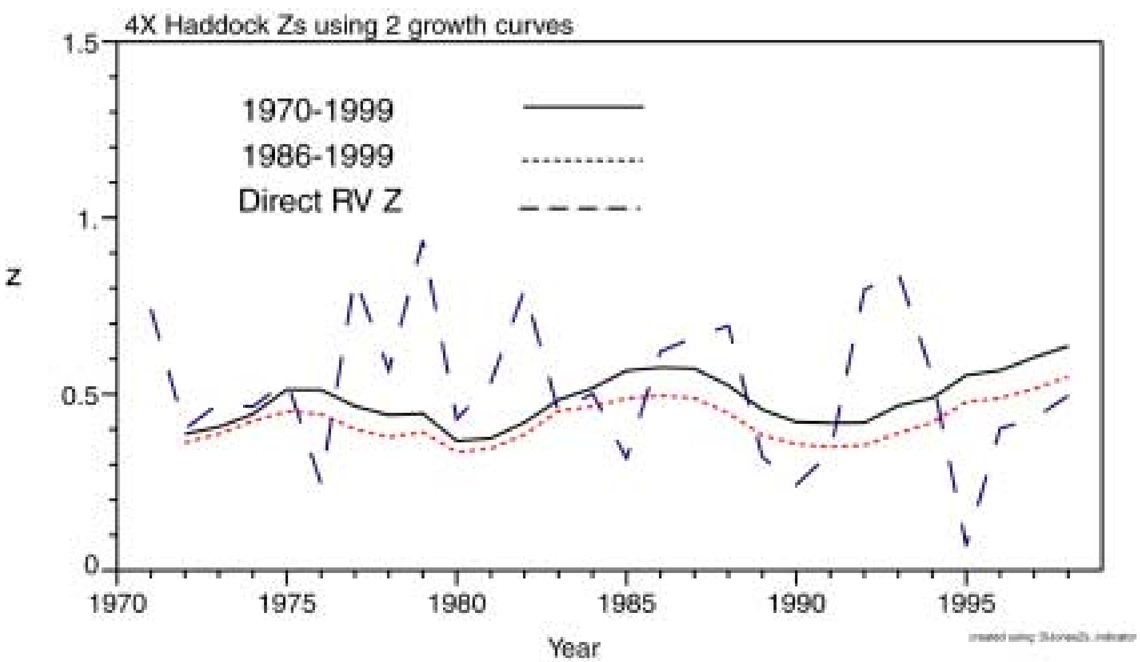
Growth curves were fit to the entire data series and to the last 15 years. Catch curve Zs were estimated as above using the growth model from all data (1970-99) and for the last 15 years (1986-99). These two series start to diverge about 1975. For reference the direct RV Z is also shown. For these data the estimates from the two methods do not agree.



4X Haddock Case Study
This stock was chosen as a contrast to the 4VW haddock above. Although there is a change in growth rate over the 30 year data period it is not as severe as for 4VW haddock. Also, the wide fluctuations in Z seen in the early years is not seen in 4X. The following figure shows the growth for the same two periods, and although there is some divergence it is not as pronounced as in 4VW.



The Z from the catch curves agree well with the RV Z in this case.



Indicator: **<u>Temperature</u>**

Characteristics: **Ecosystem**

Description: Temperature is arguably the main environmental indicator. Temperature changes influence the productivity and distribution of many fish and shellfish species. This includes affects on the growth and reproduction of individual fish, as well as on the spatial distribution and abundance of the population through recruitment. In addition, the catchability and availability of some species are often linked to changes in temperature.

Boundary Point(s): The reference points will be species, and in some cases stock, dependent. However, knowledge of the general response to temperature can be used to predict "likely" responses for those species and stocks where information on the specific effects of temperature is lacking. For example, cold waters will generally be detrimental to "cold-water" species but good for "warm-water" species. Also, colder conditions may cause problems for a particular stock of a species at the northern extreme of its distribution but a similar decline experienced by another stock at its southern extreme may help to promote stock abundance. Such differences in response are due to the differences in the absolute temperature. Temperature may also have different effects on different parts of the life cycle. Warm temperatures may promote faster growth but may lead to reduced distribution in the case of a "cold-water" species.

Properties:

Estimation:

- Areal and volume temperature indices are estimated from the available data collected from several sources including DFO surveys, fishermen run surveys, oceanographic monitoring and process studies, ships of opportunity, satellite imagery, etc.
- Example products include the area of bottom covered by a certain temperature range, the volume of cold intermediate water (CIL), the mean temperature within a given area, etc.
- Because of the large seasonal variability, especially in the upper 100-150 m of the water column, temperatures are often expressed in terms of anomalies from the long-term mean.
- Estimates of the annual or monthly mean temperatures at a particular site or within a given area are often derived from limited data; hence they do not always reflect true averages. For example, annual means are usually estimated from the available monthly means, which in some years, may only be one to three months. The assumption is that these months (or month) is representative of the year.

- Data are available in the BIO historic hydrographic database at http://www.mar.dfo-mpo.gc.ca/science/ocean/database/climapp.html. The raw data or averaged data are available upon request (see instructions on website). Climate indices including temperature and temperature related variables are available from http://www.meds-sdmm.dfo-mpo.gc.ca/alphapro/zmp/climate/climate_e.shtml.

Measurability:

- Temperature is easy to measure and is relatively accurate.
- Temperatures in the near surface layer undergo large seasonal and shorter term variability so that many measurements are required to obtain a truly representative "average" temperature and thus resolve interannual variability.
- Temperatures in the subsurface layers often exhibit less variability than in the near-surface layers. Also there tends to be large-scale coherency over time scales of a few years to decades.

Interpretability:

- To determine reference points, mechanisms and hypotheses linking specific fisheries effects to temperature changes are required.
- Where links between temperature and fish are established, these may not be constant in time as the factors controlling fish variability is many factored and the relative importance of the factors may change.
- Temperature changes may not produce a direct effect upon the fish but the observed fish response may be through a temperature mediated variable such as food or predators.

Sensitivity:

- Temperature effects on catchability and availability can occur rapidly (days to months).
- Effects on distribution may occur on either relatively short or long time scales (months to years) depending upon the magnitude of the temperature change.
- Productivity changes such as stock abundance will tend to respond on the order of years. While growth rate may be effected over short periods of time, size-at-age is cumulative and hence it may take a long time to detect the effects of temperature changes on this variable.

Weight:

The weighting will depend upon the reliability of the relationship between the species or stock in question and the temperature. Those where strong relationships can be demonstrated, then the weighting should be high whereas if the linkages are weak or assumed, the weighting should be low.

Example Application: **4VW Haddock Growth**

Indicator: Temperature through its effect on growth

Review of Performance:

Temperature anomalies (relative to 1961-90) in the northeastern Scotian Shelf as reflected in the 100 m values on Misaine Bank were relatively high in the 1950s, declined into the 1960s, varied during the 1970s but rose to a peak by the early 1980s (Fig. 1). At this time a rapid cooling occurred that reached a minimum in the early 1990s after which temperatures increased gradually through to the present. Temperatures were below normal through most of the last 15 years. Temperature variability at 100 m on Misaine Bank has been shown to be representative of the thermal conditions in the subsurface waters of the northeastern Scotian Shelf (4Vs) and eastern sections of 4W. Similar temperature conditions also have been observed in the Gulf of St. Lawrence and on the southern Newfoundland Shelf, in particular on St. Pierre Bank.

The 5-yr running means of the Misaine Bank 100 m temperature anomalies were correlated with the weight-at-age 7 of 4VW haddock from the surveys for the years 1970-1996. Similar trends in the weights-at-age were observed for ages 4-10. Approximately 62% of the variance in the length-at-age 7 was accounted for by the temperature alone (Fig. 2). A temperature-dependent regression was then developed to hindcast the haddock growth and was also used to predict the weight-at-age 7 from 1952 to 1970 taken from the commercial fishery with good results (Fig. 3). A further regression between temperature and weight at age 7 combining the years 1952 to 1996 was run with temperature accounting for 79% of the variance.

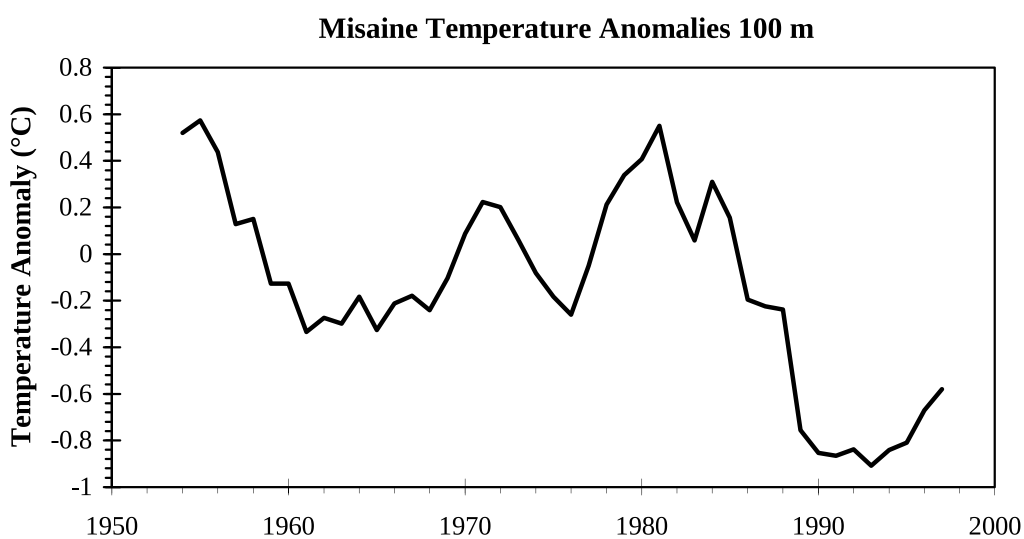


Fig. 1. Five-yr running means of the temperature anomalies at Misaine Bank 100 m.

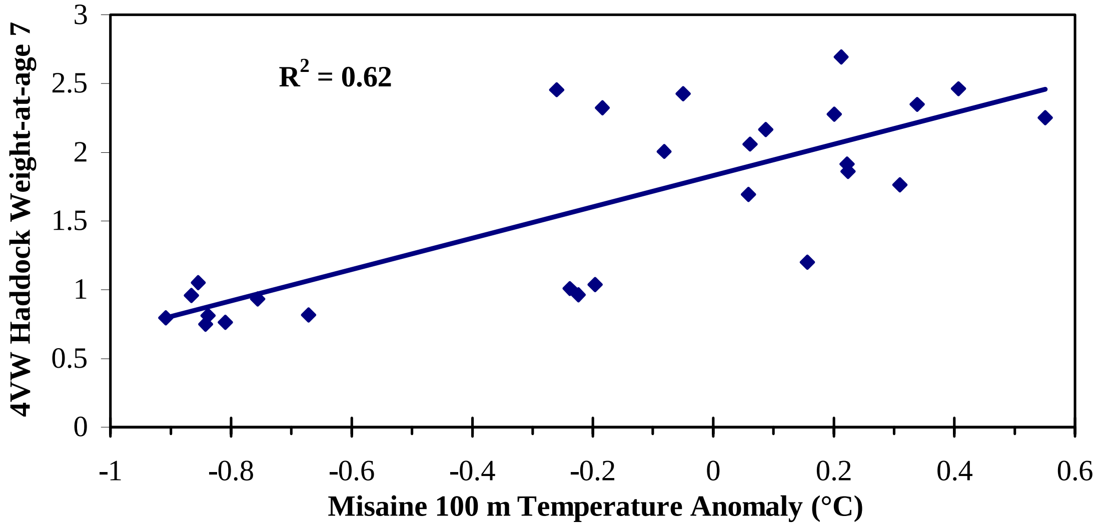


Fig. 2. Scatter diagram of Misaine Bank temperature anomalies at 100 m and weight of an age 7 haddock from 4VW.

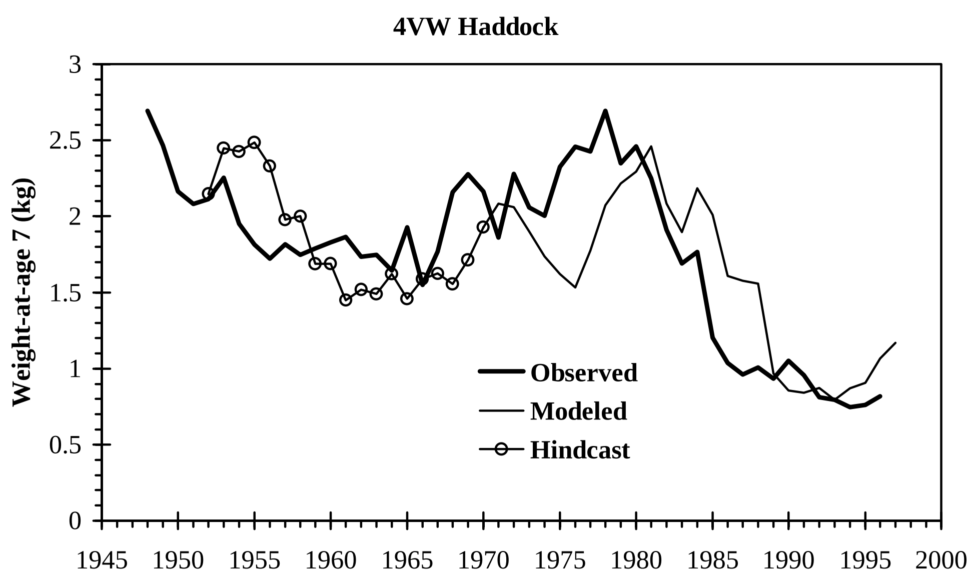


Fig. 3. Weight of an age 7 haddock from 4VW from observations and modelled based on Misaine Bank temperatures.

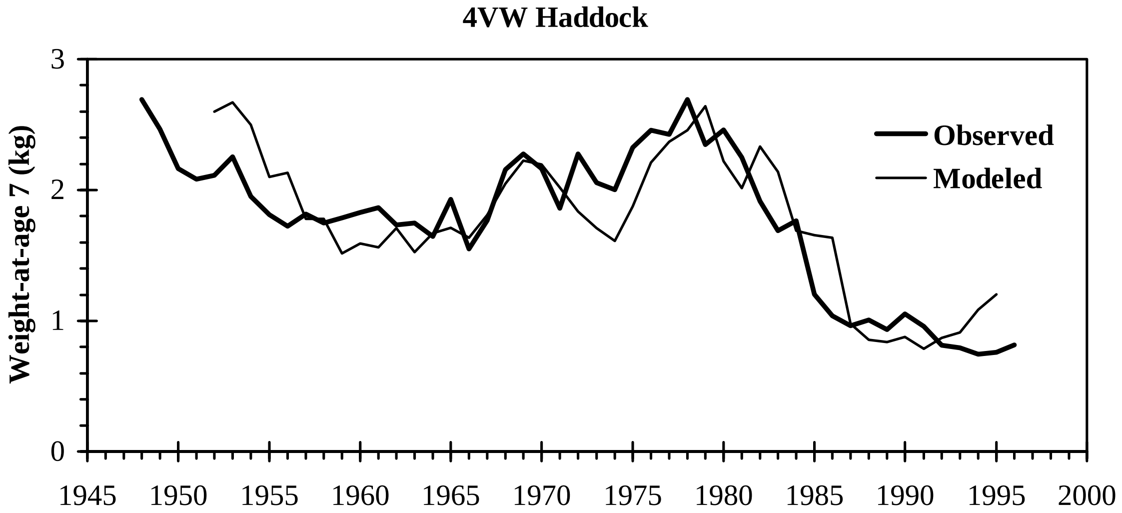
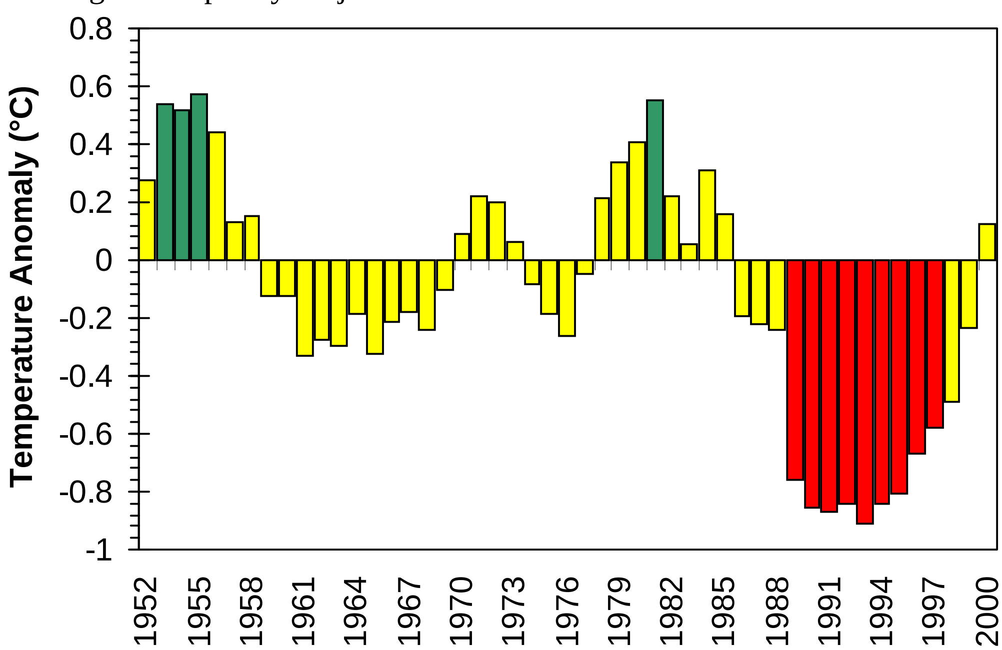


Fig. 4. The weight of an age 7 haddock from 4VW as observed and as determined from a regression model based upon temperature only.

The following is proposed for the Traffic Light categories:

Colour	Annual Temp. Anomaly	
Green	>0.31ºC	Above 1 Standard Deviation of long-term (1952-96) mean
Yellow	0.31 to -0.54ºC	Between mean and ±1 standard deviation
Red	<-0.54ºC	Below 1 Standard Deviation of long-term mean

Note that the use of ±1 standard deviation as criteria for the dividing line between the different categories is purely subjective.



Temperatures promoting strong growth were only present in the early to mid-1950s and again in the early 1980s. The 1990s had extremely low temperatures, which contributed to the low growth. Also of importance is the fact that there were several cold years in succession.

Example Application: **Distribution of Snow Crab and Capelin**

Indicator: Temperature through its effect on distribution

Review of Performance:

Temperature anomalies (relative to 1961-90) in the northeastern Scotian Shelf as reflected in the 100 m values on Misaine Bank were relatively high in the 1950s, declined into the 1960s, varied during the 1970s but rose to a peak by the early 1980s (Fig. 1). At this time a rapid cooling occurred that reached a minimum in the early 1990s after which temperatures increased gradually (Fig. 1, 2) through to the present above normal values. Temperatures were below normal through most of the last 15 years. Temperature variability at 100 m on Misaine Bank has been shown to be representative of the thermal conditions in the subsurface waters of the northeastern Scotian Shelf (4Vs) and eastern sections of 4W. Similar temperature conditions also have been observed in the Gulf of St. Lawrence and on the southern Newfoundland Shelf, in particular on St. Pierre Bank.

During this cold period, the distribution of two "cold-water" species, snow crab and capelin, expanded on the northeastern Scotian Shelf. Snow crab and capelin catches in the July groundfish surveys both showed increases through the cold period (Fig. 3, 4). As the waters warmed in recent years the number of capelin have declined substantially. Also Frank et al. (1996) showed that previous cold periods were the only times that capelin were seen on the Scotian Shelf and in the Bay of Fundy.

Reference:

Frank, K. T., J. E. Carscadden and J. E. Simon. 1996. Recent excursions of capelin (*Mallotus villosus*) to the Scotian Shelf and Flemish Cap during anomalous hydrographic conditions. Can. J. Fish. Aquat. Sci. 53: 1473-1486.

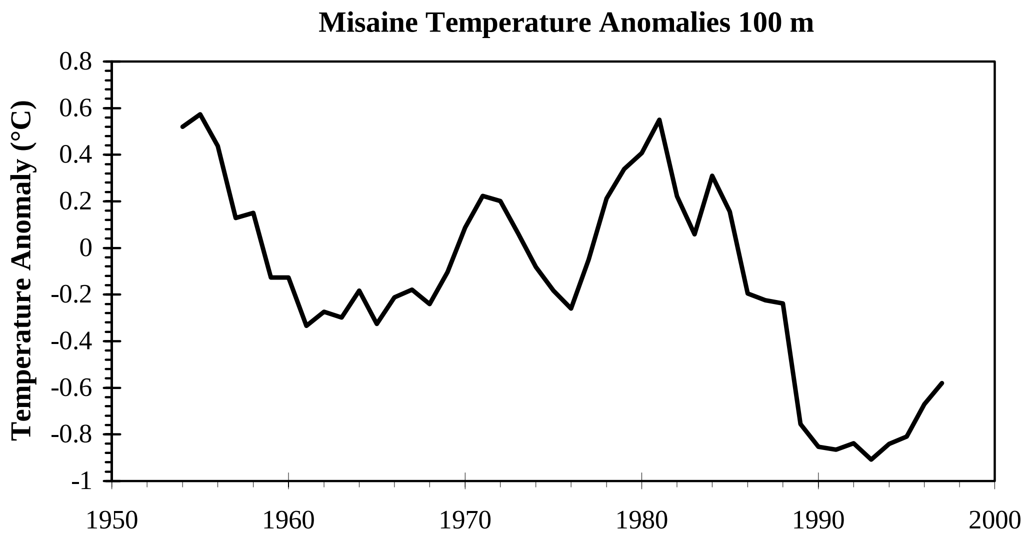


Fig. 1. Five-yr running means of the temperature anomalies at Misaine Bank 100 m.

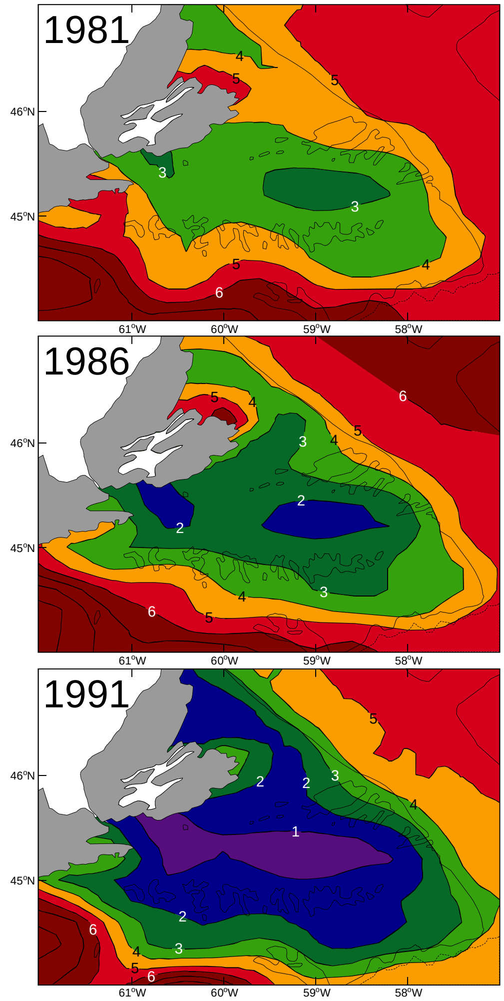


Fig. 2. The near-bottom temperatures during the July groundfish survey in 1981, 1986 and 1991. Note the increasing amount of cold water and decreasing temperature minimum.

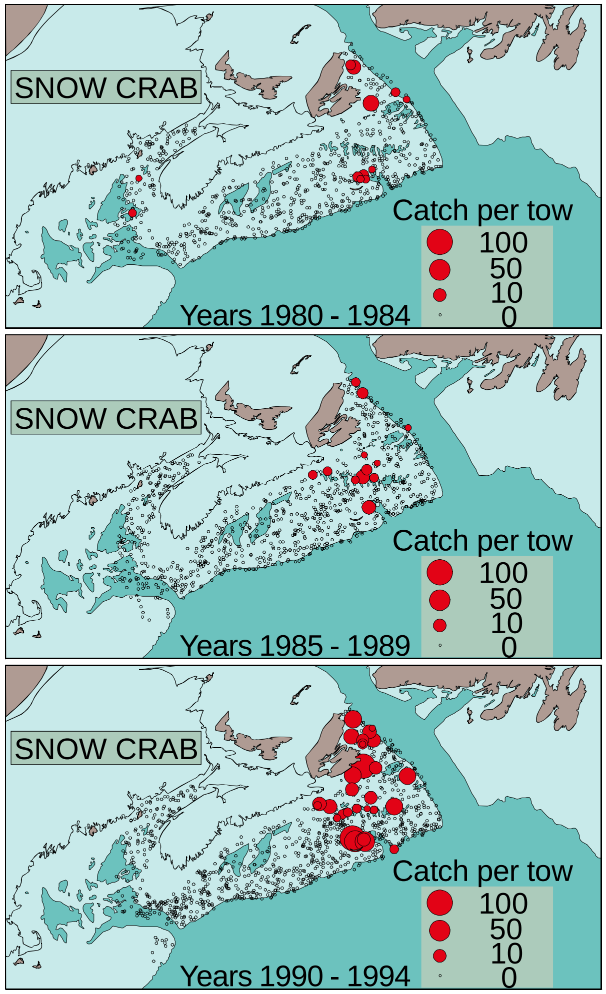


Fig. 3. The catch per tow of snow crab during the summer groundfish surveys on the Scotian Shelf grouped by 5-year periods. The black dots denote stations where no snow crabs were caught.

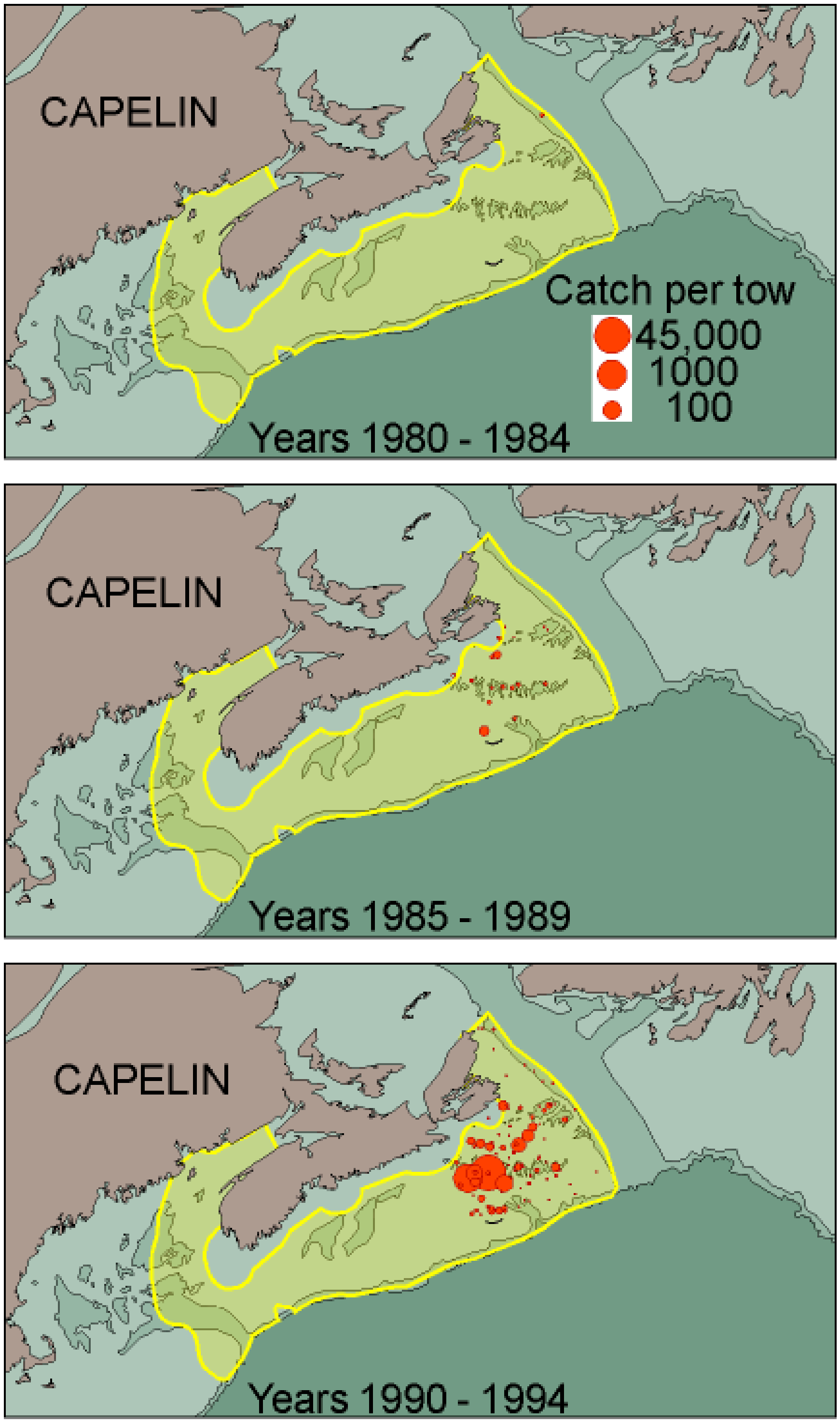


Fig. 4. The catch per tow of capelin during the summer groundfish surveys of the Scotian Shelf grouped by 5-year periods. The surveyed area is shaded in yellow.

Indicator: **<u>Length at Maturity</u>**

Characteristic: **Abundance**

Description: Length of 50 % maturity for females sampled in RV surveys. It is hypothesized that size at maturity varies as a function of stock density.

Boundary Point(s): Arbitrary boundary points, based on the available historical series, are proposed with the Green/Yellow (GY) boundary at the geometric mean of the series and the RY boundary set at 0.6•GY.

Properties:

Estimation:

- Proportion of mature fish at length is calculated from observations made during detailed sampling performed during RV surveys.
- Length of 50% maturity and confidence limits are calculated using regression methodology, with probit transformation.

Measurability:

- A classification scheme for staging gadoid maturity observations based on gross visual observations at sea has been in place since 1970.
- Observations are made by trained personnel and should be consistent from year to year.
- Distinguishing between immature and resting stages may be problematic if observations are not made near spawning time.

Interpretability:

- A physiological limit exists for the size at which individuals of a species can become sexually mature (Trippel, 1995).
- Changes are a compensatory response to exploitation and/or environmental stress, with individuals maturing at a small size where abundance is low.
- Some stocks do not show changes despite reduced population size (Trippel & Harvey, 1987). However, Trippel et al. (1997) documented substantial declines in length of sexual maturity in gadid stocks since the mid-1980's.
- Precision of SSB estimates can be improved through the use of an annual maturity ogive.

Sensitivity:

- In the case study examined, little or no lag was evident between changes in population biomass and in 50% maturity. Thus, the indicator might be expected to respond relatively rapidly to population biomass. Under these circumstances, the indicator should be useful for management intervention on a timely basis.

Weight:

Full weighting, given that sampling error should be minimal and calculation of the indicator is straight forward, assuming that the direct relationship between 50% maturity and biomass holds up for other stocks.

References:

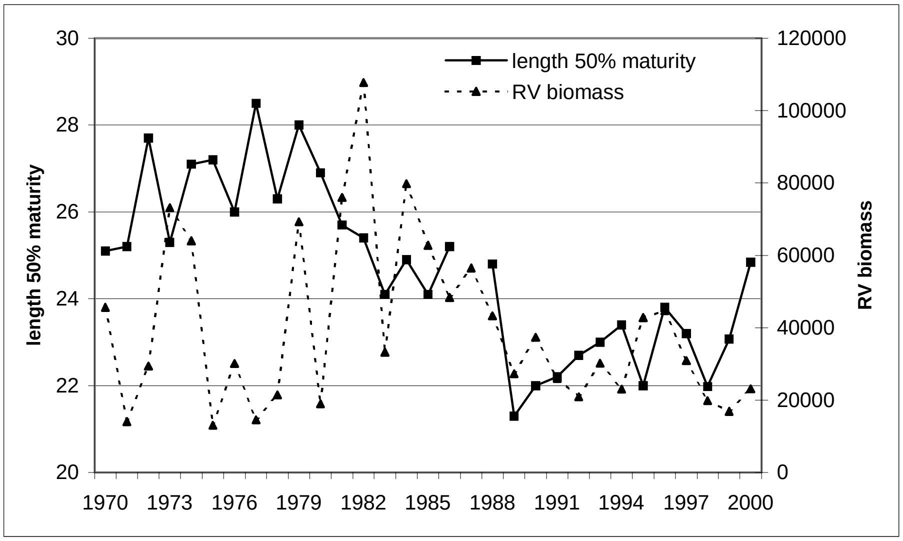
Trippel, E. A. and Harvey, H. H. 1987. Reproductive responses of five white sucker (*Catostomus commersoni*) populations in relation to lake acidity. Can. J. Fish. Aquat. Sci. 44: 1018-1023.

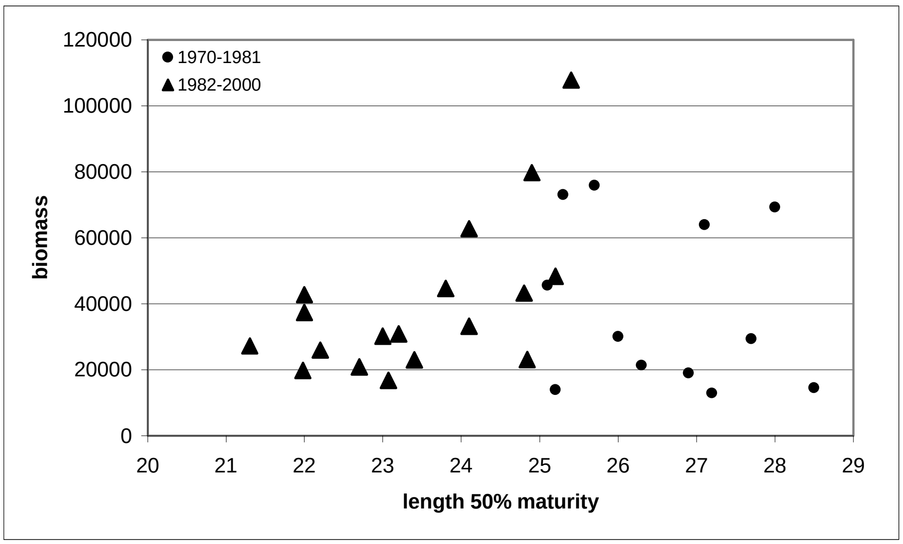
Trippel, E. A. 1995. Age at maturity as a stress indicator in fisheries. BioSci. 45(11): 758-771.

Trippel, E. A., M. J. Morgan, A. Frechet, C. Rollet, A. Sinclair, C. Annand, D. Beanlands and L. Brown. 1997. Changes in age and length at sexual maturity of Northwest Atlantic cod, haddock, and pollock stocks, 1972-1995. Can. Tech. Rep. Fish. Aquat. Sci. 2157: xii+120p.

Review of Performance (Scotian Shelf silver hake):

- The timing of the July RV survey facilitates maturity observations for silver hake, and a long (30+ years) time series of observations is available.
- Silver hake mature at a relatively young age (2 for males, slightly older for females).
- Comparing length of 50% maturity (females) to biomass estimates from the July RV survey, the index appears to track biomass trends from the early 1980's onwards.
- For the 1971 to 1981 period no relationship is seen, suggesting other factors may be influencing the indicator during this period. Although the biomass estimates have been adjusted by an accepted conversion factor to account for vessel effects, a change in research vessels from 1981 to 1982 may account for the differing trends.
- For the 1982-2000 period, a significant linear relationship ($p < 0.001$) exists between RV biomass and length of 50% maturity ($R^2 = 0.36$).
- Years where the indicator is below about 24 cm are associated with lower levels of biomass.


length 50% maturity
RV biomass
30
28
26
24
22
20
120000
100000
80000
60000
40000
20000
0
1970 1973 1976 1979 1982 1985 1988 1991 1994 1997 2000


1970-1981
1982-2000
biomass
120000
100000
80000
60000
40000
20000
0
20 21 22 23 24 25 26 27 28 29
length 50% maturity

Indicator: **Distribution**

Characteristic: Indices of spatial distribution reflect both **Abundance** and the state of the **Ecosystem**. Distribution will also have impacts on catchability and therefore the estimation of abundance of the species by trawl or longline surveys. Distribution will also have an impact on the fishing mortality where aggregation of remnant populations can result in greater availability of the population to fishing efforts. Indices of spatial distribution provide insight into the nature of the distribution and abundance of the species in question. The previous use of population estimates based on areal expansion of trawl survey results to provide a single estimate gave little or no information on the manner in which the species is distributed within its traditional area of distribution nor how the current patterns of distribution and abundance compare to historical patterns or to patterns of exploitation or physical oceanographic parameters.

Description: Area occupied and abundance are positively correlated for a number of demersal fish populations (Winters and Wheeler 1985; Creco and Overholtz 1990; Rose and Leggett 1991; Swain and Wade 1993; Marshall and Frank 1994). In general these studies show that changes in area occupied, over a range of population abundance levels, are the result of an interplay between fish density and geographic area occupied, ostensibly mediated through such density dependent processes as prey density and availability, and habitat preferences. These observations are consistent with the basin model proposed by MacCall (1990). Swain and Sinclair (1994) show that these processes may also be age or size dependent. These authors point out that no single statistic or index will provide a satisfactory view of the spatial response of a demersal fish population to changes in population abundance.

The present list of indicators is by no means exhaustive and the intent should be to examine other indicators to obtain the most complete picture possible. Other indicators which might be examine include the GINI index (Myers and Cadigan 1995) which essentially measures the departure of the species distribution from an even distribution (i.e. a linear 1:1 CDF of cumulative proportion of area vs. cumulative proportion of numbers or biomass). The advantage of this measure is that it measures against a theoretical distribution. However, it has shortcomings similar to the present indicators in that it must be judged against historical patterns to be interpretable and meaningful in terms of information on stock status.

The following measures are examined:

1. Proportion of total survey area occupied by the top nth percent of the total population. We interpret this as an index of population **concentration**. Swain and Sinclair (1994) indicated that for cod this index was positively correlated with changes in overall population abundance. They showed that for n = 95 the area occupied was highly correlated with population abundance while for n = 50 the correlation was low. They also indicated that the index was more highly correlated for older than for younger fish. We allow for the examination of any percentile but present results only for n = 75.

2. The proportion of non-zero sets is an index of **prevalence**. This is defined as the proportion of the total number of standardized survey sets completed in year i containing > 0 of the species of interest. This provides an indication of how widely the species is distributed within the survey area without reference to density.

3. The average number per non-zero survey tow or **cpue where present**. This is indicative of the average **local density** of the species of interest within the survey area. Unlike the stratified mean catch per standard survey tow this measure does not incorporate 0 sets but only estimates density where the species of interest occurs in that year.

4) The **stratified mean catch per standard survey tow**. This is a traditional measure derived from stratified surveys. A recent description can be found in Smith (1996).

Boundary Point(s): Boundary points for indices of distribution are not well established.

Concentration: For the proportion of total survey area occupied by the top nth percent of the population, the historical proportion of the survey area occupied might provide a basis for setting boundaries between acceptable and non-acceptable levels of cocentration, although there would still be significant room for debate. It has been shown that populations of some species of groundfish retreat to predictable areas at low abundance. For these populations it may be possible to define minimum areas of distribution. It will be of utmost importance to examine this measure in relation to the distribution of physical oceanographic parameters, fishing effort, and other anthropogenic factors to investigate potential causes for changes in area occupied.

Prevalence: For the proportion of non-zero sets, the historical distribution is an effective comparator. Establishing boundary conditions for prevalence is likely to be somewhat arbitrary and will likely be couched in more general terms such as 'more' or 'less' prevalent than in some previous time period. Again it will be important and informative to examine this measure in relation to the distribution of physical oceanographic parameters, fishing effort, and other anthropogenic factors to investigate potential causes for changes in prevalence.

Density where present: Boundaries for the average number per non-zero set (local density) will be difficult to establish. Essentially it tells us how tightly packed the individuals are in areas where they occur at all. Changes will be the result of a complex interaction of population abundance, habitat availability and prey density. High local densities could be the result of dense aggregations of prey items or of a lack of available habitat. As for the other measures it should not be examined in isolation but rather as one of a suite of indicators relative to the distribution of other physical and biological parameters.

Properties:

Estimation:

1) The proportion of the total survey area occupied by the top nth percent of the population was estimated as follows:
   i) Survey area is first divided into equal sized square cells. The illustrative example below uses 10 minute squares.
   ii) Estimate average catch per standard survey set within each grid cell.
   iii) Rank average catch per grid cell in descending order.
   iv) Calculate the cumulative total catch per tow and tally the total number of grid cells with each total.
   v) Count the number of cells needed to reach the threshold (in this case 75% of the total catch for that year) and express it as a proportion of the total number of survey cells occupied in that year. *Note one can also express this as a proportion of the total number of grid cells occupied in all years of the survey to estimate the current relative to the 'historical' distributional pattern. **Note one can also express this as a proportion of the number of non-zero survey sets occupied in that year or historically. This provides information on how the population is distributed within the boundaries of its known distribution rather than within the boundaries of the surveyed area.

2) The proportion of non-zero sets is the number of sets that catches species i relative to the total number sets in that time period (year).

3) The average number per non-zero set is the average numbers of species i estimated only from those sets in which species i occurred.

4) Estimation of the stratified mean catch per standard survey tow has been previously described (see for example Smith 1996).

Measurability:

- All of the indices of spatial distribution are relatively easy to measure once a trawl survey or longline survey is in place.
- Statistical properties have not been explored.
- Estimates for concentration (area containing n% of the population) and cpue where present are based on ln transformed values. Proportion of non-zero sets is expressed as the untransformed proportion.
- The proportion of non-zero sets and the proportion of area with n percent of the population are highly correlated for herring and cod at n's > 40%, however for plaice the relationship between the attributes is different. It is likely that the relationship between prevalence and concentration will vary from species to species because they are the result of interacting processes that differ from species to species. The inherent patch size for the species in question will likely be a significant determinant of this relationship.

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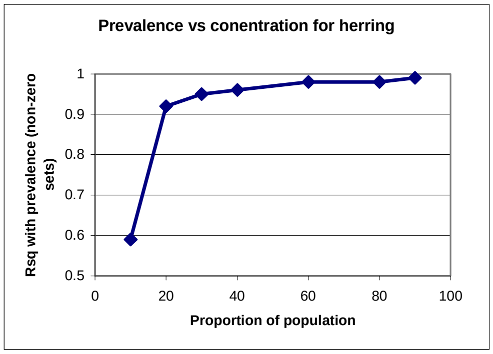

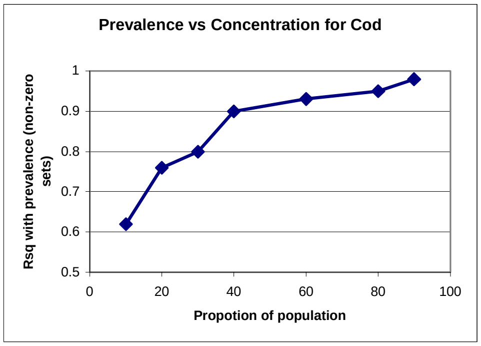

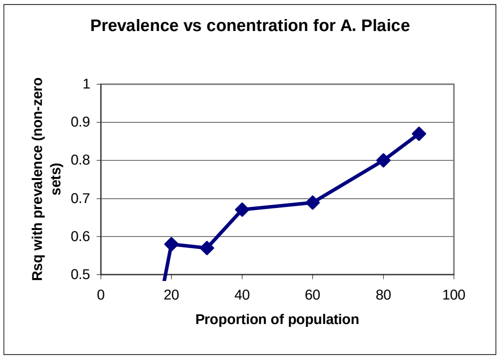

Interpretability:

The following cautions apply to all three indicators:

- Should not be interpreted in isolation as an indicator of stock size but rather in conjunction with the other distribution indicators which together give an indication of the overall distributional characteristics of the species.
- Should be interpreted in conjunction with a map of distribution (cpue).
- Should be interpreted in light of information on distribution of human activities (including fishing) and physical environmental conditions (e.g. T).

1) **Concentration** (Proportion of total stock area occupied by the top nth percent of the population).

- Gives an indication of the concentration of the species within its traditional area of distribution.
- Decreasing stock size (overall population numbers) could be the result of a local extirpation of a portion of the population. This would be reflected by a decrease in the area containing a constant proportion of the population. Decreasing stock size could also be the result of overall erosion of population numbers throughout the stock area. This would result in an increase in the area containing a constant proportion of the population. The same arguments hold for increases in stock size. Investigation of where the decreases occurred and whether or not these were associated with human activities or changes in environmental conditions will provide significant insight into population status.
- Establishing boundary conditions for this indicator will likely be by the examination of the historical patterns of concentration for the species in question. The relationship between estimated population size and concentration (if present) might be used to establish combined limits of population size and areas occupied for some pre-defined portion of the population. Changes in concentration should prompt investigations into cause.

2) **Prevalence** (Proportion of non-zero sets in the survey)

- Gives an indication of the extent to which the species occupies its traditional area of distribution.
- Decreasing prevalence may be the result of local or general reductions in population numbers. Investigation of where the decreases occurred and whether or not these were associated with human activities or changes in environmental conditions will provide significant insight into population status.
- Boundary conditions for this indicator will likely stem from an examination of historical patterns of prevalence. Relationship between overall population size and prevalence (if present) could be used to set combined population size / prevalence limits. Changes in prevalence should also prompt additional investigations to determine cause (anthropogenic vs. physical vs. biological).

3) CPUE where present (local density)

- Gives an indication of how densely the species are packed in areas where they occur.

- Should be interpreted in light of other estimates of population numbers and should likely be age / size disaggregated.
- Changes in local density may occur as a result of density dependent or density independent phenomena. It is likely that any density dependent effects on the population will have their effect at this scale. Changes in local density may also result from changes in prey density or population reduction as a result of human activities including fishing.
- Boundary conditions for cpue where present will likely result from an examination the relationship between local density and population size (by size class).
- This measure may have utility in tracking commercial catch per unit of effort.

Sensitivity:

1) Concentration

- Concentration appears to respond to changes in overall abundance at least as rapidly as the single measure of stratified cpue. The measure appears to be somewhat more stable than stratified cpue.
- Time for management intervention is at least the same as for stratified cpue and perhaps somewhat enhanced given the lower variability of the indicator.

2) Prevalence

- Prevalence and concentration appear to be correlated at least for some species and at sufficiently high proportion of population.

3) CPUE where present

- CPUE where present appears to respond more rapidly to changes in population size than stratified cpue for some species.

Weight:

The relative weighting of these indicators has not been determined.

References:

Creco, V. and W. J. Overholtz. 1990. Causes of density – dependent catchability for Georges Bank haddock *Melanogrammus aeglefinus*. Canadian Journal of Fisheries and Aquatic Science. 47: 385-394.

MacCall, A. D. 1990. Dynamic geography of marine fish populations. University of Washington Press, Seattle, Wash., 153 pp.

Marshall, C. T. and K.T. Frank. 1994. Geographic responses of groundfish to variation in abundance: methods of detection and their interpretation. Canadian Journal of Fisheries and Aquatic Science, 51: 808-816.

Myers, R. A. and N. G. Cadigan. 1995. Was an increase in natural mortality responsible for the collapse of northern cod? Canadian Journal of Fisheries and Aquatic Science, 52: 1274-1285.

Rose, G. A. and W. C. Leggett. 1991. Effects of biomass-range interactions on catchability of migratory demersal fish by mobile fisheries: an example of Atlantic cod (*Gadus morhua*). Canadian Journal of Fisheries and Aquatic Science, 48: 843-848.

Smith, S. J. 1996. Assessment of groundfish stocks based on bottom trawl survey results. NAFO Scientific Council Studies, 28: 25-53.

Swain, D. P. and E. J. Wade. 1993. Density-dependent distribution of Atlantic cod (*Gadus morhua*) in the southern Gulf of St. Lawrence. Canadian Journal of Fisheries and Aquatic Science. 50: 725 – 733.

Swain, D. P. and A. F. Sinclair. 1994. Fish distribution and catchability: what is the appropriate measure of distribution? Canadian Journal of Fisheries and Aquatic Science, 51: 1046-1054.

Winters, G. H. and J. P. Wheeler. 1985. Interaction between stock area and stock abundance, and catchability coefficient. Canadian Journal of Fisheries and Aquatic Science, 42: 989-998.

Illustrative Examples and Interpretation

1) 4VsW Cod (Figures 1 and 2)

Figures 1 shows both the time trends and interactions of each of the indices of abundance and distribution for 4VsW cod. Figure 2 shows these same data using a 3-year running average to smooth out interannual variation.

The trend in stratified numbers has been used as the major index of stock abundance for this resource. Interpretation of these trends is contained in a number of assessment documents. In general this shows that population numbers were relatively high in the early 1980s and declined to their lowest observed values between the late 1980s and mid 1990s where they have remained.

The overall prevalence of cod in the stock area, as indicated by the proportion on non-zero sets in the survey, remained relatively constant at about 75% until about 1991 and then declined to about 45%. This decline indicates that cod became less common in the stock area. The metric says nothing about overall breadth of distribution.

The local density of cod in the stock area, as measured by the average numbers caught in all non-zero sets increased from 1970 to 1981 and then declined until the present. This observation is consistent with the decline in prevalence noted above in that an erosion in cod density would not be manifested in a decline in prevalence until the erosion caused declines to 0 in a significant number of locations.

The proportion of surveyed area containing 75% of the estimated population was relatively stable from 1970 to 1981 and then began an accelerating decline until about 1996. This decline indicates that the population became increasingly confined. This was not associated with an increase in density but indicated a general erosion of population abundance.

The inter-relation between these indices is also shown.

The relationship between stratified numbers and density, prevalence, and concentration, could indicate either a positive non-linear (asymptotic) correlation, or a linear relationship with two distinct temporal phases, one prior to 1991 and one after 1991. A non-linear relationship has intuitive appeal in that it show an initially rapid response of stratified numbers to increased density, increased prevalence, and decreased concentration, and then responds less rapidly as the survey area becomes fully occupied and only density increases.

Density and prevalence, and density and concentration show a reasonably clear asymptotic relationship. As density increases cod become more prevalent because they spread out over the stock area as shown by the decrease in concentration.

Prevalence and concentration show an apparent negative linear relationship. As concentration decreases, prevalence increases.

2) 4VW American Plaice (Figures 3 and 4)

For plaice, stratified cpue declines from the late 1970s to the early 1990s. Local density follows much the same pattern as cpue while prevalence is variable but without an apparent time trend. In this case the long-term change in stratified cpue for plaice appears to be the result of a decline in local density rather than a decline in prevalence within the stock area.

3) 4VW Herring (Figures 5 and 6)

For herring, a pelagic species that has low catchability to trawl surveys, stratified cpue declines from 1970 to the early 1980s and has increased to the present. For herring this increase is the result of increases in local density as well as increased prevalence within the stock area. This indicates that herring are both caught in increasingly greater numbers at an increasing number of locations on the eastern shelf.

It is notable that the decline in cpue during the 1970s was mainly the result of a decrease in prevalence since local density remained relatively stable over this period (with the exception of the 1980 point where very few herring were caught).

4) 4VW Haddock (Figures 7 and 8)

For eastern Scotian Shelf haddock, cpue increased rapidly from the mid 1970s to the early 1980s declined slowly to the mid 1990s and shows some increase in the most recent years. For haddock local density increased rapidly from the mid 1970s to the early 1980s decreased to the mid 1980s and has increased since then. Prevalence showed the same increase as both cpue and local density but has declined substantially (from 70% to 45%) between 1982 and 1998. In this case the slow decline in cpue observed was the result of decline in prevalence coupled with slowly increasing local density.

5) 4X Barndoor Skate (Figure 9)

This cpue for this species declined to near 0 during the 1970s but has increased since 1991. The decrease was the result of declines in both local density and prevalence. The increase in cpue began as an increase in prevalence but since 1996 increased local density has also contributed.

6) 4VW Thorny Skate (Figure 10)

For thorny skate cpue was variable from the 1970s through mid 1980s and then declined rapidly to the present low. In this case both local density and prevalence showed nearly monotonic declines since 1975. Prevalence of this species has declined from over 80% to less than 40% over the duration of the survey.

7) 4VW Striped Wolffish (Figure 11)

Wolffish cpue increased through the 1980s and then declined through most of the 1990s. The increase appears to have been the result of concurrent increases in local density and prevalence, while the decline through the 1990s is more the result of a decline in prevalence.

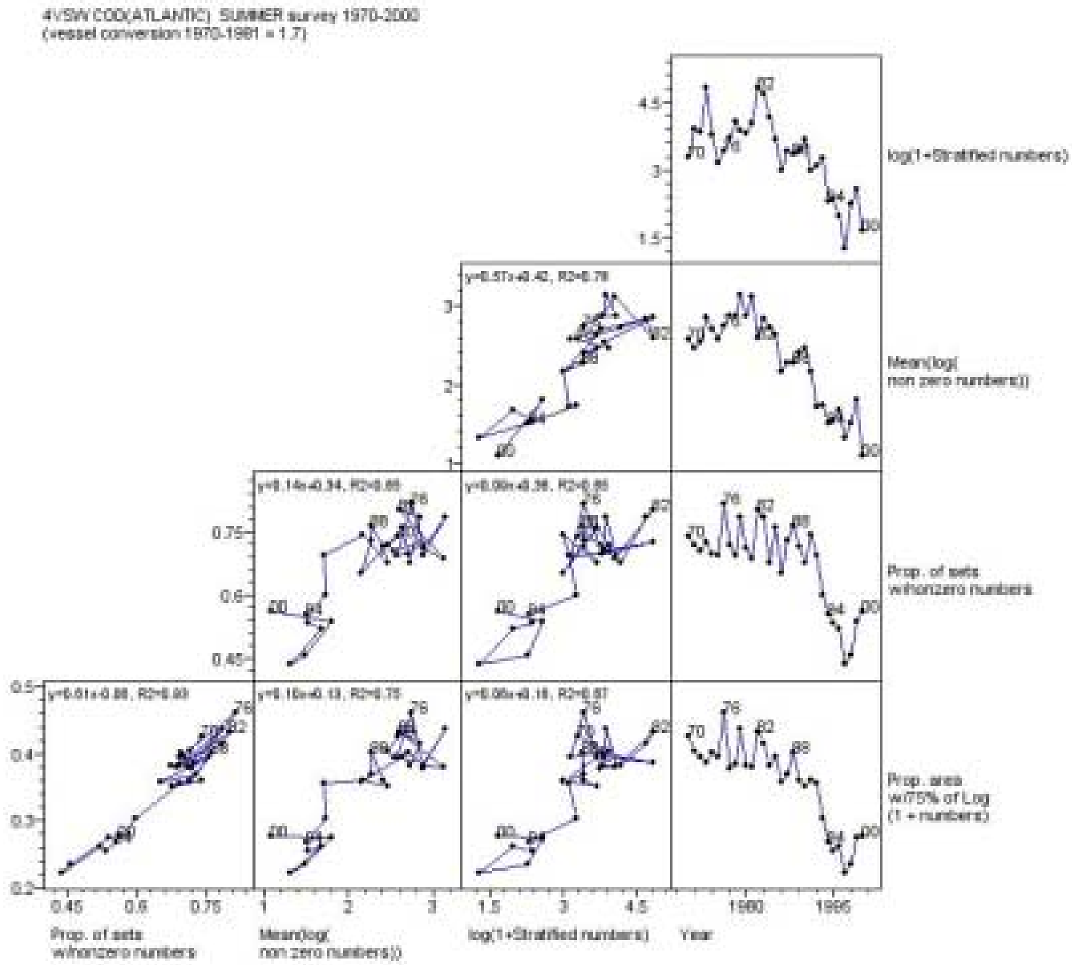

Figure 1. Distributional and abundance indices for 4VsW cod. These indices were estimated from the summer survey results (1970 – 1999) using a 10 minute grid cell to aggregate data except for the stratified numbers, which were estimated according to standard procedures.

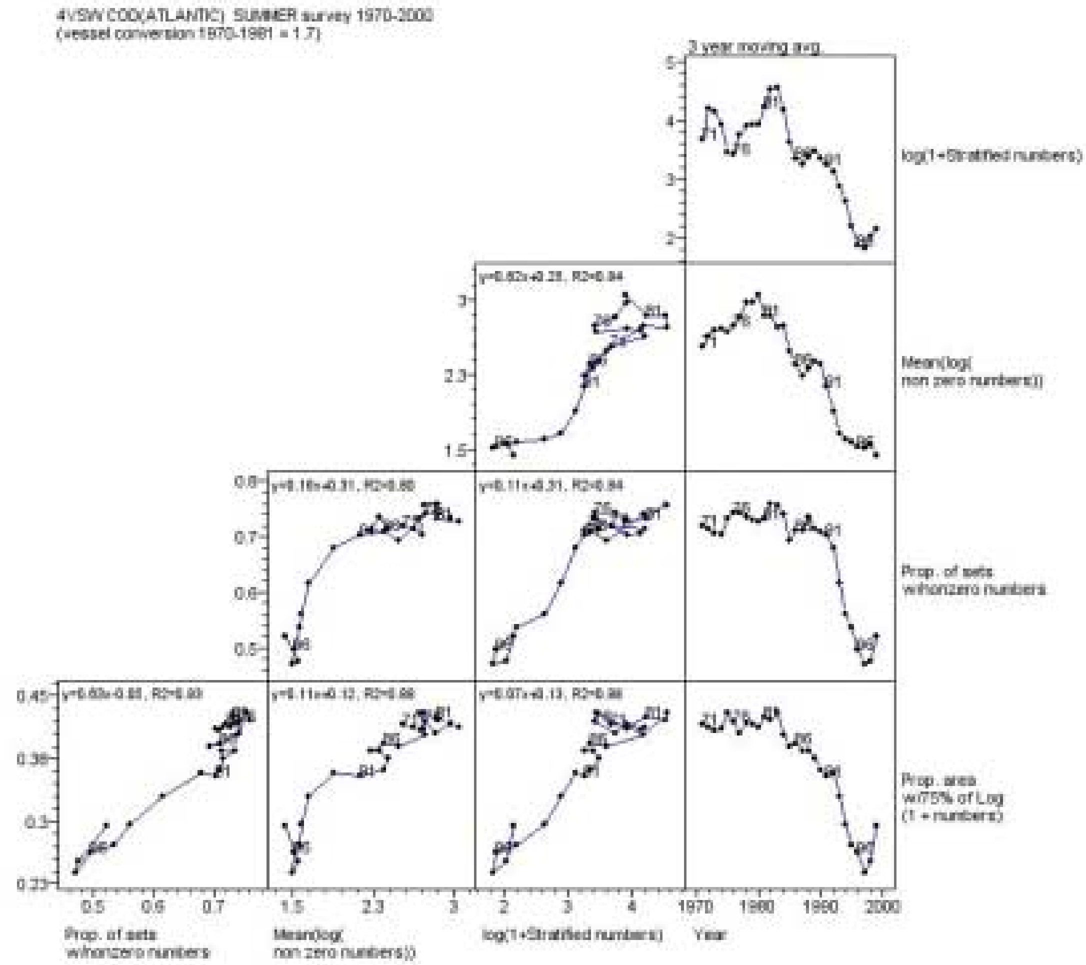

Figure 2. Distributional and abundance indices for 4VsW cod. These indices were estimated from the summer survey results (1970 – 1999) using a 10 minute grid cell to aggregate data except for the stratified numbers, which were estimated according to standard procedures. Temporal trends are expressed as 3-year running means to minimize interannual variation.

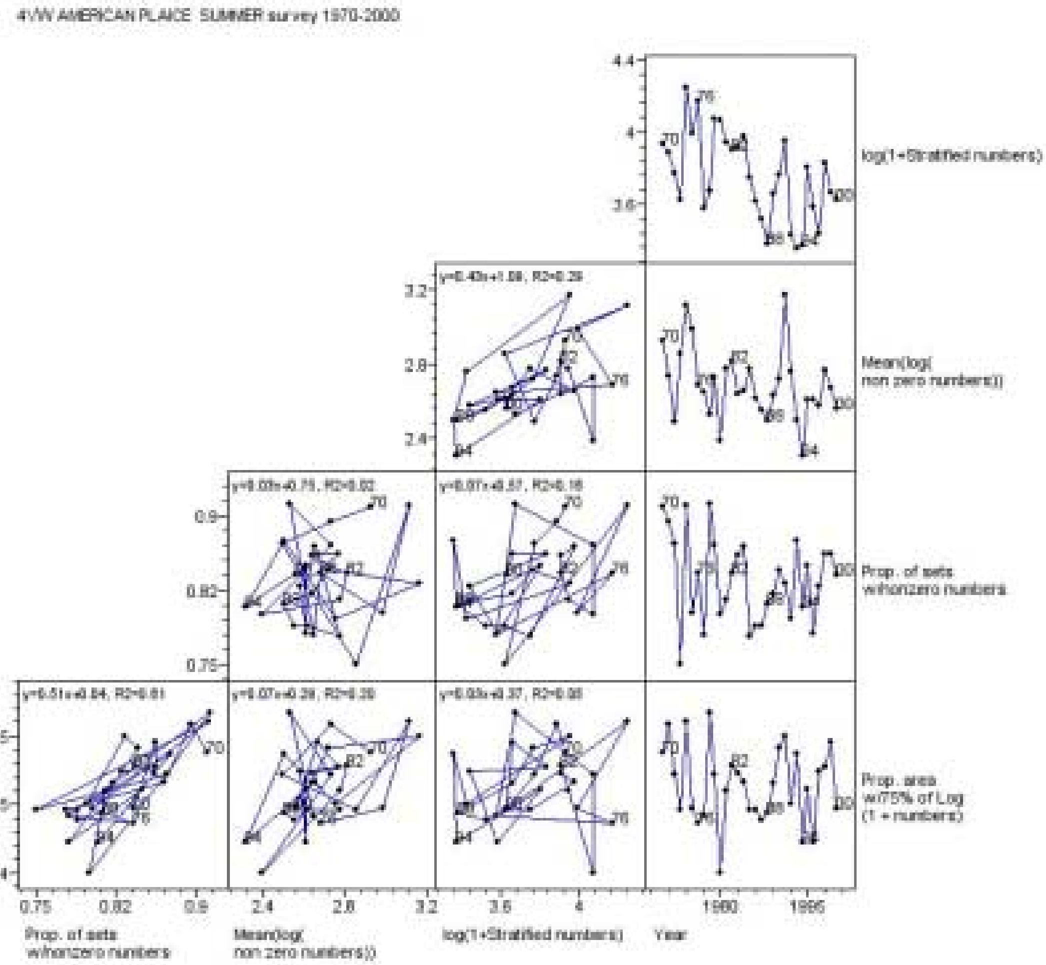

Figure 3. Distributional and abundance indices for 4VW American Plaice. These indices were estimated from the summer survey results (1970 – 1999) using a 10 minute grid cell to aggregate data except for the stratified numbers, which were estimated according to standard procedures.

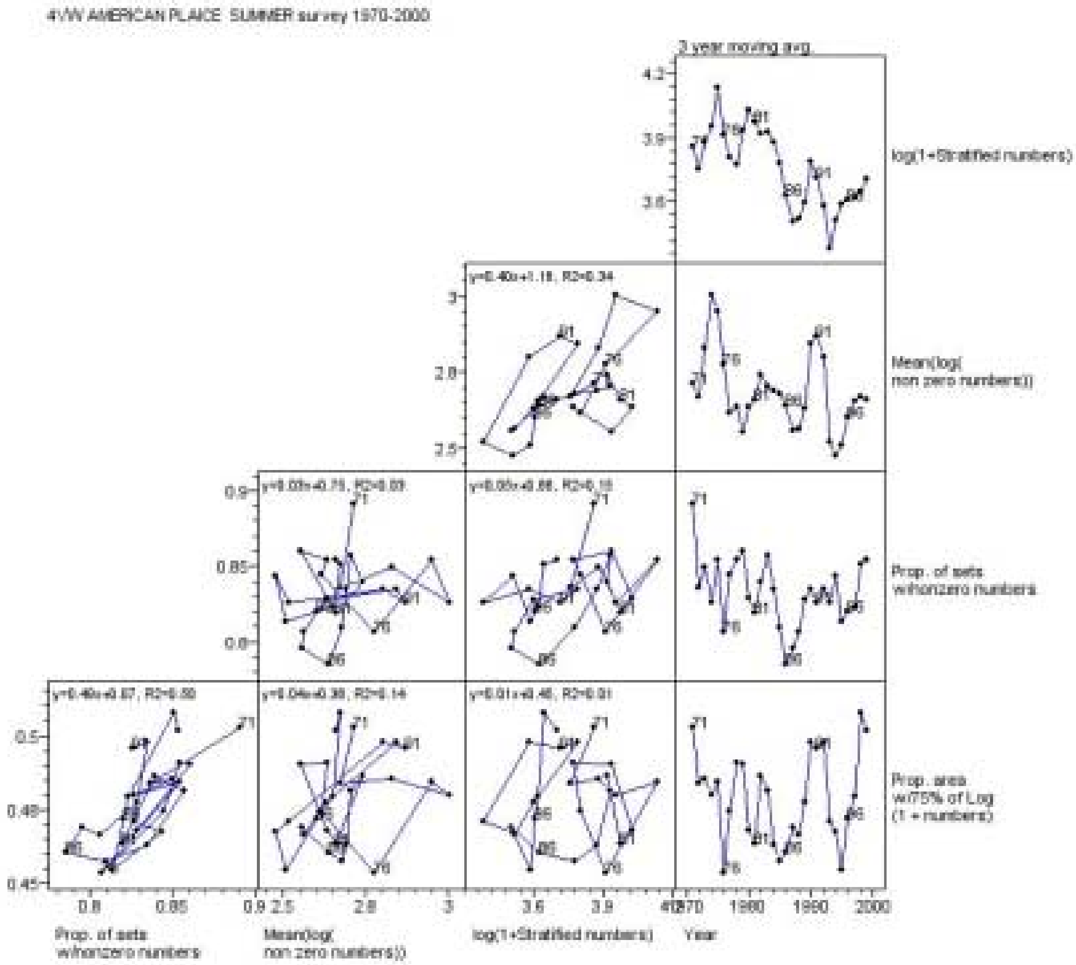

Figure 4. Distributional and abundance indices for 4VW American Plaice. These indices were estimated from the summer survey results (1970 – 1999) using a 10 minute grid cell to aggregate data except for the stratified numbers, which were estimated according to standard procedures. Temporal trends are expressed as 3-year running means to minimize interannual variation.

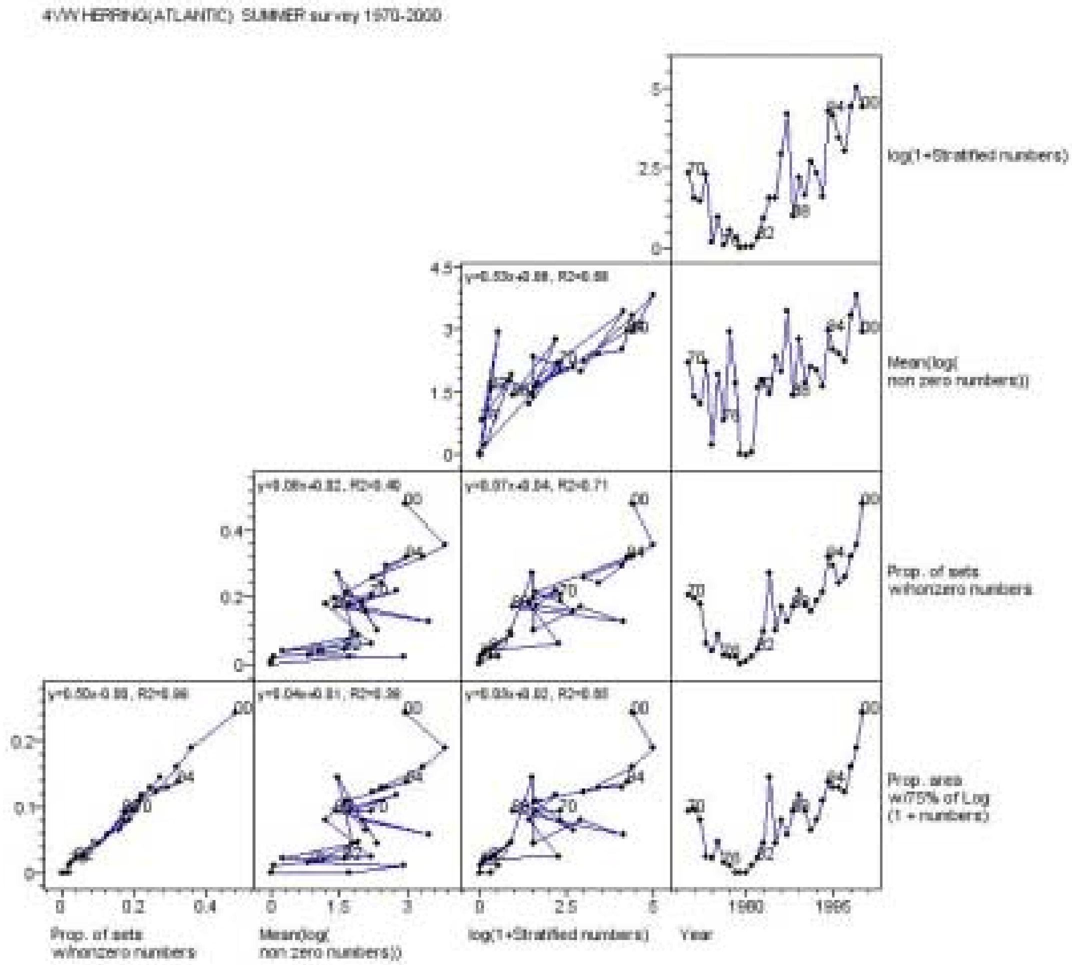

Figure 5. Distributional and abundance indices for 4VW herring. These indices were estimated from the summer survey results (1970 – 1999) using a 10 minute grid cell to aggregate data except for the stratified numbers, which were estimated according to standard procedures.

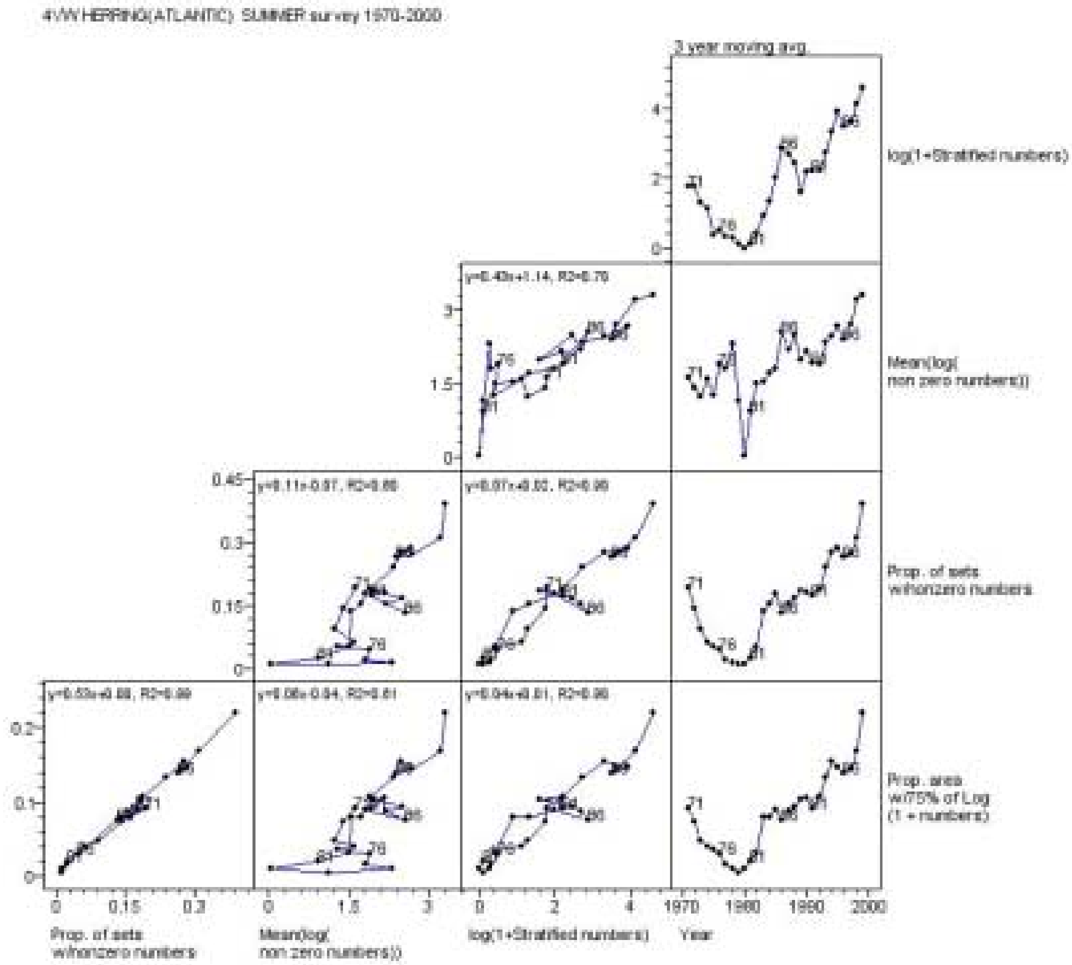

Figure 6. Distributional and abundance indices for 4VW herring. These indices were estimated from the summer survey results (1970 – 1999) using a 10 minute grid cell to aggregate data except for the stratified numbers, which were estimated according to standard procedures. Temporal trends are expressed as 3-year running means to minimize interannual variation.

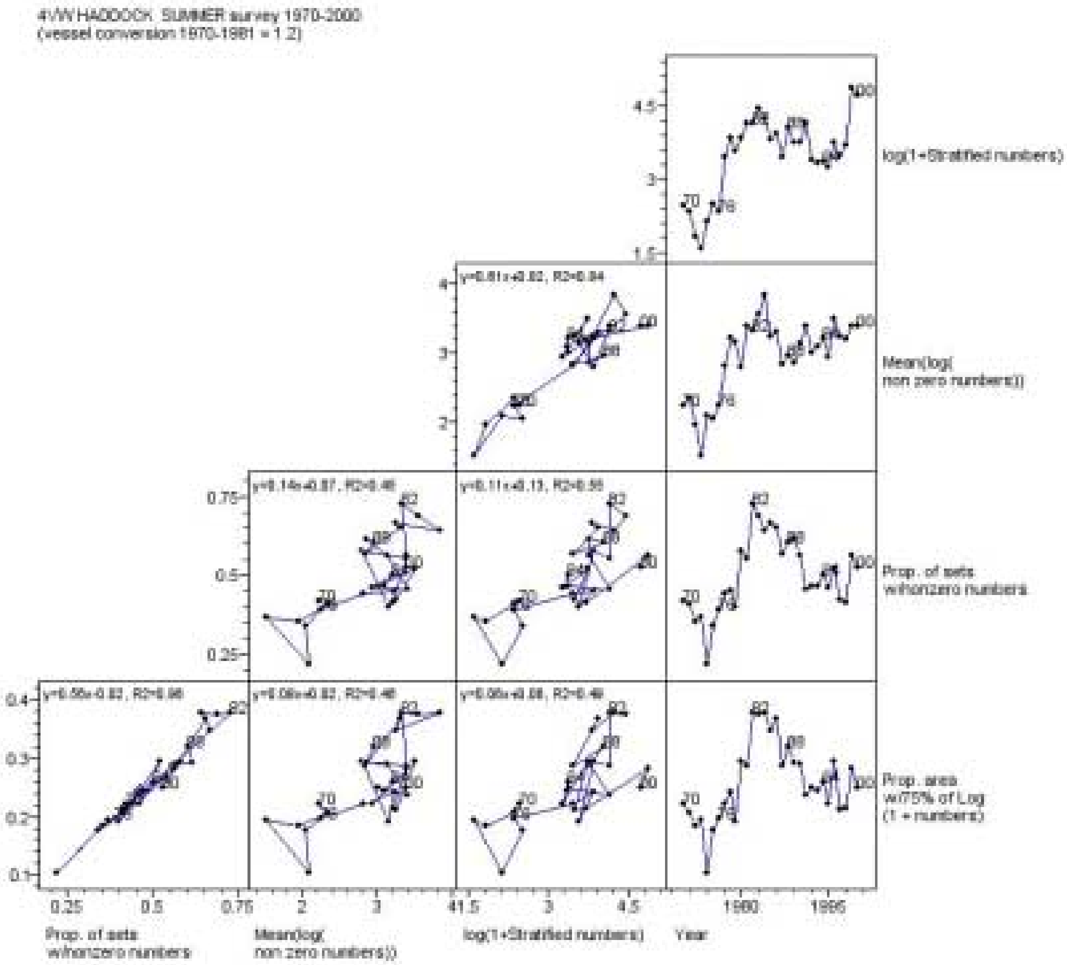

Figure 7. Distributional and abundance indices for 4VW haddock. These indices were estimated from the summer survey results (1970 – 1999) using a 10 minute grid cell to aggregate data except for the stratified numbers, which were estimated according to standard procedures.

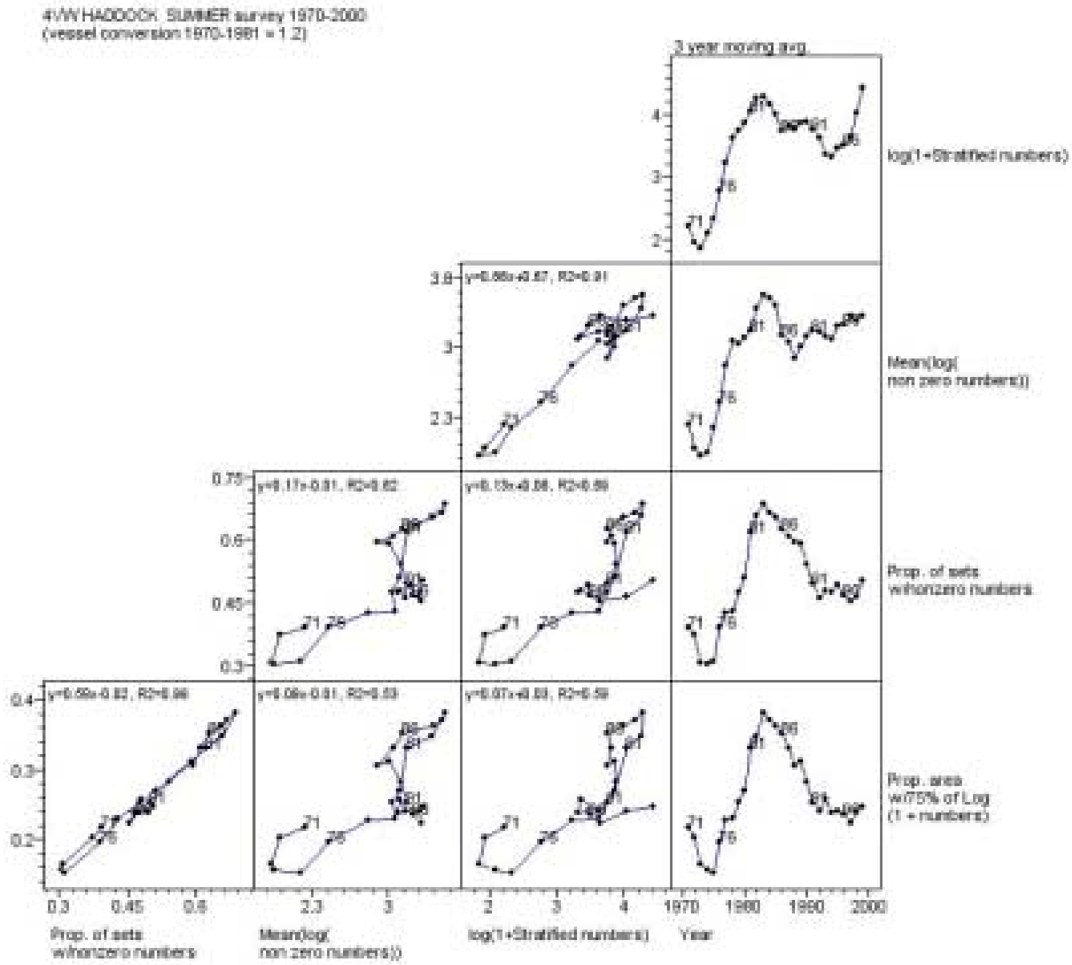

Figure 8. Distributional and abundance indices for 4VW haddock. These indices were estimated from the summer survey results (1970 – 1999) using a 10 minute grid cell to aggregate data except for the stratified numbers, which were estimated according to standard procedures. Temporal trends are expressed as 3-year running means to minimize interannual variation.

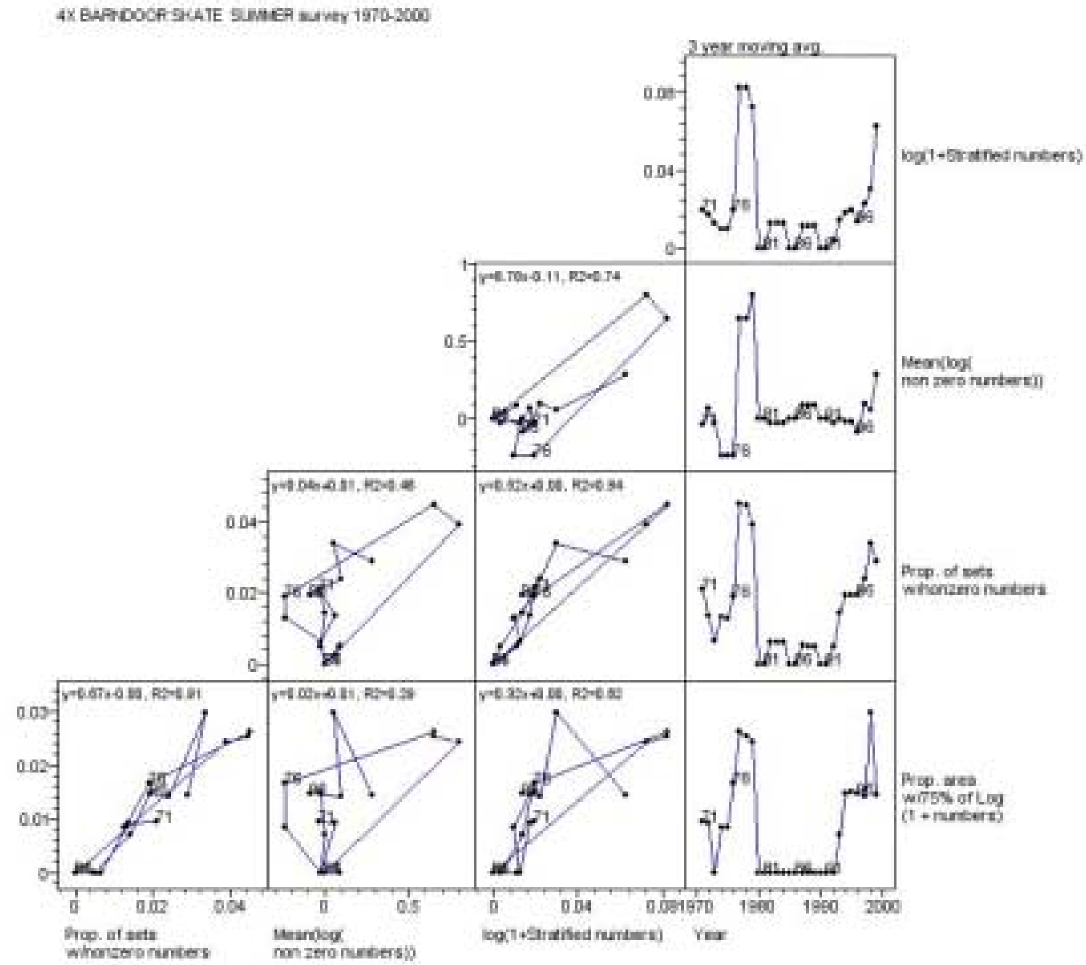

Figure 9. Distributional and abundance indices for 4X barndoor skate. These indices were estimated from the summer survey results (1970 – 1999) using a 10 minute grid cell to aggregate data except for the stratified numbers, which were estimated according to standard procedures. Temporal trends are expressed as 3-year running means to minimize interannual variation.

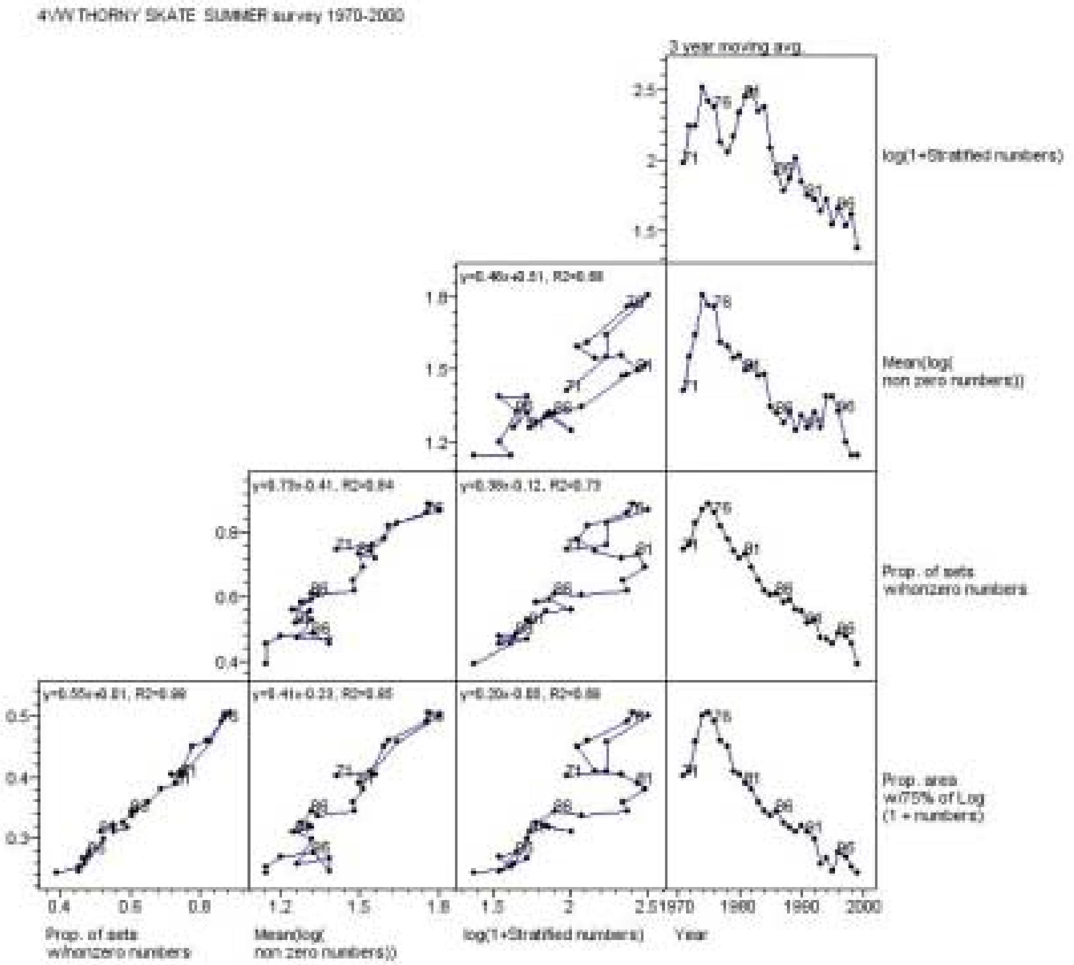

Figure 10. Distributional and abundance indices for 4VW thorny skate. These indices were estimated from the summer survey results (1970 – 1999) using a 10 minute grid cell to aggregate data except for the stratified numbers, which were estimated according to standard procedures. Temporal trends are expressed as 3-year running means to minimize interannual variation.

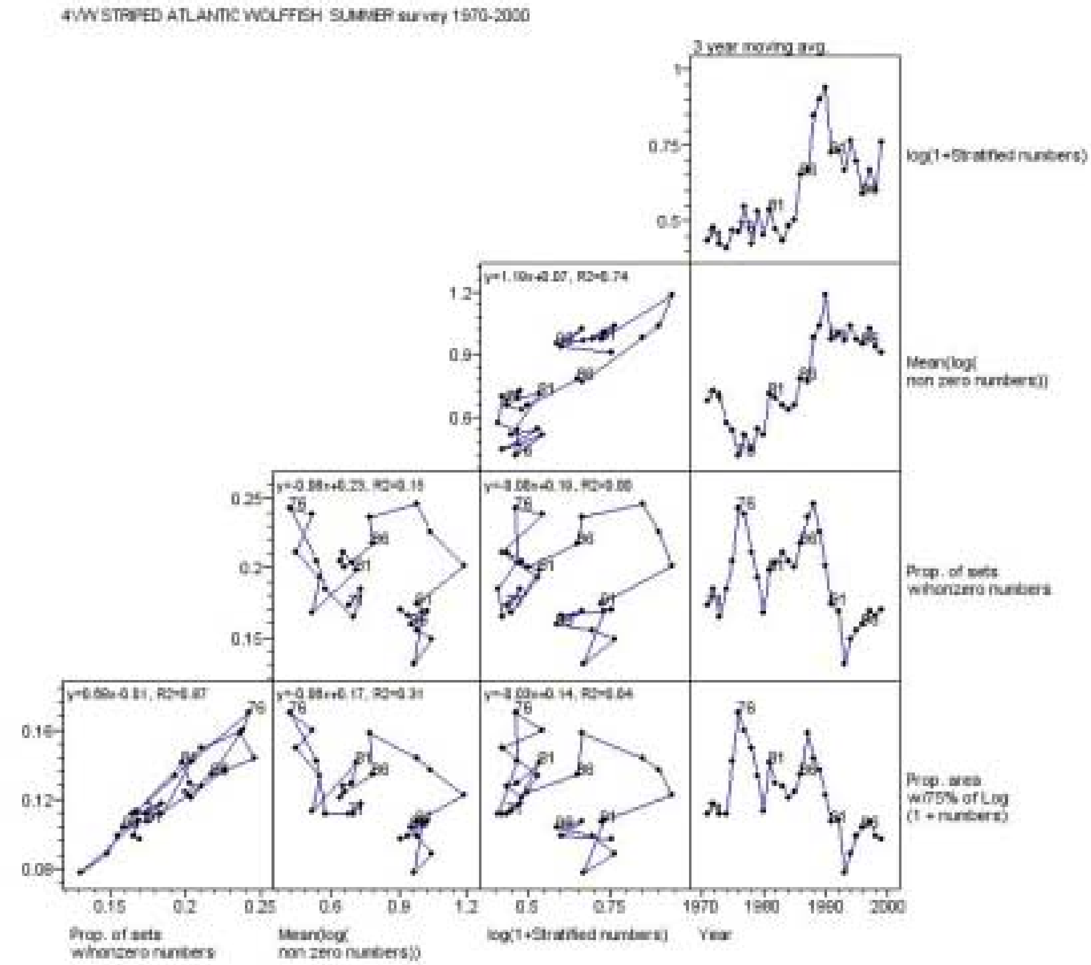

Figure 11. Distributional and abundance indices for 4VW Striped wolffish. These indices were estimated from the summer survey results (1970 – 1999) using a 10 minute grid cell to aggregate data except for the stratified numbers, which were estimated according to standard procedures. Temporal trends are expressed as 3-year running means to minimize interannual variation.