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ABSTRACT

This paper presents a review of the Committee on Endangered Wildlife in Canada criteria used to determine the status of species at risk for commercially exploited marine species designated as "special concern", and the approach of the Department of Fisheries and Oceans for stock assessment. Cod stocks in the Northwest Atlantic Canadian zones are examined and species status results are analyzed and compared, and updated values for available criteria are provided for some stocks from 2002 through to 2006. The analysis of the updated values suggests that what is needed is a more complete perspective of the fishery system as the context within which the species at risk status is being examined. To this end, a broader set of stock status indicators for the assessment of marine species is proposed that takes into account available information including all fisheries stock assessment data. A monitoring program is presented based on the principles of quality control as a guideline for stock status assessment and risk analysis.

Keywords: species at risk status, fisheries stock assessment, reference points, threshold values, process control, risk analysis, Atlantic cod.

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1. Introduction

The Atlantic Cod stocks, once treated as the non ending resource has undergone decline and collapse in late 1980's and early 1990's with lack of recovery at expected levels. Cod stocks have experienced dramatic changes in response to emerging fisheries technologies, excess fishing capacity and overexploitation. Fishermen, both offshore and inshore, were guilty of misreporting their catches, of swarming the cod on spawning grounds, of dumping tonnes of unwanted fish overboard to rot on the ocean floor (Anderssen, 1998). Seven out of ten cod stocks in the Atlantic collapsed primarily as a result of over fishing in 1980's and early 1990's (Smedbol et al., 2002, Canada 2005a).

The collapse of this vital and important fishery sounded a warning bell to many organizations and agencies involved directly in utilization and conservation of natural resources. The Department of Fisheries and Oceans (DFO), Canada is the key agency responsible for providing advice for exploitation of fish resources. The decline and collapse of many Canadian east coast groundfish stocks have been widely perceived to be the result, in part, of the weaknesses in the scientific basis for management decisions (Hutchings and Myers, 1994; Walter and Maguire, 1996; Mason, 2002; Greenpeace, 2007). In recent years, due primarily to the demise of cod stocks in the Atlantic, the Committee on Endangered Wildlife in Canada (COSEWIC) has emerged as an important critic in support of species at risk of extinction including marine aquatic species. COSEWIC focuses on the risks to the resource and assess the status of the resource based on a set of criteria. The establishment of a risk of extinction status, including "endangered" and "threatened", by COSEWIC and the assignment of a species to the list of "species at risk", consequently evokes action through the Species at Risk Act that became effective in June 2004 (Canada, 2003). In a recent COSEWIC report on Atlantic cods stocks, year-over-year abundance estimates result in the designation of the status of the aggregated Northern cod stock (in NAFO divisions 2GHJ+3KLNO) as "endangered", the Laurentian Channel north population (in NAFO divisions 3Ps+3Pn4RS) as "threatened", while the aggregated Maritime population of Atlantic cod stocks (in NAFO divisions 4T, 4Vn, 4X, 4VsW, and 5Z) as "special concern" (COSEWIC, 2003).

In the light of growing concern for Atlantic cod stock, the aim of this paper is to review and analyze current approaches of COSEWIC and DFO. The emphasis here is to realize the need of transition from science based to some ad hoc decision making for Atlantic cod stocks based on specific case at hand rather than predetermined management strategy based on scientific assessment. The analysis considers the two approaches of COSEWIC and DFO with comparison and incorporation of updated information. A discussion follows on the ways and means of a more structured approach via the method of "The Process Control" and its potential effectiveness for managing fisheries.

2. Comparative Methods

This section compares the COSEWIC species-based "criteria threshold" approach to identifying species' status with the stock-based, and annualized DFO approach to fish stock assessment and exploitation limit decision making.

2.1 COSEWIC Threshold Approach

The mandate of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is to assess the status of species that are considered to be at risk of extinction in Canada. In assessing species' risk of extinction (i.e., probability of extinction), COSEWIC categorizes each species into one of six status categories: extinct, extirpated, endangered, threatened, special concern, or not at risk. It uses a set of quantitative criteria as a tool for assessing extinction risk of species within the context of its assessment process. Table 1 presents the COSEWIC criteria and the stock status threshold values for "endangered" and "threatened".

Of the five criteria, only the population "decline rate" is widely applicable to assessed marine species. Other COSEWIC criteria, e.g., Table 1, items B-E, are simply not relevant or available to many marine species. Thus, the dominance of the estimated relative "decline rate" value dominates, and the suite of criteria may not support or trigger the stock status designations.

Current approach adopted by COSEWIC for fish stock assessment have been analyzed for the Atlantic cod stocks, *Gadus morhua*. Table 2 summarizes the COSEWIC status assessment and designation for Atlantic cod. Based on the available genetic, ecological and life history data, this species has been treated in distinct Designatable Units (DUs) namely, (i) Newfoundland and Labrador population (equivalent to NAFO Divisions 2GH, 2J3KL, 3NO), (ii) Laurentian North Population (equivalent to NAFO Divisions 3Ps, 3Pn4RS) and (iii) Maritimes population (equivalent to NAFO Divisions 4T, 4Vn, 4VsW, 4X, 5Z). The scientific basis for distinguishing these populations are: age at maturity, maximum population growth rate, temporal abundance trends, genetic differentiation at selectively neutral loci and other important traits (COSEWIC, 2003).

Based on these criteria, COSEWIC has determined that the Newfoundland and Labrador population has been assigned the status of an "Endangered species" as this stock meets the status criteria for this status (70% decline in estimated number of mature individuals over 3 generations). The justification for the assignment of this status is a decline rate in the population size estimates which is 97% since the estimates of the early 1970s, and more than 99% since the estimates of the early 1960s. There has been virtually no recovery of either the abundance or age structure of the cod to date. The known threats to persistence include fishing, predation by fish and seals and natural and fishing induced changes to the ecosystem. Regarding the assignment of risk, only the primary cause of reduction, i.e., fishing, is reported to be reversible (COSEWIC 2003).

The Laurentian North population of Atlantic cod has also met the "endangered" status criteria threshold but is instead assigned the status of "Threatened". This is because the stocks within this unit have displayed an ability to recover from over-fishing and conservation measures have already been instituted for this unit. The estimated population numbers are currently at a low level as a group and overall have declined by about 80% over the past thirty years. The identifiable threats to their persistence include fishing, predation by fish and seals, and natural and fishing induced changes to the ecosystem.

The Maritimes population comprises a heterogeneous assemblage of stocks that are at low levels of abundance as a group, and it has been designated by COSEWIC as a species of "Special concern". The low levels of abundance are not unprecedented for the cod in the Southern Gulf, Southwest Scotian Shelf, Bay of Fundy and Georges Bank, but those on the Eastern Scotian Shelf are at historic lows and have continued to decline in the absence of directed fishing. Overall, COSEWIC estimates cod in the entire region have declined 14% in the last 30 years and have demonstrated sensitivity to human activities. Threats to persistence include directed fishing, bycatch in other fisheries, natural predation and natural and fishing induced changes to ecosystem.

The designation of the status for the populations of Atlantic cod has been based primarily on decline in the population in terms of index of abundance of mature individuals. Other criteria, such as Small distribution (geographic range), decline or fluctuations, have been observed for these populations in terms of Extent of Occurrence and Area of Occupancy with decline. The observed values for these parameters are much above the thresholds so these criteria have not been given weight in the overall assessment.

2.2 DFO Approach

DFO is the key agency regulating the exploitation of the fish resources in Canadian waters. Initial management of groundfish was based on mesh size regulation, but in early 1970s, catch quotas based on F maximizing yield per recruit (Fmax) were introduced. By 1975, $F_{0.1}$ was introduced as a more conservative approach. Since 1977, $F_{0.1}$ remained the basis for scientific advice and management of groundfish fisheries. For severely depleted stocks, F was set below $F_{0.1}$ from 1978 to 1983 for faster stock rebuilding. Increasing fishing pressure with lesser productivity and no apparent stock rebuilding led to two moratoria, one in 1993 followed by reopening in 1998 and other in 2003. DFO management practices came under criticism by Canadian Auditor General in 1997 by not implementing the Precautionary Approach (PA), for lacking clear fisheries management objectives and performance measures, and for not having a national policy for conserving and sustaining the resource (Shelton, 2007). DFO responded by developing a new approach termed "Objective based fisheries management" that incorporated the PA. Pilot studies under OBFM have been carried out and in practice; the only fishery with this approach is for Atlantic seals. This framework has yet to be evaluated quantitatively with regard to PA compliance through simulation trials (Rivard, 2006).

As a result of declaration of the status of the cod stocks by COSEWIC, there were high probabilities that Northern cod stocks would be listed under SARA. However, in April 2006, the Canadian Government announced that these three cod stocks not be listed under SARA. Instead, comprehensive recovery plans would be completed. Reasons included were economic and social costs. This led to three provincial-industry cod action trams (CATs) established for Newfoundland/Labrador, Maritimes, and Quebec in 2003 founded for developing term Rebuilding strategies (Canada, 2005a,b,c). However, no quantitative analyses have been carried out to date to support the CATs, and strategies are expressed in general terms with no specific goals or target rebuilding rates (Shelton, 2007).

2.3 Comparison of COSEWIC and DFO Approaches

Considering Atlantic cod, the approaches adopted by DFO and COSEWIC have been analyzed. COSEWIC presented its results for the Atlantic cod in a report in 2003. At the same time, Smedbol et al. (2002) presented their stock status analysis by considering four important terms of references which correspond to the criteria adopted by COSEWIC for designation of the status. Table 3 and 4 tabulates the comparative observations from the two agencies for the alternative Atlantic cod stock definitions based on these two important documents (COSEWIC 2003, Smedbol et al., 2002).

An important difference between the two approaches applied to cod is with respect to the definition of each stock, i.e., aggregated groups by COSEWIC and, individual management units by DFO. DFO assesses cod stocks based on defined management units, e.g., the NAFO management divisions. COSEWIC, on the other hand, treats the species as Designatable Units (DUs) that leads to the aggregation of many of the DFO management units into a single species definition. This is the first line of difference between the two agencies where such an aggregation of stocks has led to diverged interpretations of the stocks status.

The COSEWIC approach is based on decline in estimated adult abundance (i.e., estimated number of spawners) in aggregated stocks' population. The data used in the COSEWIC report for the cod stocks in the Atlantic are taken primarily from the disaggregated annual stock assessment reports from DFO (Smedbol et al., 2002). However, for each of the disaggregated cod stocks as compiled by the DFO assessment and stock status reports, annual estimated abundance and biomass values are different than those when considered by COSEWIC in aggregations. This makes it difficult to compare the COSEWIC stock thresholds to the DFO reference point estimates. The two agencies place their reference points in a different order along a biomass or abundance axis as a consequence of these aggregations.

Another fundamental difference in these approaches is with respect to the time frame considered during assessment. COSEWIC uses an historical time dimension measured in terms of generations or decades. DFO analyses are calibrated to historical data with almost complete emphasis on current estimates and limited 1-year projections under assumed exploitation scenarios. Meanwhile, estimation of decline depends critically on the time period used to measure absolute and relative declines. Different emphasis in the timed definition of decline further exasperates the differences between the management response policies from the two agencies.

Spatial considerations in terms of 'extent and area of occurrence' are an important criteria in the stock status assessment process of COSEWIC. However, spatial occurrence measures are generally not included in DFO stock assessments. Further, an important criterion observed by COSEWIC is the 'number of mature individuals' that form the basis for the risk status. The COSEWIC threshold for this criterion evoking concern is 10,000 mature individuals. However, in many marine cases, DFO estimation for mature individuals, e.g., for cod, is at least two orders of magnitude greater than the COSEWIC threshold (Smedbol et al., 2002).

In light of these differences, there has been a growing concern that the methods used by COSEWIC to classify species according to risk of extinction do not work well for marine species (Canada, 2005d). In particular, there is disagreement among the scientific community over the suitability of the quantitative criteria for evaluating extinction risk of marine fishes. Of the five quantitative criteria used by COSEWIC, the abundance decline criterion is the one that is most commonly used for marine fish. It is this criterion that has been criticized as being inappropriate for commercially exploited marine fish because threshold values are thought by some to be too low. As a result, exclusive application of the criteria (without consideration of any special life history characteristics of species) could lead to categorizations of species that are overly conservative, and not reflective of the actual risk of the species becoming extinct (Canada, 2005d). Overall, there is a pressing need to clarify the relationships between the reference point approaches used in DFO fisheries management, and the criteria set used by COSEWIC for establishing stock status and invoking policy decisions.

On the other hand, based on analysis of approaches adopted by DFO, important conclusions are: (1) assessment errors can contribute to overfishing through optimistic long-term forecasts leading to the build-up of overcapacity or through optimistic assessments; (2) stock size overestimation is a major risk when commercial catch per effort is used as an abundance trend index; and (3) the risk of recruitment overfishing exists and may be high even for very fecund species like cod. The high cost of information for accurate stock assessment may call for an alternative approach to management. Development of predictive models for such regulatory options is a major challenge for fisheries assessment science (Walters and Maguire, 1996).

2.4 Updated Information on Selected Cod Stocks (2002-2006)

In this section, information on the Atlantic cod stocks is updated to 2006 to demonstrate the computability of the comparable criteria values for estimating stock status. To illustrate, we focus on the 4TVn cod stock in the southern Gulf of St. Lawrence, and report on stock estimation values from 2002 to 2006. Stock estimation values from 2002 to 2006 are reported via the annual DFO stock assessment reports for the 4TVn cod stock. These 4TVn stock assessment reports are carried out annually with the sole exception of 2004 when the assessment of this stock was not done (Chouinard et al., 2000, 2001, 2002, 2003, 2005, 2006).

Based on these annual stock population estimation reports for 4TVn cod, annual updated values for some of the comparable COSEWIC stock status criteria as presented in Table 5 are determinable. In particular, updated estimates for stock abundance (COSEWIC criteria A and C) are presented in Table 5 for 4TVn cod. Other criteria, e.g., for geographic range and probability of extinction, are not determinable from updated stock assessments.

Table 5 reports on the rate of change in the population abundance (numbers of fish) for the mature population estimated to be all fish ages 5+. Estimates of stock abundance (numbers of 4TVn cod) for annual total stock (ages 3+ cod) (Figure 1) and for annual mature proxy stock (ages 5+ cod) (Figure 3) are presented for the period 1971 to 2006. Figures 2 and 4 show the respective declines for the 3+ abundance estimates and the 5+ abundance estimates over the COSEWIC three times mean generation time (3 x 9.5 years or 29 years) for 4TVn cod. **S**tock abundance estimates for the "total stock" (ages 3+) for 4TVn cod note the convergence of the historical data to the catch and survey data (Figure 1). Since 2000 however, the latest estimates are not converged. The pattern of alternatively high and revised lower assessment year values might indicate that observations of newly recruited year classes are biased upward and subsequently revised downward once more observations of the incoming year classes are obtained. Overall, the trend since 2000 of aggregated 3+ abundance has been declining.

Changes in the 3+ abundance estimates over the IUCN standard of three times the mean generation time (9.5 years for 4TVn cod) or 29 years leads to the results shown in Figure 2 below. This figure shows the overall pattern of decline (less than 25%) over the 29 period. It is also noted from Figure 1 that the 29 year shift includes comparison to the historical low period (1973-1975 versus 2001-2003) in the estimate of the time series of 3+ abundance.

Figure 3 (abundance) and Figure 4 (29 year percentage changes) report the results for the age 5+ abundance estimates for 4TVn cod based on the updated stock assessment reports. Unlike the 3+ abundance estimates, the 5+ abundance estimates (as a "jack-knife" proxy for the abundance of mature fish) are tempered by the existence of subsequent years of observations beyond the recruiting year estimates at age 3. Consequently, there is a smoothing out of the data beyond the apparent bias of the initial year estimates. The estimates of 5+ abundance (as reported in Table 4) show a year-over-year pattern of decline from 2000 to 2005 resulting in near historical low levels but increasing in the last year, 2006.

The update and use of information from the annual stock assessment reports for 4TVn cod related to the fixed COSEWIC criteria (Figures 1-4) provide only a partial view of stock status. Figures 5 and 6 below augment the COSEWIC stock status criteria by including the measure of spawning stock biomass (SSB). This measure, computed annually based on the calculated proportional mature 4TVn cod spawners by age, is a more accurate measure of spawning stock

3. Discussion

This section presents ideas for reconciling the COSEWIC and DFO approaches. Evidence from the example of 4TVn cod illustrates the potential difficulties associated with use of the COSEWIC based restricted decline indicators, especially in reference to marine species. At the same time, this example points out that there is an enhanced set of stock status estimates available that could be used to track decline from the extensive results of regular marine stock assessment (VPA) analyses, e.g., biomass estimates as well as abundance estimates. In this section we present a standard mechanism used in production and operations management for quality control applied to the case of dynamic tracking, monitoring and control of stock status estimates that takes into account: (i) the use of multiple stock status indicators; and (ii) incorporates principles of management by objectives.

3.1 Process Control

The principles of "process control" are well-established in the area of production and operations management and in the context of "total quality management", TQM (Nahmias, 2005). Process control makes use of "control charts" to determine if the underlying distribution of a measurable variable is undergoing a shift. A control chart uses information about the process variation to examine if the process is moving beyond acceptable variation stated as desirable tolerances. If the process is "in control" and moving as expected, then subsequent observations are expected to lie within the tolerances; the hypothesis that the process is "in control" is rejected if the observations fall outside the desired tolerances. Action must therefore be taken to reorient the system. For example, Figure 7 presents a "control chart" for the 4TVn cod stock using the mean weight of cod at age 6 as the relevant indicator. The observation about weight at age is significant to determining the stock biomass estimate and is a useful indicator of stock health.

Given that the annual variation in the weight at age may be substantial, this indicator elicits a management response. Such a response should be based on current and historical observations. Figure 7 sets a “target” and a “limit” value for the mean weight of age 6 cod in 4TVn. These reference values should be considered as management (not “scientific” or “biologically-based”) references that commit managers to a response, e.g., if the observed mean weight drops below the 0.90 lower limit, as in 1994, 1995, 2002, 2005, then, for example, the 4TVn Total Allowable Catch (TAC) could be modified downward as a conservative response. Such a rule could be set in advance of the observation and could also be determined as a function of other related indicators and observations about the stock

3.2 Stock Monitoring and Control

The DFO “Precautionary Approach” described above with its Critical/Cautious/Healthy Zone delimiters is analogous to the control chart methods with the added requirement that control chart zonal observations require prespecified management response. In Figure 8, the 4TVn ages 3+ abundance estimates are charted for the post-1990 period from the 2000 to 2006 stock assessments (Chouinard et al., 2006-2000). The thresholds values of 300,000 t (Healthy to Cautious) and 150,000 t (Cautious to Critical), are set based on recent history and not on any intrinsic biological reproductive understanding. Evidence from Figure 8 illustrates that, in spite of year-over-year retrospective corrections, the stock remains in the “cautious” zone until 2002 when it slips into the “critical” zone, i.e., falls below the 150,000 t threshold. This observed decline in the abundance estimate for 2002 (and 2003) should have triggered a predictable management shift in that year in order to make known the public policy for the benefit of all fishery system participants (in fact, in 2003, DFO declared a moratorium on the fishing of 4TVn cod, however the stock has not appreciably rebounded since that time). Furthermore, this shift should be designed to address the abundance decline by directing more scientific resources toward its estimation, and changing fishing exploitation and policy in favour of improving the abundance indicator.

The use of the control chart can be developed and applied to different measurable criteria, such as are developed in the stock VPA analyses. The operationalization of the control chart approach requires a commitment to setting management-imposed limits based on historical observations and for the purposes of setting policy actions. Furthermore, these management actions can be well-known to all participants in the fishery (and argued and discussed beforehand for acceptability) on a “what-if” basis so that the focus is on the indicators and not on anticipated but undeclared management response.

4. Conclusions

The robustness of decline criteria to estimate the risk of extinction is an issue of debate among fishery scientists and conservation biology communities like COSEWIC (Matsuda et al., 1998, FAO, 2001, Hutchings, 2001, Powles et al., 2000, Mace, 2004). Even the documented extinctions of marine species are rare and there is limited experience to date with extinction in the marine environment. Simple criteria-based approaches on their own may not be possible or appropriate for some groups, given the limited experience with extinction in the sea and thus, there are questions about applying extinction criteria to marine species. Accordingly, it is argued for considering a wider range of biological indicators and data on all aspects of marine species status especially where this information is available (Powles et al., 2000).

Another important consideration is to concentrate on the underlying threats that may impact the decision to assign a stock status level to a species including the reliability of indicators of stock-recruitment processes. Similarly, contextual specific information including life history traits can be incorporated directly into quantitative assessment criteria, or used to modify the conclusions of quantitative assessments (Butterworth, 2000, Reynolds et al., 2005).

Evidence from the above discussion suggests that the standard COSEWIC criteria and DFO precautionary approach can be reconciled by considering all readily available information for the status of the stock and then making strategic decisions based on moving the stock in the desired direction for improving its stock status over time. The well-heeled and basic principles of "management by objectives" (Drucker, 1954) and process control require fisheries management implementation and do not require inordinate scientific debate over biologically-justified objectives and theoretical control levels. Rather, it is a matter of putting the quality control practice into place from a management perspective.

The control chart approach described above is an operational management response tool for improved decision making. As such, it is considered inappropriate to try and determine "biologically" defined limits and thresholds. Potential gains made in trying to determine a biological basis for a conservative management action are out-weighed by the difficulty in trying to explain an ephemeral value or set of values that, in all likelihood, will loose their meaning over time in any case. Further, a wider set of criteria be considered for determining ultimate stock status. The requirement for such an evaluation is motivated by the Federal Regulatory Policy (Canada, 1999). It should also take into account multiple criteria of the marine ecosystem including biological sustainability, economic viability, social stability, and administrative efficiency. In order to support the integrated approach, appropriate means for collection and analysis of data across all fishery dimensions must be implemented. This requires a line of support from clients, local offices, regions, and the fisheries regulator. It also requires the involvement of all fishery participants. This realization empowers participants in the fishery system and will lead ultimately to mechanisms for effective shared management of Canada's fishery resources.

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Table 1: COSEWIC CRITERIA AND STATUS THRESHOLD VALUES

DECLINE CRITERIA	COSEWIC Status ENDANGERED	THREATENED
A. TOTAL POPULATION		
i) NUMBER OF MATURE INDIVIDUALS	70% WITH THREATS CEASED;	50% WITH THREATS CEASED;
SPAWNERS - 3X RATE OF DECLINE	50% WITH THREATS CONTINOUS	30% WITH THREATS CONTINOUS
	(IN 10 YEARS OR 3 GENERATIONS UPTO MAXIMUM OF 100 YEARS)	(IN 10 YEARS OR 3 GENERATIONS UPTO MAXIMUM OF 100 YEARS)
B. GEOGRAPHIC RANGE		
i) EXTENT OF OCCURRENCE	< 5,000 SQ KM	< 20,000 SQ KM
ii) AREA OF OCCURRENCE	< 500 SQ KM	< 2,000 SQ KM
iii) NUMBER OF LOCATIONS	≤ 5	≤ 10
iv) EXTREME FLUCTUATIONS	> 1 ORDER OF MAGNITUDE	> 1 ORDER OF MAGNITUDE
C. SMALL TOTAL POPULATION		
i) NUMBER OF MATURE INDIVIDUALS	< 2500 MATURE INDIVIDUALS	< 10,000 MATURE INDIVIDUALS
ii) RATE OF DECLINE	20% (IN 5 YEARS OR 2 GENERATIONS UPTO MAXIMUM OF 100 YEARS)	10% (IN 10 YEARS OR 3 GENERATIONS UPTO MAXIMUM OF 100 YEARS)
D. VERY SMALL POPULATION		
i) NUMBER OF MATURE INDIVIDUALS	< 250 MATURE INDIVIDUALS	< 1000 MATURE INDIVIDUALS
ii) AREA OF OCCURRENCE	< 20 SQ KM	< 20 SQ KM
iii) NUMBER OF LOCATIONS	≤ 5	≤ 5
E. QUANTITATIVE ANALYSIS		
i) PROBABILITY OF EXTINCTION	20% IN 20 YEARS OR 5 GENERATIONS	10% IN 100 YEARS

Table 2: COSEWIC SPECIES AGGREGATION STATUS ASSESSMENT BY CRITERIA FOR COD IN THE ATLANTIC				
	CRITERIA	**COSEWIC COD STOCK AGGREGATION**	**COSEWIC OBSERVATIONS (2003)**	**COSEWIC STATUS (THRESHOLD INTERPRETATION)**
A.	**TOTAL POPULATION**			
	i) NUMBER OF MATURE INDIVIDUALS	2GHJ, 3KLNO	97% (1968-2001)	**ENDANGERED**
	SPAWNERS - 3X RATE OF DECLINE	3Ps, 3Pn4RS	81% (1974-2001)	**THREATENED**
		4T, 4Vn, 4VsW, 4X, 5ej,m	14% (1974-1997)	**SPECIAL CONCERN**
B.	**GEOGRAPHIC RANGE**			
	i) EXTENT OF OCCURRENCE	2GHJ, 3KLNO	620,000 SQ. KM	**NO CONCERN**
		3Ps, 3Pn4RS	155,000 SQ KM	**NO CONCERN**
		4T, 4Vn, 4VsW, 4X, 5ej,m	250,000 SQ KM	**NO CONCERN**
	ii) AREA OF OCCURRENCE	2GHJ, 3KLNO	300,000 SQ KM	**NO CONCERN**
		3Ps, 3Pn4RS	90,000 SQ KM	**NO CONCERN**
		4T, 4Vn, 4VsW, 4X, 5ej,m	160,000 SQ KM	**NO CONCERN**
	DECLINE IN AREA OF OCCURRENCE	2GHJ, 3KLNO	365,000-290,000 SQ KM	
			21%(1960's - 2001)	**NO CONCERN**
		3Ps, 3Pn4RS	96,000-89,000 SQ KM	
			7%(1991- 2001)	**NO CONCERN**
		4T, 4Vn, 4VsW, 4X, 5ej,m	179,000-140,000 SQ KM	
			22%(1970's - 2001)	**NO CONCERN**
	iii) NUMBER OF LOCATIONS	All stocks	UNKNOWN	**N/A**
	iv) EXTREME FLUCTUATIONS	All stocks	UNKNOWN	**N/A**
C.	**SMALL TOTAL POPULATION**			
	i) NUMBER OF MATURE INDIVIDUALS	2GHJ, 3KLNO	45,000,000 (5+)	**NO CONCERN**
		3Ps, 3Pn4RS	63,000,000 (5+)	**NO CONCERN**
		4T, 4Vn, 4VsW, 4X, 5ej,m	88,000,000 (5+)	**NO CONCERN**
D.	**VERY SMALL POPULATION**			
	i) NUMBER OF MATURE INDIVIDUALS	All stocks	NOT APPLICABLE	**N/A**
	ii) AREA OF OCCURRENCE	All stocks	NOT APPLICABLE	**N/A**
	iii) NUMBER OF LOCATIONS	All stocks	NOT APPLICABLE	**N/A**
E.	**QUANTITATIVE ANALYSIS**			
	i) PROBABILITY OF EXTINCTION	All stocks	UNKNOWN	**NO CONCERN**
		2GHJ, 3KLNO		**ENDANGERED**
	OVERALL COSEWIC INTERPRETATION	3Ps, 3Pn4RS		**THREATENED**
		4T, 4Vn, 4VsW, 4X, 5ej,m		**SPECIAL CONCERN**

Table 3: COSEWIC-DFO OBSERVATIONS

	CRITERIA	COSEWIC STOCK AGGREGATION	COSEWIC OBSERVATIONS (2003)	DFO MANAGEMENT GROUP	DFO OBSERVATIONS (SMEDBOL ET AL., 2002)
A.	**TOTAL POPULATION**	2GHJ, 3KLNO	97% (1968-2001)	2J3KL	93.06% (1962-2001)
	SPAWNERS - 3X				
	RATE OF DECLINE	3Ps	46% (1968-2001)	3Ps	42.88% (1959-1998)
		3Pn4Rs	93%(1975-2002)	3Pn4RS	81.04% (1974-2002)
		4T	23% (1973-2002)	4TVn	34.3% (1973-2002)
		4Vn	95% (1981-2000)	4Vn	95.5% (1981-2000)
		4VsW	75% (1970-1997)	4VsW	80.8% (1970-1997)
		4X	78% (1979-2002)	4X/5Y	74.6% (1980-2000.5)
		5Z	70% (1979-2002)	5Zej,m	73.6% (1978-2001)
	NUMBER OF MATURE	2GHJ (5+)	43,000,000	2J3KL (5+)	5,000,000 (2000)
	INDIVIDUALS	3KLNO (5+)	2,000,000		
	(SPAWNERS'	3Ps (5+)	35,000,000	3Ps	30,000,000 (2000)
	POPULATION)	3Pn4RS (5+)	28,000,000	3Pn4RS	43,000,000 (2000)
		4T (5+)	72,000,000	4TVn	90,500,000 (1993-2002)
		4Vn (5+)	2,000,000	4Vn (5+)	1,965,000 (2000)
		4VsW (5+)	5,000,000	4VsW	4,304,000 (1998)
		4X/5Y (4+)	5,000,000	4X/5Y (4+)	7,633,000 (2000)
		5Z (3+)	4,000,000	5Zej,m (3+)	4,433,000 (1995-2001)
B.	**GEOGRAPHIC RANGE - AREA OF OCCURRENCE**				
	RATE OF DECLINE	2GHJ, 3KLNO	300,000 SQ KM	2J3KL	300,000 SQ KM
	(1983-2001)		22%(275,000-215,000SQKM)		
	RATE OF DECLINE (1983-2001)	3Ps	16 % (38,000-45,000 SQ KM)	3Ps	55,000-60,000 SQ KM
	RATE OF DECLINE	3Pn4RS	24% (58,000-44,000 SQ KM)	3Pn4RS	94,460 SQ KM (1990+)
	(1991-2001)	4T	0 % (58,000-58,000 SQ KM)	4TVn	56,000 SQ KM
	RATE OF DECLINE	4Vn	0 % (12,000 SQ KM)	4Vn	11,500 SQ KM
	(1970-2001)	4VsW	46 % (65,000-35,000 SQ KM)	4VsW	102,000 SQ KM
		4X/5Y	11 % (45,000-40,000 SQ KM)	4X/5Y	63,600 SQ KM
		5Z	0 % (14,000 SQ KM)	5Zej,m	16,800 SQ KM
	AGE AT MATURITY	2GHJ, 3KLNO	6 years	2J3KL	6 years
		3Ps	6 years	3Ps	7 years
		3Pn4Rs	4 years	3Pn4RS	5 years
		4T	4.5 years	4TVn	4.5 years
		4Vn	4.5 years	4Vn	5 years
		4VsW	4 years	4VsW	3.82 years
		4X/5Y	2.5 years	4X/5Y	2.63 years
		5Z	4.9 years	5Zej,m	2.09 years
	MEAN GENERATION	2GHJ, 3KLNO	11 years	2J3KL	7 years (1962-2001)
	TIME	3Ps	11 years	3Ps	7years (1959-1998)
		3Pn4Rs	9 years	3Pn4RS	6 years (1974-2002)
		4T	9.5 years	4TVn	6.46 years (1950-2002)
		4Vn	9.5 years	4Vn	10 years (1981-2000)
		4VsW	9 years	4VsW	8.82 years 1979-1995)
		4X/5Y	7.5 years	4X/5Y	7.63 years (1979-1985)
		5Z	7.5 years	5Zej,m	7.09 years (1986-1995)

	Table 4: COSEWIC AND DFO DIFFERENCES IN MARINE STOCK STATUS MEASURES			
	ISSUE	**COSEWIC**	**DFO**	**COMMENTS**
1.	**STOCK DEFINITION**	Species broadly aggregated	Disaggregated management areas	COSEWIC broad definitions may mask known stock problems or exaggerate others; DFO areas not biologically-defensible
2.	**RELEVANCE OF CRITERIA AND THRESHOLD VALUES**	Narrowly defined for marine species since based on IUCN terrestrial measures	Multiattribute values based on VPAs specific to stock estimates in management areas	COSEWIC criteria often not relevant for marine species; DFO absolute criteria not linked to decision making rules
3.	**DEFINTION OF DECLINE**	Generational estimates on population changes; restricted quantitative measures applied categorically	Multiple estimates applied only to current status compared to static thresholds for decision making on exploitation	COSEWIC long time measures subject to variability rendering uninformative; DFO measures do not take into account history
4.	**SPATIAL CONSIDERSATIONS**	Extent of occurrence measures included	Little or no emphasis on spatial and life cycle characteristics	COSEWIC attempt to include space not informative in marine context; DFO avoidance of spatial stock dynamics unfortunate
5.	**OVERALL RISK**	No defining means of combining limited measurable criteria	No defining means of combining multiple criteria from VPA and other	Neither COSEWIC nor DFO able to provide quantitative summary of measures

Table 5: 4TVn STOCK STATUS ASSESSMENT BY COSEWIC CRITERIA			
	CRITERIA	**COSEWIC OBSERVATIONS (2003)**	**DFO OBSERVATIONS (4TVn cod assessments)**
A.	**TOTAL POPULATION**		
	i) NUMBER OF MATURE INDIVIDUALS	23% (1973-2002) for 4T STOCK	38.11 % (2002)
	SPAWNERS - 3X RATE OF DECLINE		21.62% (2003)
		14% (1974-1997) for	2.02% (2004)
		AGGREGATED STOCK	-55.07% (2005)
		(4T, 4Vn, 4VsW, 4X, 5ej,m)	45.22% (2006)
B.	**GEOGRAPHIC RANGE**		NO DATA
C.	**SMALL TOTAL POPULATION**		
	i) NUMBER OF MATURE INDIVIDUALS	72,000,000 (5+) for 4T STOCK	72,286,000 (5+) (2002)
			64,334,000 (5+) (2003)
		88,000,000 (5+) for	59,967,000 (5+) (2004)
		AGGREGATED STOCK	56,044,000 (5+) (2005)
		(4T, 4Vn, 4VsW, 4X, 5ej,m)	60,900,000 (5+) (2006)
E.	**QUANTITATIVE ANALYSIS**		
	i) PROBABILITY OF EXTINCTION	UNKNOWN	NO DATA

Figure Legends

Figure 1

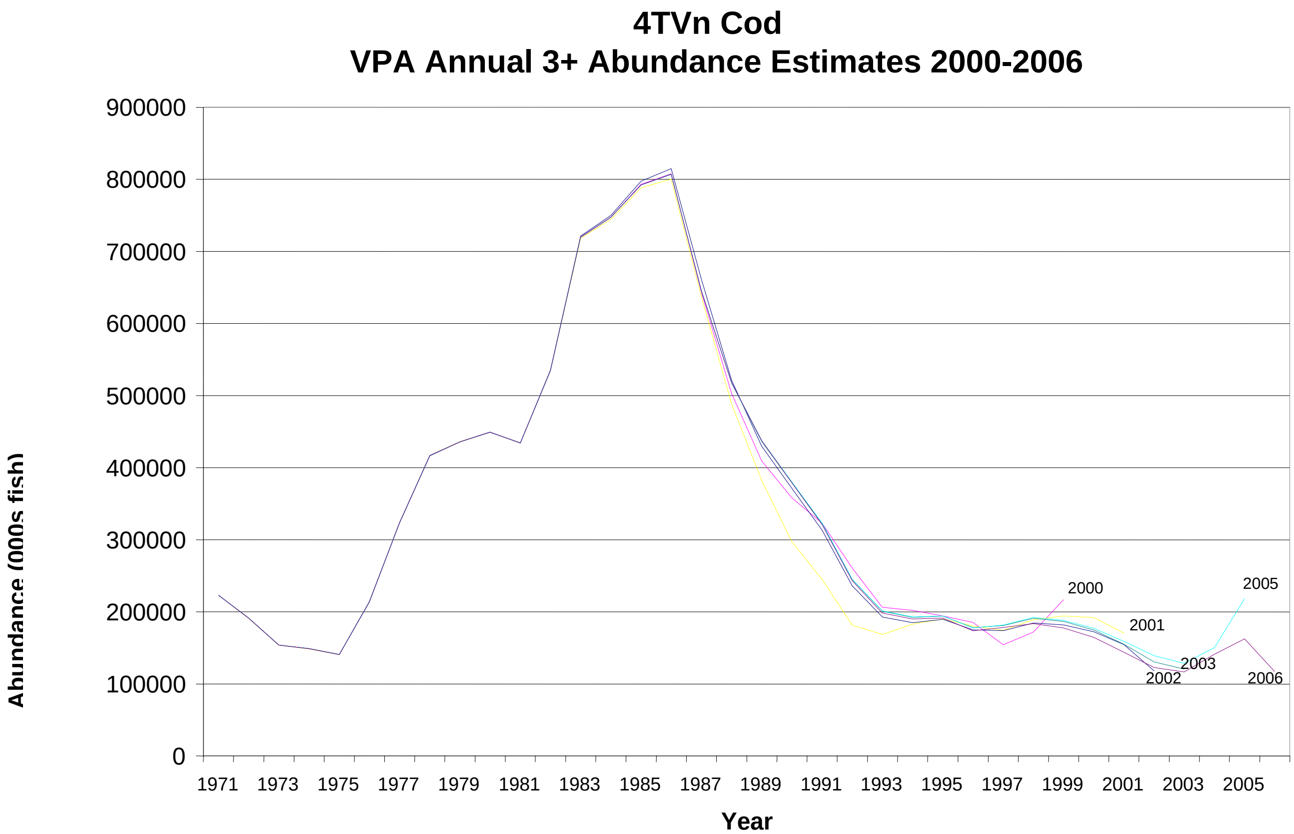

4TVn Cod
VPA Annual 3+ Abundance Estimates 2000-2006
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
Abundance (000s fish)
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
Year
2000
2001
2002
2003
2005
2006

Figure 2

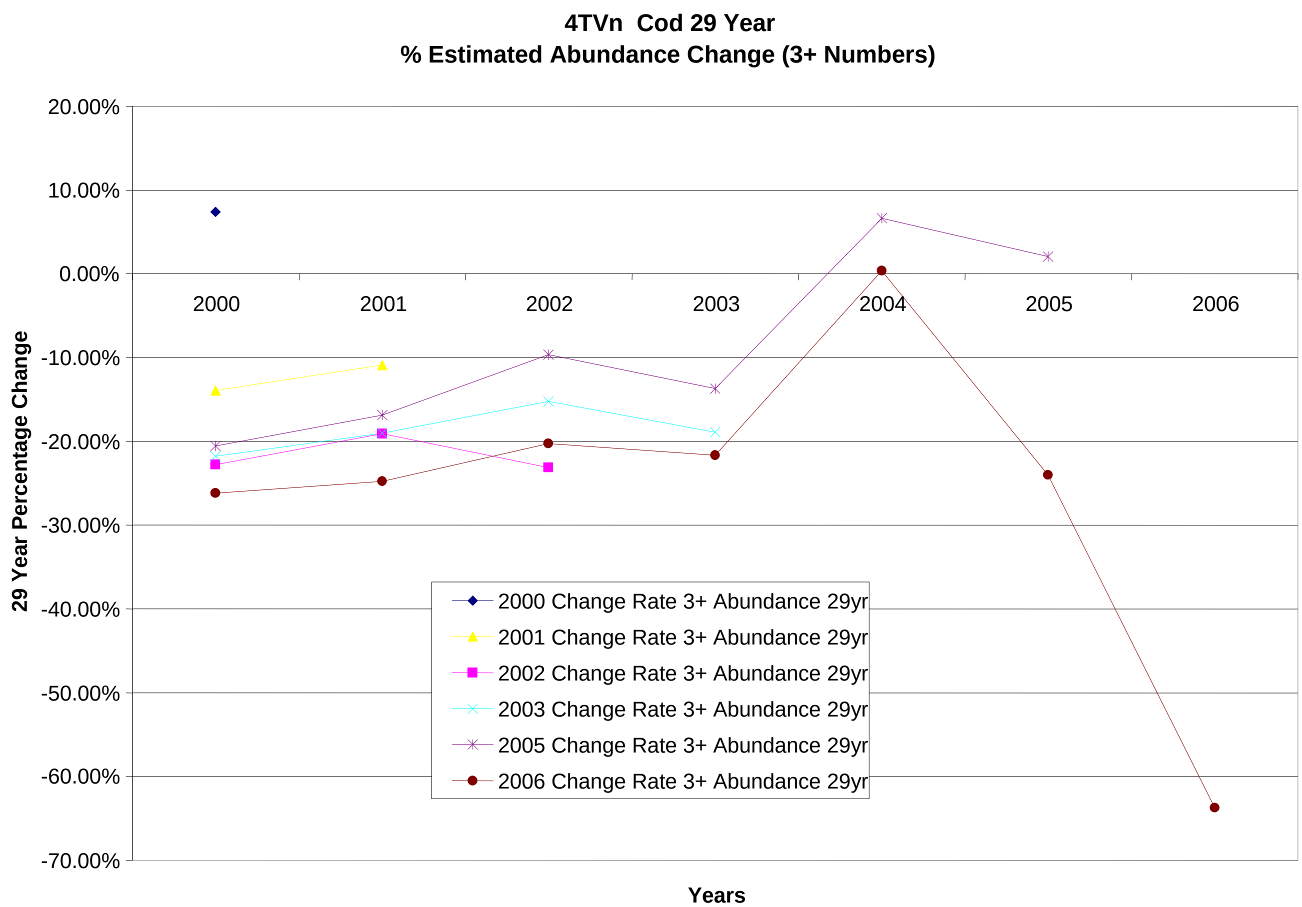

4TVn Cod 29 Year
% Estimated Abundance Change (3+ Numbers)
20.00%
10.00%
0.00%
-10.00%
-20.00%
-30.00%
-40.00%
-50.00%
-60.00%
-70.00%
29 Year Percentage Change
2000
2001
2002
2003
2004
2005
2006
Years
2000 Change Rate 3+ Abundance 29yr
2001 Change Rate 3+ Abundance 29yr
2002 Change Rate 3+ Abundance 29yr
2003 Change Rate 3+ Abundance 29yr
2005 Change Rate 3+ Abundance 29yr
2006 Change Rate 3+ Abundance 29yr

Figure 3

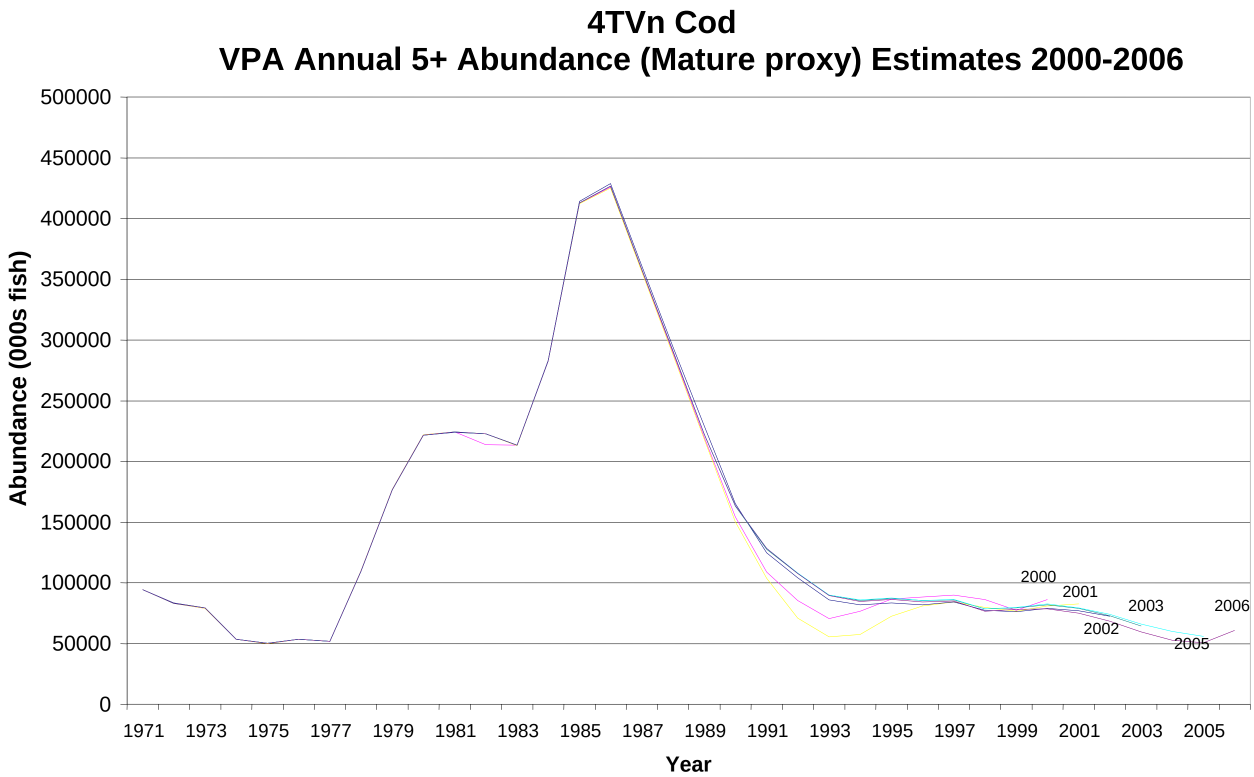
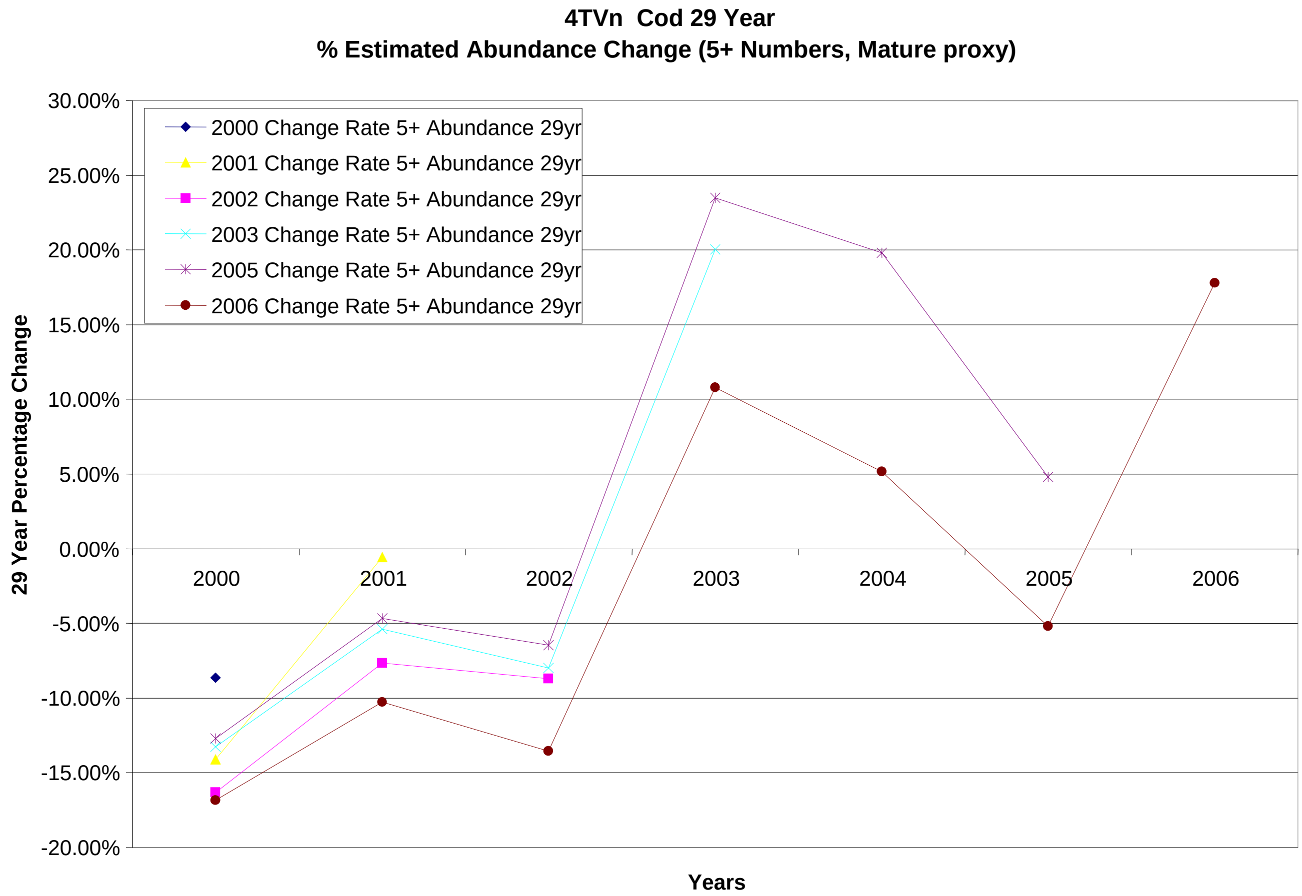

4TVn Cod
VPA Annual 5+ Abundance (Mature proxy) Estimates 2000-2006
Abundance (000s fish)
500000
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
Year
2000
2001
2002
2003
2005
2006

Figure 4



4TVn Cod 29 Year
% Estimated Abundance Change (5+ Numbers, Mature proxy)
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
-5.00%
-10.00%
-15.00%
-20.00%
29 Year Percentage Change
2000 Change Rate 5+ Abundance 29yr
2001 Change Rate 5+ Abundance 29yr
2002 Change Rate 5+ Abundance 29yr
2003 Change Rate 5+ Abundance 29yr
2005 Change Rate 5+ Abundance 29yr
2006 Change Rate 5+ Abundance 29yr
2000
2001
2002
2003
2004
2005
2006
Years

Figure 5

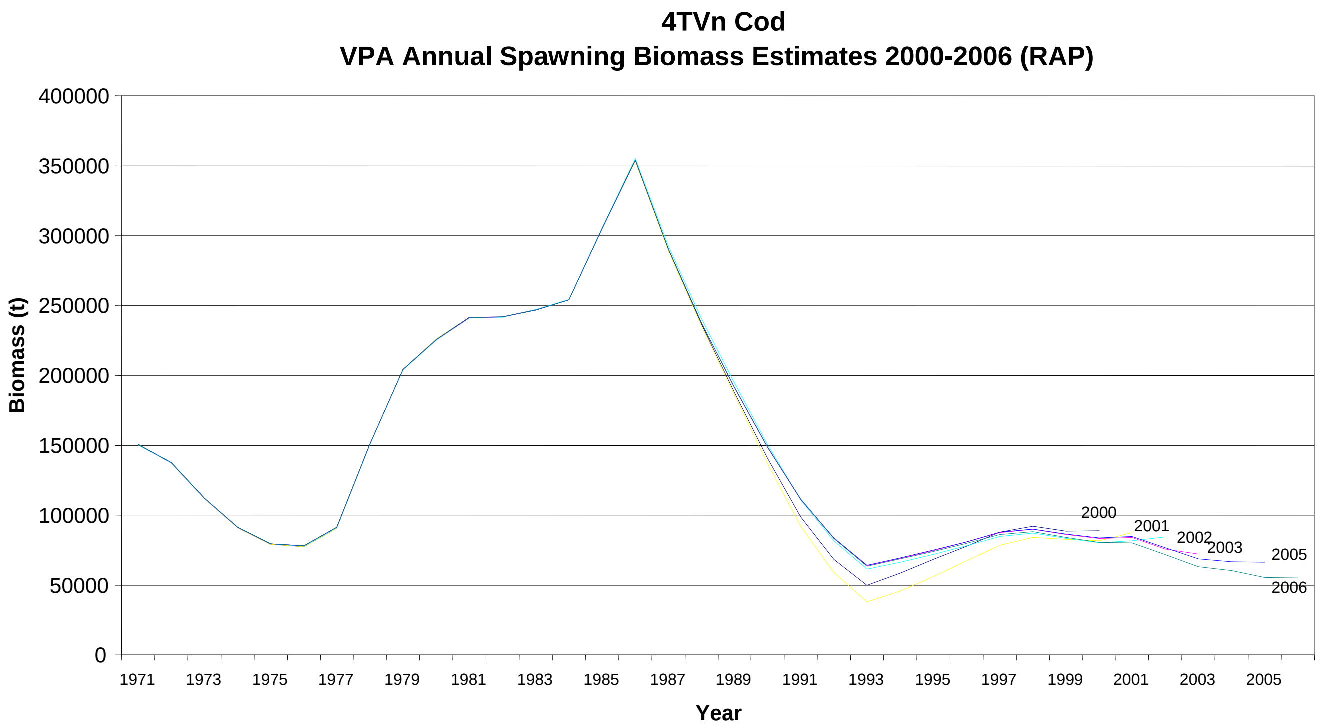
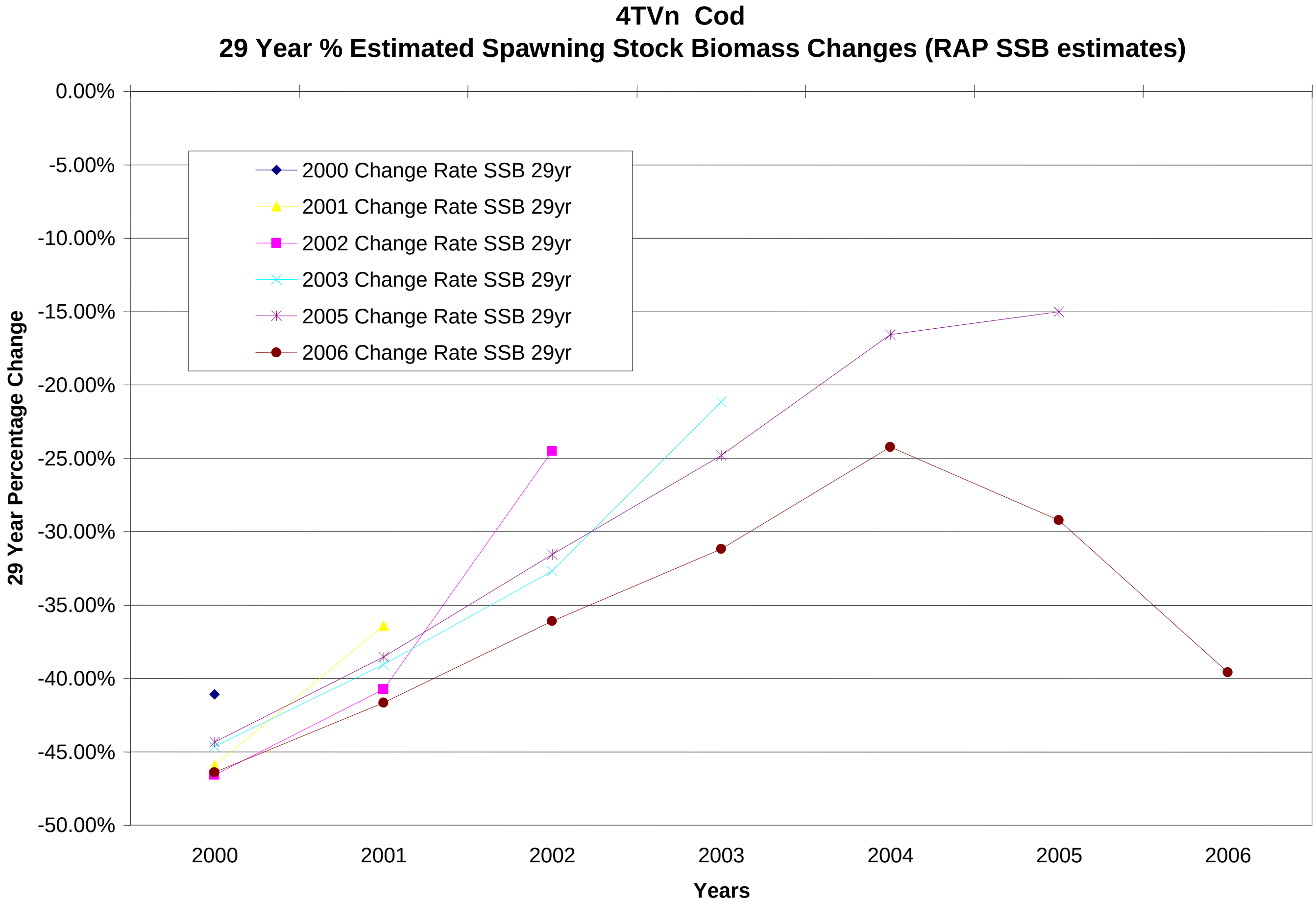

4TVn Cod
VPA Annual Spawning Biomass Estimates 2000-2006 (RAP)
Biomass (t)
400000
350000
300000
250000
200000
150000
100000
50000
0
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
Year
2000
2001
2002
2003
2005
2006

Figure 6



4TVn Cod
29 Year % Estimated Spawning Stock Biomass Changes (RAP SSB estimates)
29 Year Percentage Change
0.00%
-5.00%
-10.00%
-15.00%
-20.00%
-25.00%
-30.00%
-35.00%
-40.00%
-45.00%
-50.00%
2000 Change Rate SSB 29yr
2001 Change Rate SSB 29yr
2002 Change Rate SSB 29yr
2003 Change Rate SSB 29yr
2005 Change Rate SSB 29yr
2006 Change Rate SSB 29yr
2000
2001
2002
2003
2004
2005
2006
Years

Figure 7

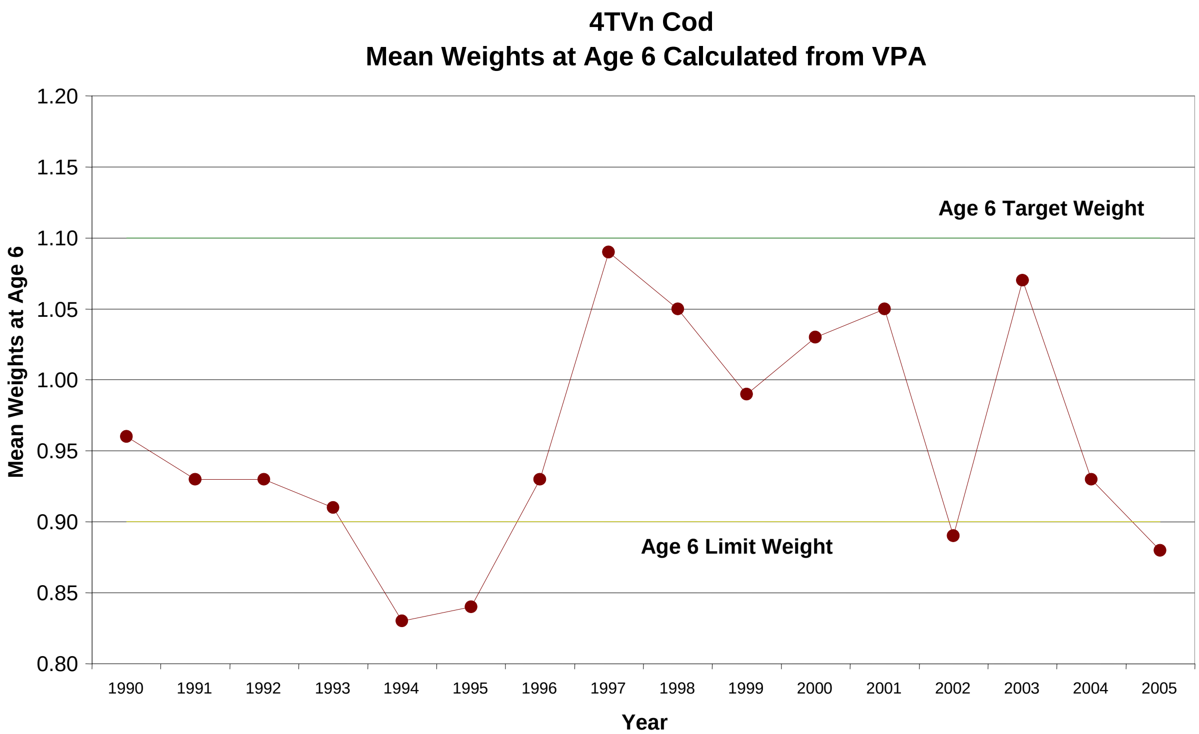
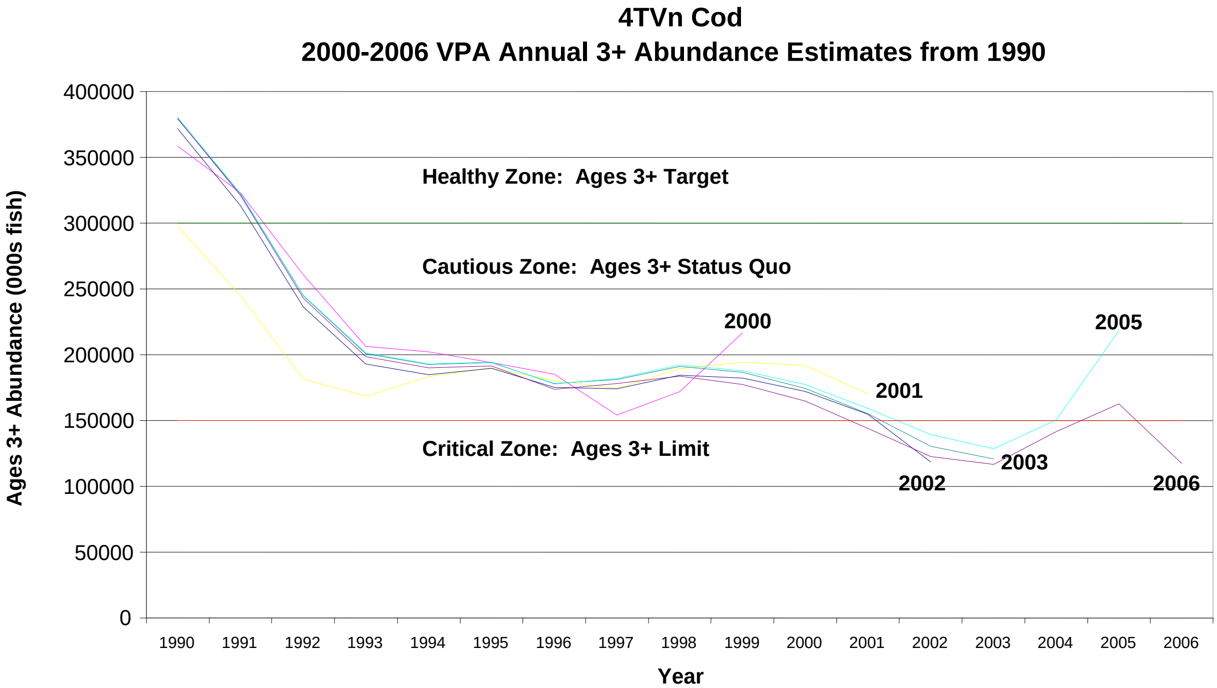

4TVn Cod
Mean Weights at Age 6 Calculated from VPA
Mean Weights at Age 6
Year
Age 6 Target Weight
Age 6 Limit Weight
1.20
1.15
1.10
1.05
1.00
0.95
0.90
0.85
0.80
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005

Figure 8


4TVn Cod
2000-2006 VPA Annual 3+ Abundance Estimates from 1990
Ages 3+ Abundance (000s fish)
400000
350000
300000
250000
200000
150000
100000
50000
0
Healthy Zone: Ages 3+ Target
Cautious Zone: Ages 3+ Status Quo
Critical Zone: Ages 3+ Limit
2000
2001
2002
2003
2005
2006
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
Year