

Risk Analysis Framework for Cost Benefit Analysis and Strategic Fisheries Management

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WORKING PAPER
WP.10.11

July 2010
ISSN 0701-3086



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A previous draft of this working paper was presented to the Annual Science Conference of the International Council for the Exploration of the Sea (ICES) meeting held in Halifax, Nova Scotia, Canada, September 22-26, 2008, Session O, Paper number 2. ICES CM 2008/O:02.

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ABSTRACT

This paper investigates the requirements for integrated decision making for fisheries described as system. Founded on the principles of decision analysis developed within the field of management science, it provides the requisite methodology for improved decision support and risk assessment and management. A system model is proposed for the fisheries system that takes into account the multiple criteria of the marine ecosystem including biological sustainability, economic viability, social stability, and administrative efficiency. This decision support system integrates traditional biological stock assessment methods with operational management considerations, and a scientific approach to decision making. An illustrative case study based on the cod fishery in NAFO division 4TVn is used to demonstrate the proposed methodology.

Keywords:

integrated fisheries system analysis, economic, social, biological and administrative impacts, risk management, risk analysis, multicriteria decision analysis

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1. Introduction

Managing fisheries and related marine ecosystems systems involves many, varied, and conflicting criteria. For example, the *Fisheries Act of Canada* (Canada 2006b) requires that the Minister of Fisheries and Oceans authorize decisions leading to a sustainable fishery for the economic benefit of all Canadians. Thus, quantifiable social and economic benefits from fishing and exploitation of the resource form part of the evaluation of the fishery system along with the quantifiable impacts on the resource. The management goal mandated by the *Fisheries Act* is to allow exploitation for profit while not exceeding the conservation and sustainability objectives of the resources. Policy reviews designed to address the conflicts of conservation and exploitation are typically descriptive, propose no substantial change, and do not provide clear operational direction from “motherhood” strategic objectives (e.g., Canada 2004). Planning in these systems requires multicriteria models for decision support as part of an organization’s successful strategic and operational process (Wooster 1988). Moreover, these models are by design useful for evaluating management policy taking into consideration all benefits and costs as required under the *Federal Regulatory Policy* (Canada 1999).

In this paper, the fishery system is described as a management system characterized by biological, social, economic, and administrative objectives. Specification of these objectives and evaluation of management policies against the attainment of these objectives form the basis of the fishery system management evaluation process. Moreover, in fisheries management problems involving multiple and diverse decision-makers, structured multiple criteria decision making (MCDM) methods promote the development of consensus positions among participants. Based on past successes and documented applications, fisheries policy case studies using MCDM methods are an effective policy evaluation tool for understanding fish stock status in the full system context (Lane 2007).

Atlantic cod stocks has been considered for the application of this model since these have been an issue of immense concern due to an alarming decline and lack of recovery at the expected levels. Cod stocks have experienced dramatic changes in response to emerging fisheries technologies, excess fishing capacity and overexploitation, and fish stock decline due to apparent ecosystem shifts since the 1960’s. Seven out of ten cod stocks in the Atlantic collapsed primarily as a result of overfishing in 1980’s and early 1990’s (Smedbol, 2003). This distressing condition has arrested the attention of many organizations and agencies involved directly in conservation of biodiversity.

The Department of Fisheries and Oceans (DFO), Canada is responsible for providing advice regarding the management policies. 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. Although both of these organizations, DFO and COSEWIC, have the common goal of conservation and sustainability of the cod stocks, there exists a debatable conflict regarding the proposed management actions for the Atlantic cod stocks based on the stock assessments.

Keeping these discrepancies in mind, the aim of this paper is to propose a framework under which the two approaches of COSEWIC and DFO can be harmonized. Attempts are directed toward an attempt to provide the best estimate of status of cod stocks with its translation into effective management policies. The paper develops a quantitative, integrated system that proceeds from known data to simulation of impacts, and to multicriteria decision analysis. The paper thus presents a systematic approach for evaluation of policy alternatives under different scenarios, which takes into account the biological, economic, social and administrative perspectives to draw useful policy implications by understanding the fisheries system.

2. Fisheries System Analysis

The argument that the COSEWIC criteria and the DFO for determining stock status can benefit from other information readily available from the fisheries stock assessment reports such as exist for 4TVn cod. This argument is extended to develop a comprehensive “system” view of stock status (Charles 2001). The approach is consistent with the principle of “management by objectives” attributed to Drucker (1954). The International Council for the Exploration of the Seas (ICES) has espoused the notion of “fishery systems” in its international committee work on Fishery Systems (ICES 1999, 2005, 2006). Examples of the application of fishery systems analysis as developed here is provided in Lane and Stephenson 1998,1996, Xue and Lane (2006) and Zhao et al (2006), Bendickson et al (2005). Significantly, the system view also directly addresses the needs of the *Federal Regulatory Policy* (Canada 1999) that requires the identification of all costs and benefits of applied regulatory policy including the implications associated with listing stocks on Schedule 1 of the Species at Risk Act (Canada 2003).

2.1 Multiple Objectives Integrated Modeling

In complex resource management, decision makers often take opposing views on the relative importance of, for example, resource sustainability issues (viewed as more important in the long-run), compared to social and financial considerations (viewed as more politically important in the short-term). To deal with such issues, an integrated modeling and evaluation framework is developed comprised of two linked methodological subsystems:

I. Fishery Spreadsheet Analysis - specifies policy inputs, objectives targets, and data parameters for the biological, economic, social and administrative dimensions of the system and calculates the quantitative indicators for policy alternatives; and

II. Multiple Criteria Decision Analysis - processes utility-based trade-offs of the fishery system dimensions and policy impacts relative to the attainment of specified targets by alternative management scenarios and ranks the performance of each alternative.

I. Fishery Spreadsheet Analysis Subsystem. The spreadsheet model calculates annualized outcomes for quantitative policy performance information for the fishery system dimensions: (1) the biological resource (stock abundance and biomass); (2) the economic (industry profit by gear type); (3) the social (employment and labour earnings); and (4) the administrative (management) cost. The indicators are quantitative measures directly comparable to specified objectives (targets) for each fishery dimension. The quantitative impacts of the alternative policy scenarios are transformed into utility values to be used in the multicriteria decision analysis subsystem. This transformation synthesizes the fisheries policy evaluation information into dimensionless

utility values (“utiles”) based on a generic S-shaped utility curve that is applied to each fishery system indicator as a function of the percentage of realized objective or target value specified for the indicator. The representative utility transformation curve (or “indifference curve”, Evans and Olsen 2002) for the percent of the indicator target realized is illustrated in Figure 1. Fishery indicators are allocated a utility value ranging between zero (0%) and one (100%) in accordance with the degree (percentage of target realized) to which they satisfy a specified target value.

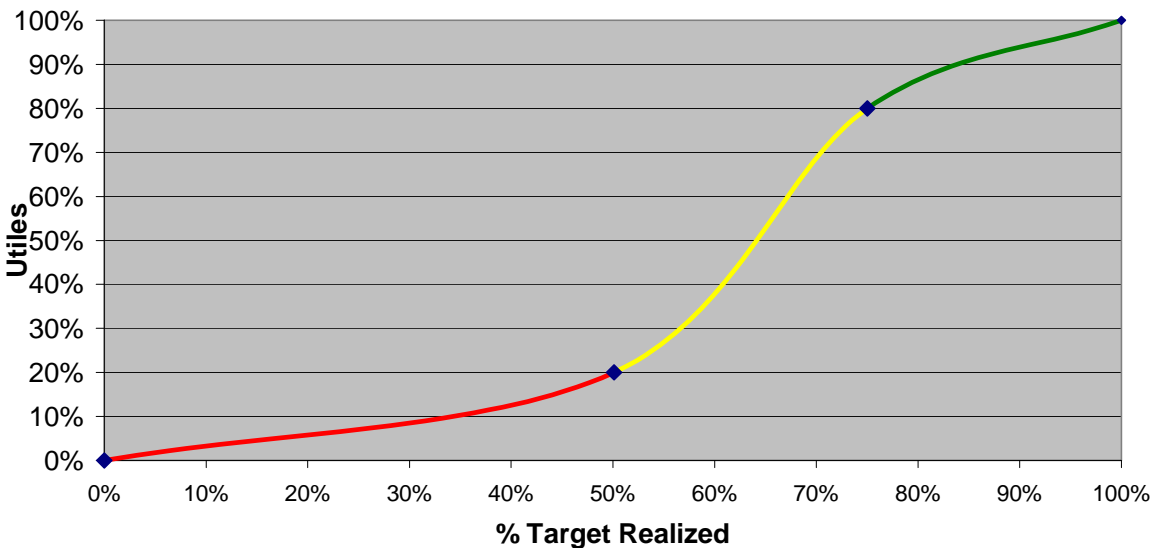
For example, suppose the current policy scenario under evaluation records an abundance estimate of 80 thousand metric tonnes for the stock, against an abundance objective of 100 thousand metric tones. The value of the “target realized” as a percentage is 80/100 or 80%. Using the utility transformation curve (Figure 1), 80% maps into a utility value of approximately 85% or utiles.

This relatively high utility falls in the green coloured area of the utility curve indicative of a favourable position (compared with the reduced yellow and red areas of the curve in Figure 1). The suite of indicator scaled (on 0-1) and dimensionless utility values are used as input in the multicriteria decision making analysis subsystem described below and allow the direct comparison and trade-offs of different measurable criteria.

Finally, the utility (or trade-off) curve reflects the decision maker’s relative risk by measuring the trade-offs in dimensionless “utiles” that are directly comparable across different criteria. The curve segments reflect the riskiness of the decision maker with respect to the realized objective target. For example, if the target realized is low (red zone) then the decision maker is characterized by a risk seeking behavior that would be worthwhile (in utile terms) only if a significant gain in the target is achieved. In the yellow zone, the decision maker is characterized by both a risk-seeking trade-off zone (at low yellow realized target levels) and by a risk aversion behaviour (at high yellow realized target levels) when increases in targets yield smaller relative utile gains. The green zone is entirely risk averse in that the decision maker is willing to give up fewer utiles in order to gain further target realization as the measure approaches the target level (at 100% target realized).

Figure 1

Standardized Utility Curve for all Indicators



II. Multiple Criteria Decision Analysis Subsystem. The multicriteria decision analysis subsystem evaluates alternative policy scenarios based on the utilities for each of the fishery system indicator values and ranks the policies according to the indicator weights derived from decision makers' pairwise comparisons using the methodology of the Analytical Hierarchy Process (AHP) (Saaty 1980). In the AHP interactive trade-off methodology, the relevant information of the multicriteria problem is composed into a hierarchy describing the goal, criteria, and subcriteria (Figure 2). The AHP problem is formulated by acquiring the decision maker's pairwise comparison of the importance of the fishery system hierarchy elements. These elements are synthesized by soliciting answers to the decision maker's pairwise comparisons of the elements of each level of the hierarchy. Based on these pairwise comparisons, weights are established using AHP that permit calculation of relative rankings of policy scenario alternatives. The AHP software, *Expert Choice* (Expert Choice 2005) is used to calculate criteria and sub-criteria weights for the different indicators of the fishery system.

With this information, the weights of the fishery system dimensions for the biology, economics, social, and administrative criteria and their subcriteria are determined (as reported in Figure 2). It is noted, for example, that the consequence of the pairwise comparison inputs result in the biological indicator for "Stock Biomass Target SSB 5+" as having the highest relative weight of the five biological indicators (37%). Similarly, the overall biological dimension is rated (53.5%) as being nearly twice as important as the next highest rated dimension, economics (27%).

Finally, using the utility values (as mentioned in the previous subsystem) as input, policy scenario alternatives are ranked and compared against the expected impacts of competing alternatives. Decision makers' trade-offs among the criteria and sub-criteria in the hierarchy can substantially alter policy alternative rankings.

3. Application

This section presents the data and analysis of the fishery system multicriteria model applied to the case of the southern Gulf of St. Lawrence cod stock in NAFO Divisions 4TVn.

3.1 4TVn Cod Fishery System Objectives

Quantitative objectives or targets for the 4TVn cod fishery system correspond to the indicators for each of the fishery system dimensions, namely, the biological, economic, social, and administrative elements. The quantifiable indicators correspond to the indicators of the AHP hierarchy described in Figure 2. Table 1 below presents the specific indicators and targets for the case of the 4TVn cod stock.

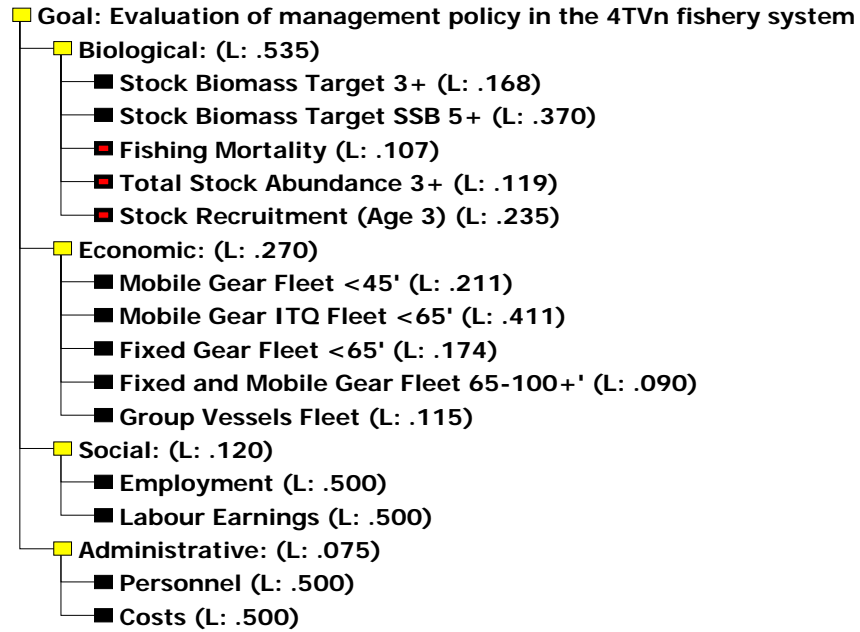
Table 1. 4TVn Cod Fishery System Objectives

<i>Dimension</i>	<i>Indicator</i>	<i>4TVn Cod Target Value</i>	<i>Sources</i>
I. Biological	1 Total Biomass (ages 3+)	over 200,000 t (see also Figure 3)	Chouinard et al (2006-2001), Canada (2005a), FRCC (2003)
	2 Spawning Stock Biomass (ages 5+ proxy)	over 100,000 t (see also Figure 3)	
	3 Fishing Mortality	under 0.30	
	4 Total Abundance (ages 3+)	over 300,000 fish (see also Figure 1)	
	5 Recruitment (age 3)	over 150,000 fish	
II. Economic	1 MG < 45' Fleet NOI	over \$8,000 per yr	Canada (2007), Canada (2006a), Canada (2005a),
	2 FG < 65' Fleet NOI	over \$10,000 per yr	
	3 MG ITQ < 65' Fleet NOI	over \$20,000 per yr	
	4 FG + MG 65-100+' Fleet NOI	over \$50,000 per yr	
	5 Group Vessels Fleet NOI	over \$15,000 per yr	
III. Social	1 Employment (Annual FTEs)	over 300 FTEs per yr	Canada (2007), OECD (2000)
	2 Labour Earnings	over \$15,000,000 per yr	
IV. Administrative	1 Personnel (Annual PYs)	under 35 PYs	Canada (2003b), OECD (2000)
	2 Management Costs	under \$3,000,000	

Figure 2

Model Name: 4TVN AHP DATAGRID

Treeview



* *Distributive mode*

Source: Screen dump from *Expert Choice*, AHP decision software for the 4TVn cod fishery system problem.

The specific fishery objectives for the 4TVn cod fishery provide an operational definition of a “responsible fishery system” (OECD 2000). These objectives also represent targets for which the regulator and the public, the harvesters, processors, and the fishing communities would be expected to concur as desirable (although perhaps conflicting) outcomes for this fishery. As such, there may not be any possible coincident attainment of all targets. Nevertheless, the targets permit the evaluation and relative comparison of policy alternative impacts across the entire spectrum of the fishery system. The following paragraphs outline the indicator targets by dimension of the system.

3.2 4TVn Cod Fishery System Evaluations

The evaluation of the system indicators were measured annually for policy parameters and compared against the targets of Table 1. The 1998-2005 measurement values are described below.

Biological targets. The recent history of the 4TVn cod stock abundance and biomass estimates were done from published DFO reports (Chouinard et al 2006, 2005, 2003, 2002, 2001, 2000). The ensuing abundance and biomass targets are set relative to this recent history. It is noted that despite low exploitation levels and moratoria since 1993, the stock status has remained low since the precipitous fall that occurred in the mid-1980s.

Economic targets. The average viability of the designated harvesting gears (mobile gear, MG and fixed gear, FG,) quota groups, Canada 2006a) is measured in terms of the average vessel annual Net Operating Income (NOI) as in the standard *pro forma* profit statement report of Table 2. In the “single species” analysis of the current model, it is noted that vessels in each gear category also earn income from fishing other species under licence. These earnings are not reported in this analysis of 4TVn cod. Thus, the reporting of NOI for average vessels by gear type represent only the contribution of 4TVn cod to overall earnings. These objective levels are based on the range of nominal net operating income levels over the course of the planning period (Canada 2005a).

Table 2. MG ITQ Fleet <65' Pro Forma Annual Net Operating Income

Annual Profit Statement

Year:	1998	1999	2000	2001	2002	2003	2004	2005
Operating Revenue								
Blocks	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Fillets	\$9,597	\$18,375	\$19,649	\$20,148	\$16,635	\$929	\$6,846	\$7,525
Whole/Dressed	\$9,339	\$17,036	\$14,976	\$15,012	\$9,804	\$562	\$5,353	\$7,775
Other	\$766	\$2,716	\$3,838	\$3,306	\$2,177	\$100	\$875	\$1,004
Total Operating Revenue	\$19,702	\$38,127	\$38,463	\$38,467	\$28,616	\$1,592	\$13,074	\$16,304
Operating Costs								
Fuel, Oil, Grease, etc.	\$1,223	\$2,812	\$2,932	\$3,292	\$2,962	\$179	\$1,381	\$1,620
Ice	\$122	\$281	\$293	\$329	\$296	\$18	\$138	\$162
Provisions	\$306	\$703	\$733	\$823	\$740	\$45	\$345	\$405
Gear and Electronics	\$1,500	\$1,500	\$1,500	\$1,500	\$1,500	\$1,500	\$1,500	\$1,500
Total Material and Supplies	\$3,151	\$5,297	\$5,458	\$5,944	\$5,498	\$1,741	\$3,365	\$3,688
Dockside Monitoring, Obs	\$2,000	\$2,000	\$2,000	\$2,000	\$2,000	\$2,000	\$2,000	\$2,000
Crew Share - Labour	\$9,063	\$17,538	\$17,693	\$17,695	\$13,163	\$732	\$6,014	\$7,500
Captain's Share - Labour	\$1,970	\$3,813	\$3,846	\$3,847	\$2,862	\$159	\$1,307	\$1,630
Total Labour Costs	\$11,033	\$21,351	\$21,539	\$21,541	\$16,025	\$891	\$7,322	\$9,130
Total Operating Costs	\$16,184	\$28,648	\$28,998	\$29,485	\$23,523	\$4,633	\$12,687	\$14,818
Net Operating Income	\$3,518	\$9,479	\$9,465	\$8,981	\$5,093	(\$3,041)	\$388	\$1,486

Source: 4TVn Integrated Fishery System Spreadsheet Model.

Social targets. The average levels of annual employment in the 4TVn cod harvesting sector are estimated as per the DFO quota reporting systems (Canada 2006a). Estimated annual social indicators values attributed to 4TVn and social targets (Table 3) are based on historical levels of employment in the industry and estimates of the population demographics of the Atlantic region (including the provinces of Prince Edward Island, New Brunswick, Nova Scotia, and Quebec) that operate in the Gulf of St. Lawrence.

Table 3. 4TVn Annual Social Indicators Report

Estimated Actual Workforce

Year:	1998	1999	2000	2001	2002	2003	2004	2005
Harvesting Employment (Captain and Crew) in PYs	38	88	86	89	72	4	32	39
Processing Employment in PYs	58	133	133	139	116	6	50	59
Total 4TVn Cod Workforce (PYs)	96	220	219	228	188	10	82	99
Social Employment Objectives (PYs)	300	300	300	300	300	300	300	300

Estimated Labour Earnings

Year:	1998	1999	2000	2001	2002	2003	2004	2005
Harvesting Earnings (Captain and Crew) in nominal \$000s	\$1,675	\$3,242	\$3,270	\$3,271	\$2,433	\$135	\$1,112	\$1,386
Processing Earnings in nominal \$000s	\$4,158	\$9,480	\$9,489	\$9,899	\$8,277	\$458	\$3,573	\$4,224
Total 4TVn Cod Labour Earnings	\$5,833	\$12,721	\$12,760	\$13,169	\$10,710	\$593	\$4,685	\$5,610
Social Labour Earnings Objectives	\$15,000	\$15,000	\$15,000	\$15,000	\$15,000	\$15,000	\$15,000	\$15,000

Source: 4TVn Integrated Fishery System Spreadsheet Model.

Administrative targets. The 1995 Canadian “Program Review” specified targets for cost reduction in federal departments, e.g., 30% cut in costs relative to 1997 levels of expenditures. DFO cuts to the administrative costs for the 4TVn cod fishery were used to estimate the strategic employment and cost support level of the federal government for this fishery. This amounted to annual administrative costs estimates of approximately \$3 million. The administrative targets expressed in terms of person years (35 PYs) were measured for the administrative tasks of fisheries science, habitat science and management, monitoring, enforcement, licensing, and quota management. Current estimates are approximately 20% above the set targets for administration (Table 4).

3.3 4TVn Cod Policy Scenarios

For the 4TVn cod case study, two analyses of the multicriteria fishery system evaluations are presented. These analyses are described as follows: (1) historical review 2001-2005; and (2) 2007 alternative policy review.

(1) Historical Review 2001-2005. This analysis presents the annual results of the most recent 5 year annual period for which data are available. Tables 1 through 4 provide evidence of the historical data that are compiled in the fishery spreadsheet analysis. The results provide a comparison of the historical annual performance of the fishery system.

Table 4. 4TVn Annual Administrative Costs Report

Annual Administrative Costs

Year:	1998	1999	2000	2001	2002	2003	2004	2005
Administrative Functions (\$000s)								
Science (Research & Assessment)	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000
Science Vessels	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000
Regional Director	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100
Total Science Branch	\$2,100	\$2,100	\$2,100	\$2,100	\$2,100	\$2,100	\$2,100	\$2,100
Fisheries & Habitat Management								
Licensing	\$200	\$200	\$200	\$200	\$200	\$200	\$200	\$200
Monitoring	\$450	\$450	\$450	\$450	\$450	\$450	\$450	\$450
Enforcement	\$250	\$250	\$250	\$250	\$250	\$250	\$250	\$250
Program Support (Statistics)	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100
Quota Management	\$75	\$75	\$75	\$75	\$75	\$75	\$75	\$75
Total Fish and Habitat Management	\$1,075	\$1,075	\$1,075	\$1,075	\$1,075	\$1,075	\$1,075	\$1,075
Total Administrative Costs	\$3,175	\$3,175	\$3,175	\$3,175	\$3,175	\$3,175	\$3,175	\$3,175
Administrative Costs Objectives	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000

Source: 4TVn Integrated Fishery System Spreadsheet Model.

(2) 2007 Alternative Policy Review. This analysis presents the results of alternative management policies applied to 2006 and 2007 and the impacts of these policies along the fishery dimensions of the fishery system for 2007. It is assumed that all price and cost data remain the same as for 2005 levels in the model. Stock (age 3) recruitment values are estimated at the average level of the 2003 and 2004 age 3 recruitment years (approximately 50,000 age 3 fish). The applied management policies are defined below:

Table 5. 2007 Alternative Policy Set

<i>Policy</i>	<i>Description</i>	<i>2006 and 2007 Catches and Fs</i>
Status Quo	Low level of exploitation; average of 2004 and 2005	2300t; F=0.075
Moratorium	No fishing	0t; F=0.0
Increased Catch	High relative level of exploitation	5900t; F=0.2

4. Application Results

The results of the 4TVn cod fishery policy scenarios are presented for (1) the historical review 2001-2005, and for (2) the 2007 policy alternatives. The multicriteria results for the policy scenarios are presented graphically to illustrate the comparative impacts for each dimension of the fishery system.

(1) Historical Review 2001-2005. The radar graphs of Figures 3 and 4 report, respectively the results of the historical review for the biological dimension indicators and the overall utility measures attributed to each of the years 2001 to 2005.

Figure 3 shows the annual results for each of the five (5) indicator values of the biological dimension. The graph shows the outlines for the AHP weighted targets, tolerance values (denoted as 75% of the target), and limit values (50% of the targets) for each of the axes of the pentagon. The shape of these weighted target polygons reflect the implied importance of each axis (indicator) (see also Figure 8 above). The figure also shows the annual results for each year from 2001 to 2005. The graph tracks the biological indicators matching the historical estimates of stock abundance and biomass (Figures 1 and 3). In particular, the SSB proxy annual results slide down the radar graph of Figure 3 as the estimates fall year-over-year (Figure 3). Similarly, the fishing mortality measures attain the target values (or below) in each year of the time series and are therefore assigned high utility values for this indicator.

Figure 3

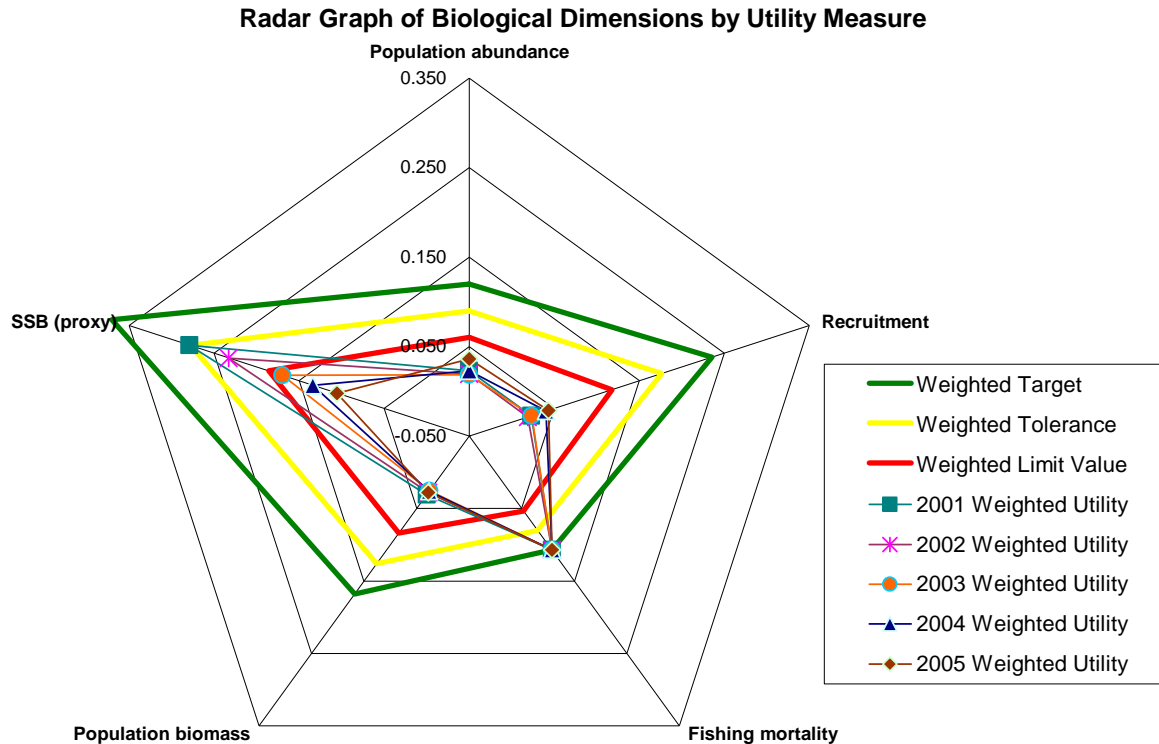
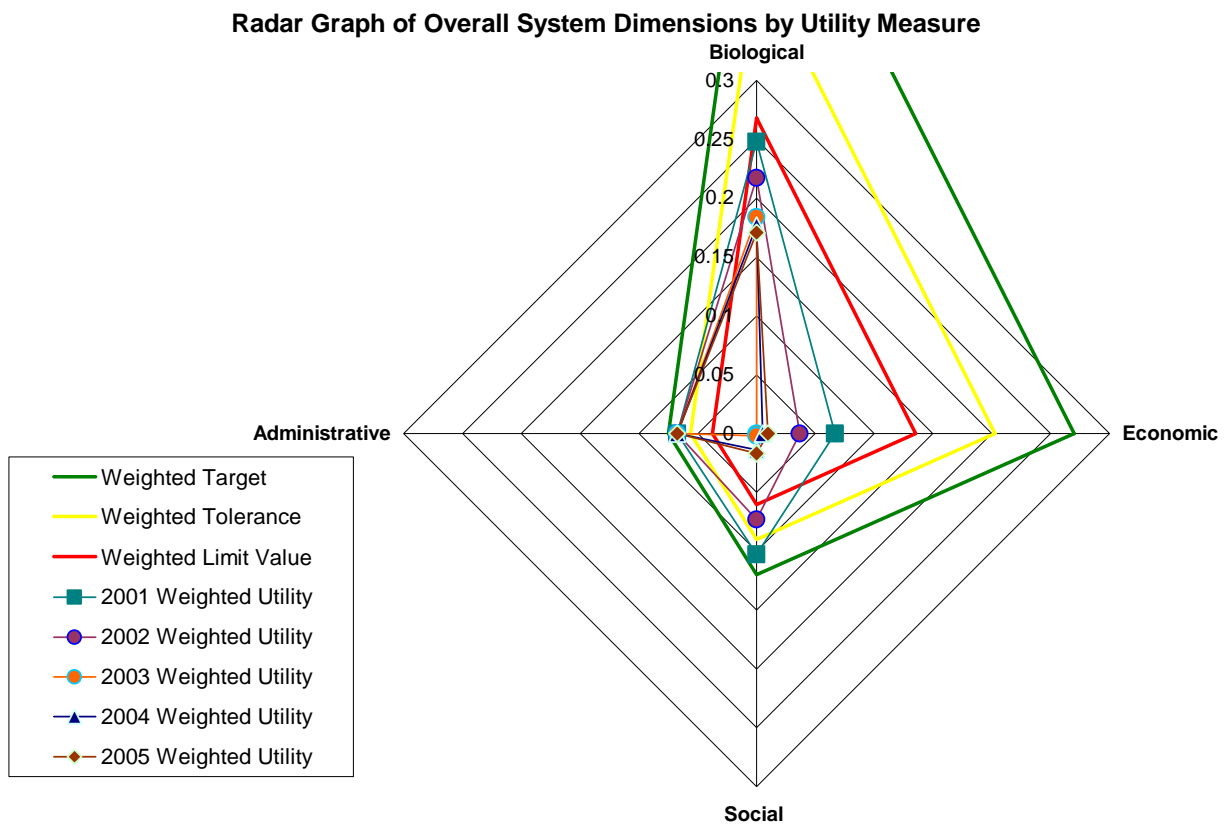


Figure 4 illustrates the overall results for the historical review across the biological, economic, social and administrative dimension of the fishery system. As for the previous figure, the overall weighted targets, tolerances, and limit values are polygons that reflect the weights of the dimensions (Figure 2) with the biological dimension denoting the most important axis of the system. As for the case of the annual biological indicators, the overall annual utility values demonstrate the deterioration of the main axes (biological, economic, and social) in successive years in correspondence with the stock decline, and the reduction in catch and landed value.

Figure 4



It is concluded that the multicriteria utility model of the recent historical review are consistent with the overall status of the 4TVn fishery system.

(2) 2007 Alternative Policy Review. The radar graph of Figure 5 and Table 6 present the overall utility measures attributed to each of the three alternatives for 2007, namely, the Status Quo, Moratorium, and Increased Catch scenarios as defined in Table 5 above.

Figure 5 compares the three policy scenarios on the radar graph for the biological, economic, social, and administrative dimensions of the fishery system. The results of Figure 5 and Table 6 show the non-dominated results of the policies. On the one hand, the Moratorium scenario dominates the biological dimension, and the Increased Catch scenario dominates both the economic and the social dimensions across the three alternative policies. The overall total utility results (Table 6) rank the Increased Catch scenario (0.309) ahead of the Status Quo scenario (0.280) with the Moratorium last (0.276).

These results are arguably not different enough to distinguish one policy scenario from the other. Moreover, as a decision support device, the multicriteria utility application should not be judged to be categorical. Rather, the method is a good indicator to decision makers about the dimension gaps that policy makers need to address in order to rationalize their ultimate policy selections and operationalize any given policy.

Figure 5

**Radar Graph of 2007 Scenarios
System Dimensions by Utility Measure**

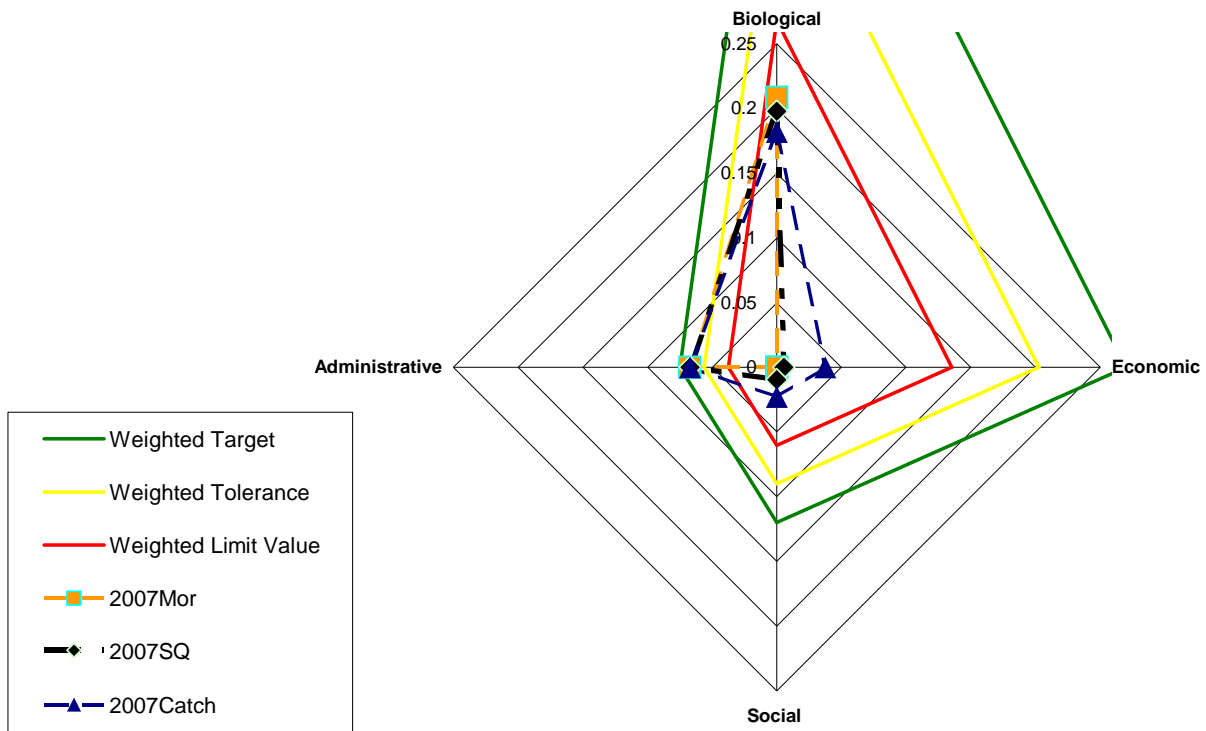


Table 6. Weighted Multicriteria Rankings for 2007 Policy Alternatives

		Fishery System Dimensions				Overall Weighted Values
		1 Biological	2 Economic	3 Social	4 Administrative	
Green	Weighted Target	0.535	0.27	0.12	0.075	1
Yellow	Tolerance	0.401	0.203	0.090	0.056	
Red	Limit Value	0.268	0.135	0.060	0.038	
Scenario	Weighted Utility					
2007SQ	Weighted Utility	0.198	0.005	0.010	0.067	0.280
2007Mor	Weighted Utility	0.208	0.000	0.000	0.067	0.276
2007Cath	Weighted Utility	0.182	0.038	0.023	0.067	0.309

5. Conclusions

The paper presents a model for the complete multicriteria evaluation of a fishery system. The requirement for such an evaluation is motivated by the *Federal Regulatory Policy*. The COSEWIC approach to species at risk evaluation is recognized as an internationally-based resource analysis. However, as such, it develops an evaluation only along a single dimension of the fishery system that, in itself, would not meet the legal requirements of the *Federal Regulatory Policy*.

The proposed integrated framework for the multicriteria evaluation of the fishery system provides both the means for logical decision support as well as a direct means of overall policy accountability and performance measurement as required under the *Federal Regulatory Policy*. In order to support the integrated approach, appropriate means for collection and analysis of data across fishery dimensions (“stovepipes”) must be implemented. This requires a line of support from clients, local offices, regions, and the centre. It also requires the involvement of all fishery participants. In turn, the use of multicriteria measures engages all participants in the overall governance process. This realization empowers participants in the fishery system and will lead ultimately to mechanisms for effective shared management of Canada’s fishery resources.

Acknowledgements

The authors acknowledge the support of the School of Management of the University of Ottawa in developing this research. They also acknowledge the financial support of the Canadian Fisheries, Oceans, and Aquaculture (C-FOAM, www.C-FOAM.management.uottawa.ca) Research Cluster and the NSERC Discovery Grant No.0122822 to D. Lane. The authors are happy to provide copies of the 4TVn integrated Excel spreadsheet model to interested parties. Please send all requests via email to the authors.

5. REFERENCES

- Benidickson, J., Chalifour, N., Prevost, Y., Chandler, J., Dabrowski, A., Findley, C.S., Deziel, A., Kilmurray, H.M. and Lane, D. 2005. Practicing precautions and adaptive management: Legal, Institutional and procedural dimensions of scientific uncertainty. Report to SSHRC & Law Commission of Canada, Institute of Environment, University of Ottawa, Canada. 85 pp.
- Canada. 2007. Costs and Earnings Survey: Atlantic Region Report 2004. Department of Fisheries and Oceans. Policy Sector. DFO/2006-1143. Ottawa. 30p+appendices.
- Canada. 2006a. Commercial Quota Reports 1990-2006. Department of Fisheries and Oceans. http://www.dfo-mpo.gc.ca/communic/statistics/commercial/quota_reports/index_e.htm
- Canada. 2006b. *Fisheries Act of Canada*. (R.S., 1985, c. F-14) <http://laws.justice.gc.ca/en/F-14/text.html>.
- Canada. 2005a. Strategic Vision: Long-term Recovery and Sustainability of the Southern Gulf of St. Lawrence 4TVn Cod Stock. Department of Fisheries and Oceans, Gulf Region. 36p. http://www.dfo-mpo.gc.ca/cod-morue/Strategie-gulf_e.htm
- Canada. 2005b. Report on the Marine Fish Workshop and Recommendations for COSEWIC. Unpublished manuscript. Halifax, Nova Scotia, 2-4 March 2005. 23p.
- Canada. 2004. A Policy framework for the management of fisheries on Canada's Atlantic coast. Fisheries and Oceans, Canada. DFO 2004-64, 41p.
- Canada. 2003b. 2003-04 Estimates. A Report on Plans and Priorities. Fisheries and Oceans Canada.
- Canada. 1999. Government of Canada Regulatory Policy. Privy Council Office, Government of Canada. November 1999.
- Charles, A.T. 2001. *Sustainable Fishery Systems*. Blackwell Aquaculture, Fisheries, and Fish Biology Series. Blackwell Press. 394p.
- Chouinard, G.A., L. Currie, Poirier G.A., Hurlbut T., Daigle D., and Savoie L. 2006. Assessment of the southern Gulf of St. Lawrence cod stock. Canadian Science Advisory Secretariat Research Document 2006/006. 93p.
- Chouinard, G.A., Currie L., Poirier G.A., Swain D., Benoît H., Hurlbut T., Daigle D. and Savoie L. 2005. Assessment of the southern Gulf of St. Lawrence cod stock. Canadian Science Advisory Secretariat Research Document 2005/007. 98p.
- Chouinard, G.A., Swain D., Currie L., Poirier G.A., Rondeau, A., Benoit, H., Hurlbut, T. and Daigle, D. 2003. Assessment of the southern Gulf of St. Lawrence cod stock. Canadian Science Advisory Secretariat Research Document 2003/015. 118p.

- Chouinard, G.A., Swain D., Currie L., Poirier G.A., Rondeau, A., Benoit, H., and Hurlbut, T. and Daigle, D. 2002. Assessment of the southern Gulf of St. Lawrence cod stock. Canadian Science Advisory Secretariat Research Document 2002/015. 118p.
- Chouinard, G.A., Swain D., Currie L., Poirier G.A., Rondeau, A., Benoit, H., and Hurlbut, T. 2001. Assessment of the southern Gulf of St. Lawrence cod stock. Canadian Science Advisory Secretariat Research Document 2001/020.
- Chouinard, G.A., Swain D., Currie L., Poirier G.A., Rondeau, A., Benoit, H., and Hurlbut, T. 2000. Assessment of the southern Gulf of St. Lawrence cod stock. Canadian Science Advisory Secretariat Research Document 2000/020.
- COSEWIC 2003. COSEWIC assessment and update status report on the Atlantic cod *Gadus morhua* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xi + 76p.
- Drucker, P.F. 1954. *The Practice of Management*. Harper & Row: New York.
- Evans, J. and Olson, D. 2002. *Introduction to Simulation and Risk Analysis*. Prentice-Hall. 392p.
- Expert Choice. 2005. *Expert Choice 2000*. <http://www.expertchoice.com/software/>.
- ICES 2006. Report of the Study Group on Fisheries Management Strategies. ICES/CM 2006/ACFM:19.
- ICES 2005. Report of the Advisory Committee on Fisheries Management, Advisory Committee on Ecosystems, and Advisory Committee on the Marine Environment. ICES Advice 2005, Volume 1, 140p.
- ICES. 1999. Report of the Comprehensive Fishery Evaluation working Group Key Largo, Florida, 1999. International Council for the Exploration of the Sea. 155p.
- IUCN. 2005. Guidelines for using the IUCN RedList Categories and Criteria.). IUCN Species Survival Commission. IUCN Gland, Switzerland and Cambridge, UK. 52p.
- IUCN 2001. IUCN Red List Categories and Criteria: Version 3.1. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK. ii + 30p.
- Lane, D.E. 2007 PLANNING IN FISHERIES RELATED SYSTEMS: Multicriteria models for decision support. In Bjorndal, T. (ed.) Handbook on Operations Research in Natural Resources. International Series in Operations Research and Management Science. Springer. 237-272.
- Lane, D.E. and Stephenson, R.L. 1998. "Toward a framework for risk analysis in fisheries decision making". *ICES Journal of Marine Science*. 55(1), 1-13.
- Lane, D.E. and Stephenson, R.L. 1996. "SATURN: A Framework for Integrated Analysis in Fisheries Management". Special Issue of *INFOR*. 34(3), 156-180.

- OECD. 1997. Evaluation of the Potential Gains and Costs of the Transition to Responsible Fisheries: Model for Analysis. OECD Fisheries Committee Report. September. AGR/FI(97)10. 34p.+appendices.
- OECD. 2000. Transition to Responsible Fisheries: Economic and Policy Implications. OECD Committee for Fisheries. September. 272p.
- Saaty, T.L. 1980. *The Analytic Hierarchy Process*. McGraw-Hill, New York.
- Smedbol, R.K., Shelton, P.A., Swain, D.P., Frechet, A. and Chouinard, G.A. 2002. Review of the population structure, distribution and abundance of cod (*Gadus morhua*) in Atlantic Canada in a species-at-risk context. Canadian Science Advisory Secretariat Research Document 2002/082. 134p.
- Wooster, W.S. (ed.) 1988. *Fishery Science and Management: Objectives and Limitations*. Lecture Notes on Coastal and Estuarine Studies. Vol 28. Springer-Verlag, New York.
- Xue, Lingyun, Lane, D.E. 2006. Evaluation of Strategic Policies for Fisheries Systems. Proceedings of the 4th World Fisheries Congress, Vancouver, May 3-5, 2004. To appear.
- Zhao, Y., Lane, D.E., Michalowski, W., Stephenson, R.L., Page, F. 2006. Integrated Systems Analysis for Coastal Aquaculture. Proceedings of the 4th World Fisheries Congress, Vancouver, B.C., June. 25p. To appear.