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Conflict resolution in fisheries management using decision rules: an example using a mixed-stock Atlantic Canadian herring fishery

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The process of developing and implementing decision rules resolved a mixed-stock herring fishery crisis in Cape Breton, Nova Scotia, Canada. The fishery occurs in an area which receives a large migrating stock on a set of smaller local stocks. A purse seine fleet follows the migrating stock into the area as part of their autumn and winter fishery. Little is known about the smaller local stocks which are harvested as by-catch in the seiner fishery and in directed inshore fisheries by local boats. A situation of constantly shifting regulations during the 1996 fishing season led to a series of incidents that included a wharf occupation and prevention of seiner offloading. As a result of these conflicts it was decided to develop decision rules that would allow the fishery to continue in a safe manner and would clearly identify the information and analyses needed to change the rules.

The decision rules were developed by using computer simulations to estimate exploitation rate scenarios on each stock component. These simulations determined the following general guidelines for the decision rules. First, if fishing occurs where mixing of schools from stocks is random and proportional to their abundance, then average exploitation rates will be equal among stocks but exploitation rates will be more variable on the smaller stock(s). Second, if fishing occurs where small stocks are concentrated, then exploitation rates will be higher on the small stocks. A combination of data analysis and computer simulations was used to develop decision rules concerning catch allocations, when and where to start fishing, and size of fish to catch.

The decision rules were formulated in a series of workshops and stock assessment review meetings attended by industry, managers, and scientists. This process was successful because it broke down barriers among these groups and used quantitative general guidelines to develop the decision rules. The process is readily transferable to other fisheries and provides a means of avoiding or resolving fisheries management crises.

Key words: mixed-stock fishery, fisheries management, conflict resolution, herring, decision rules.

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Introduction

A key objective of many fishery managers is to limit exploitation rates below identified levels. However, maintaining exploitation rates below these levels in a mixed stock fishery, where fish originating from more than one location are harvested, is a difficult management problem. Ideally the abundance, origin and catch from each stock would be known. Determining exploitation rates would then be a simple matter of adding up the catches from each stock and dividing by the stock abundance. Managers could then alter the fishery to adjust exploitation where it was too high or, alternatively, could provide additional fishing opportunities in under-utilized areas. Often, however, this information is either incomplete or unknown.

Mixed stock fisheries, like unit stock fisheries, may attract different interest groups with competing

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objectives. The addition of competing interests increases the difficulty of managing these fisheries. Decisions based on limited information, whether precautionary or not, are likely to be attacked for being arbitrary and unfair and promote conflict among industry representatives, managers and scientists. Thus, there is a requirement for an objective and transparent decision making framework that is acceptable to all parties.

The need for a transparent and well-defined decision framework recently became apparent in an Atlantic Canadian herring fishery on the east coast of Cape Breton, Nova Scotia (NAFO Division 4Vn). A large stock from the southern Gulf of St Lawrence (NAFO Division 4T) migrates into this area for overwintering and a fleet of six purse seine vessels follows the stock as part of their autumn and winter fishery. The biological characteristics of this stock are well known (Claytor and LeBlanc, 1999). Several local stocks are also present in the area and are harvested as by-catch in the seiner fishery and by local inshore fisheries. The abundance and catch of these local stocks is unknown. As a result, this fishery contains two elements, competing interests and limited information, that lead to conflict and difficult management.

In 1996, a number of management measures were changed to allow the seiners more flexibility to catch 4T herring in 4Vn (Claytor, 1997). Opposition to these changes came from fishery unions representing local trapnetters and gillnetters. These groups argued that there was insufficient knowledge on the status of local stocks to justify these changes and that the changes were compromising conservation. The fishery stopped and re-started several times during the year because of concern over local fish in the catch, and at one point offloading by the seiners was prevented because of a wharf occupation. Each time the fishery re-started, additional restrictions were applied. Finally, poor weather and movement of herring out of the fishing area lead to a decision by the seiners to stop fishing before their 4Vn allocation was caught.

These constantly shifting regulations were not satisfactory for the herring industry. The seiners argued that their fishery, which had operated for many years with no ill effect, was suddenly being disrupted for political, and not scientific reasons. Local groups argued that there was insufficient knowledge to permit changes in the seiner fishery and that their local stocks were endangered by the seiner activity. As a result of these conflicts, it was decided to develop decision rules that would allow the fishery to continue in a safe manner and would clearly identify the information and analyses needed to change the rules. The effectiveness of management would be evaluated against the decision rule objectives in annual stock assessment review meetings attended by science, industry, and management representatives.

This paper provides an example of how analytical and computer modeling techniques can be used to produce simply stated decision rules for managing fisheries. A three-part framework that established decision rules in the 4Vn mixed stock herring fishery is developed. First, computer simulations determined the general guidelines that directed the development of the rules. These simulations determined the exploitation rates expected on each stock component and in particular identified situations that would lead to very high exploitation rates on the smaller and more vulnerable populations in the fishery. Second, a combination of available data and computer simulations were used to develop decision rules concerning catch allocations, when to start fishing, size of fish to catch and where to fish. Third, a process of reviewing and revising these rules by management, industry and science was implemented. The development of the decision rule framework focuses on a specific example and how it resolved conflicts in the overwintering herring fishery on the east coast of Cape Breton, Nova Scotia, Canada (NAFO Division 4Vn). However, the guidelines derived and the framework developed have general applications. First, they build on the requirements identified for including industry, managers, and scientists as part of the decision making process by Pearse and Walters (1992) and Lane and Stephenson (1998). Second, they provide a means of introducing decision rule algorithms, as suggested by Wilimovsky (1985) and de la Mare (1998), into fisheries management. Hopefully, they can be used to guide the development of decision rules for a variety of mixed stock and other fisheries.

A specific example: The 4T overwintering herring fishery in 4Vn

Biology of 4T Southern Gulf of St Lawrence herring

NAFO Division 4T encompasses the southern Gulf of St Lawrence (Fig. 1). Herring originating in this area consist of two seasonally defined spawning components. Spring spawning occurs primarily in May but extends into June at depths <10 m. Autumn spawning occurs from mid-August to mid-September at depths from 5 to 20 m. First spawning for both seasonal components occurs primarily at age 4 but 50% of age 3 herring sampled on 4T spawning grounds are in spawning condition. The largest spring-spawning populations are in the Northumberland Strait between New Brunswick and Prince Edward Island, followed by the Magdalen Islands. Relatively small spring-spawning populations occur in Chaleur Bay (New Brunswick-Québec), eastern Prince Edward Island, and Pictou, Nova Scotia (Fig. 1). The largest autumn-spawning population is in Chaleur Bay. Smaller autumn populations are found in the

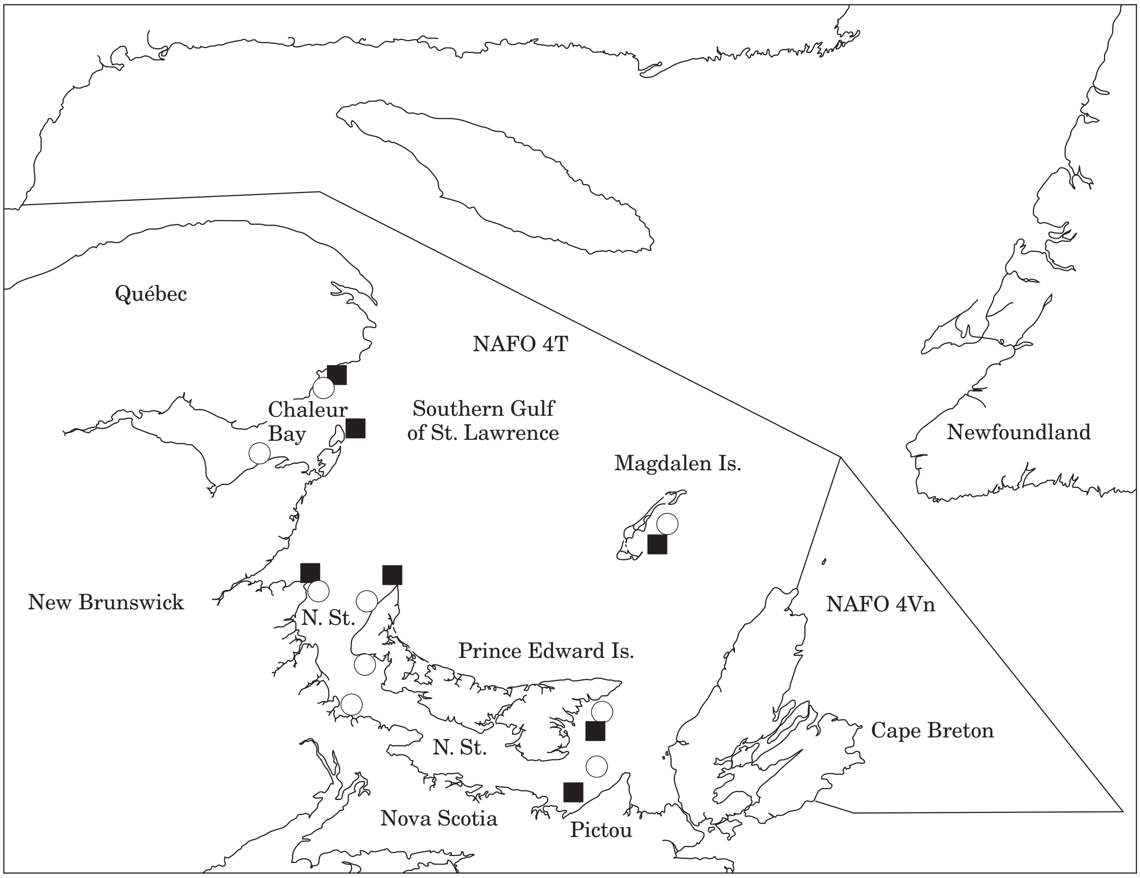

Figure 1. Location of spring and fall spawning populations for southern Gulf of St Lawrence (4T) herring. N. St, Northumberland Strait. Open circles are spring spawning locations, closed squares are fall spawning locations.

Northumberland Strait between New Brunswick and Prince Edward Island, eastern Prince Edward Island, Pictou, Nova Scotia, and the Magdalen Islands (Fig. 1) (Claytor *et al.*, 1998).

After spawning, herring form large schools on the north side of Prince Edward Island and in Chaleur Bay (Claytor *et al.*, 1998). They remain in these areas until mid-October when they begin to migrate to eastern Cape Breton (4Vn) where they overwinter (Fig. 1). Herring return to 4T from 4Vn in the spring as the ice begins to recede. Herring age 2 and less possess anti-freeze proteins (Chadwick *et al.*, 1990) and remain in the Gulf of St Lawrence for the winter or migrate later to 4Vn.

Southern Gulf of St Lawrence herring are harvested by an inshore fleet on spring and autumn spawning grounds for a food and bait market in the spring and a roe market in the autumn. The gillnet fleet is allocated 77% of the 4T herring quota. Purse seiners harvest pre or post-spawning aggregations in the spring and autumn for a food market. In late autumn and early winter purse seiners follow 4T herring into 4Vn where a fishery on the overwintering portion of the population occurs (Claytor *et al.*, 1998).

Stock mixtures expected in 4Vn

Fish stocks present in 4Vn at any one time include small stocks that spawn in the area and larger stocks that migrate from 4T, and to a lesser extent from 4WX. Herring from 4T predominate in the overwinter catch (Chadwick *et al.*, 1993); comments concerning large migratory stocks in 4Vn are restricted to this population. The principal locally spawning stocks are spring spawners in the Bras d'Or Lakes and herring that spawn in the autumn along the coast from Bird Islands to Glace Bay. In addition, very small and localized autumn spawning has been reported in the Neils Harbour area and the Bras d'Or lakes (Fig. 2). Local stocks spawning along the coast remain in 4Vn for overwintering. Spring spawners from the Bras d'Or Lakes also appear to overwinter in 4Vn, although small numbers of herring are harvested in the lake during the winter. The size of

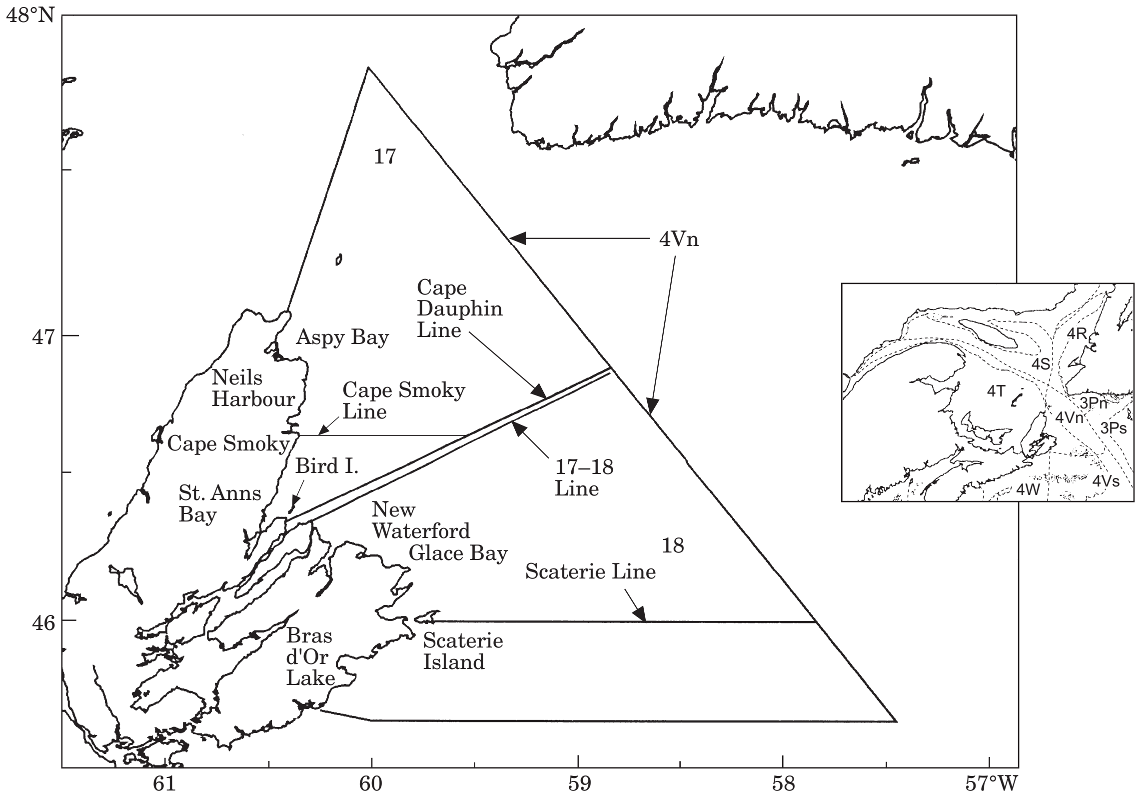

Figure 2. Map showing 4Vn with areas of migratory 4T and 4WX stocks in inset. The 17–18 line separates 4Vn into northern and southern sections for statistical reporting.

these local stocks is not precisely known but they are much smaller than the 4T stock. The presence of this diverse group of stocks made application of the decision rules important in achieving the objective of limiting exploitation rates within identified levels.

Herring originating in 4T overwinter in 4Vn starting in October. These herring may begin to arrive in small numbers in October and remain until returning to 4T in the spring when the ice begins to break up. As a result, herring found in 4Vn from May to October are most likely from local spawning populations, while herring found in 4Vn from October to April are mixtures of small local populations and herring from the larger neighbouring 4T stock. In addition, juvenile herring, age 2 or less, may remain in the southern Gulf of St Lawrence during the winter, or at least delay their migration to 4Vn later than adult herring because they possess anti-freeze proteins (Chadwick *et al.*, 1990). As a result, it is expected that juvenile herring found in 4Vn from May to January are most likely of local origin (Table 1).

Each of these herring stocks has a different migratory pattern into and within 4Vn. Thus, depending on where and when fisheries occur, one or several stocks may be expected to be vulnerable to exploitation. This by-catch is of particular concern if one of the stocks is very small or in a declining situation. This concern for a small and declining stock (Bras d'Or Lakes herring) and the unknown size and status of other local origin 4Vn stocks is a major management issue in the 4Vn herring fisheries.

Description of 4T overwintering herring fishery and local fisheries in 4Vn

Local Fisheries

Local herring fisheries in 4Vn are primarily for lobster bait and include trapnets and gillnetters along the coast and in the Bras d'Or Lakes during the spring, and a combination of trapnets, small seiners, and gillnets

Table 1. Presence of Local 4Vn herring, 4T migratory adults and juveniles in 4Vn at various times of the year.

Months	Local 4Vn	Stock 4T Adults	4T Juveniles
May–mid October	×		
mid October–December	×	×	
January–April	×	×	×

during the autumn in coastal areas. The local coastal spring gillnet bait fishery is coincident with the lobster fishery and takes place from mid-May to mid-July in depths of about 15 fathoms. The local lobster fishery has about 500 participants and use about 0.15 t of fish a day for bait. The lobster fishery lasts about 50 days. Thus, about 3500 t of fish, of which an unknown proportion are herring, are harvested each year in this fishery. The spring Bras d'Or Lakes fishery has about 30 participants with reported landings ranging from 100 t to 300 t in recent years. The Bras d'Or Lakes also support a small autumn fishery, and a small winter ice fishery for herring by the Eskasoni First Nation.

Overwintering fishery

In the late 1960s and early 1970s the 4Vn purse seine fishery consisted of domestic and foreign vessels. This fishery occurred primarily from November to December with some catches from January to April and reported total landings ranged from 2000 to 18 000 t (Table 2). Since 1983, the 4T overwintering fishery in 4Vn has consisted of six purse seine vessels (>20 m) from the southern Gulf of St Lawrence and it is these boats which are active in the fishery at the present time. During the 1980s, catches were concentrated in November and December. During the 1990s, the season started in the last week of October or on 1 November and catches have occurred entirely in November. The exception was 1996, when one night of fishing occurred on 3–4 December (Table 2).

This fishery harvests primarily 4T herring which enter the 4Vn area during the autumn and winter as part of their overwintering migration (Chadwick *et al.*, 1993). The 4T stock consists of about 55–75% autumn spawners and 25–45% spring spawners. Recent landings of autumn and spring spawners in 4T have been between 55 000 and 85 000 t, and the combined autumn and spring spawner biomass is about 500 000 t (Claytor *et al.*, 1998). Landings for both spawning groups in 4Vn combined from 1978 to 1997, ranged from 2600 t to 4700 t. From 1978 to 1986, autumn spawners ranged from 50% to 80% of the catch. In more recent years, from 1987 to 1997, a higher proportion, of the catch (80% to 96%) in 4Vn has been autumn spawners (Table 3).

Table 2. Reported landings (t) for combined foreign and domestic fleets by purse seine fishery in 4Vn from 1963 to 1997. Foreign fleets fished in 4Vn from 1965 to 1976.

Year	Nov–Dec	Jan–Apr	May–Oct	Total
1963	0	0	35	35
1964	0	0	5	5
1965	0	0	47	47
1966	0	0	49	49
1967	0	0	17	17
1968	11 567	1671	273	13 511
1969	8996	5109	443	14 548
1970	300	4782	16	5098
1971	8297	1897	17	10 211
1972	9914	4985	45	14 944
1973	14 107	1166	2955	18 228
1974	11 690	1080	30	12 800
1975	5447	0	216	5663
1976	10 164	0	266	10 430
1977	7070	3562	0	10 632
1978	2850	0	5	2855
1979	803	2220	3	3026
1980	3528	323	16	3867
1981	3433	0	0	3433
1982	3520	0	0	3520
1983	3807	174	0	3981
1984	3925	0	0	3925
1985	3470	0	0	3470
1986	4352	0	0	4352
1987	2373	0	0	2373
1988	3074	0	0	3074
1989	2117	0	0	2117
1990	4711	0	0	4711
1991	4789	0	0	4789
1992	4228	0	0	4228
1993	3947	0	8	3955
1994	3184	0	6	3190
1995	3988	0	0	3988
1996	4114	0	162	4276
1997	3605	0	0	3605

Background leading to need for Decision rules

In 1992, it was decided to include all herring caught in 4Vn by the Gulf seiners as part of the 4T stock assessment. Since 1995, the 4200 t allocation for the 4T overwintering fishery in 4Vn has come from the overall 4T autumn spawner catch allocation. This decision was based on analyses of historical tagging data, length-frequencies, and acoustic surveys which indicated that most of the herring caught in the 4Vn purse seine fishery were of 4T origin (Simon and Stobo, 1983; Chadwick *et al.*, 1993). Recent comparisons of age structures and mean weights between the 4T and 4Vn fisheries are consistent with this conclusion (Anon, 1998). This decision did not mean or imply that no local stocks or 4WX herring were caught in this fishery, only that the predominant part of the catch was from 4T and these fish should be accounted for in that stock assessment. Prior to 1992, catches in 4Vn were not included in either 4T or 4WX herring assessments.

Other regulations affected the overwintering fishery prior to the decision rules by restricting fishing locations of purse seine vessels. Fishing by the six southern Gulf seiners was restricted to areas north of the Cape Dauphin line in an attempt to concentrate their fishery on 4T overwintering herring and protect Bras d'Or lakes herring. Fishing by the approximately 40-boat purse seine fleet from 4WX was restricted to the area south of the Scaterie line to focus their fishery on overwintering

Table 3. Purse seine catches in 4Vn by spawning group since 1978 showing total allocated catch (TAC) and percentage of fall spawners in the catch.

Year	Autumn spawners	Spring spawners	Total	TAC	Percentage autumn spawners
1978	1833	808	2641	8000	69
1979	1418	1496	2913	3000	49
1980	2981	870	3852	4500	77
1981	2120	1162	3282	3000	65
1982	2150	1373	3523	3000	61
1983	2808	1167	3976	5000	71
1984	3000	1004	4005	3500	75
1985	2822	778	3600	3500	78
1986	3105	1214	4319	4200	72
1987	2093	279	2372	4200	88
1988	2438	138	2576	4200	95
1989	1959	159	2117	4200	93
1990	3942	721	4663	4200	85
1991	3871	921	4792	4200	81
1992	3955	292	4247	4200	93
1993	3722	219	3940	4200	94
1994	2968	276	3244	4200	91
1995	3990	153	4142	4200	96
1996	3543	734	4276	6423	83
1997	3462	143	3605	4200	96

4WX stocks and avoid local stocks. These restrictions eliminated fishing by purse seiners in the area between the Cape Dauphin and Scaterie lines (Fig. 2).

The issues that provoked the development of the decision rules began in 1996. In that year the allocated catch in 4Vn was increased from 4200 t to 6423 t and the fishery was scheduled to begin on October 15 (Claytor, 1997). Opposition to these changes came from fishery unions representing local trapnetters and gillnetters. These groups argued that there was insufficient knowledge on the status of local stocks to justify such a change and that the purse seine activity was compromising conservation because the potential for overharvesting local stocks was too high. Two meetings were held prior to the beginning of the fishery and it was decided to start the fishery on 18 October 1996 with a test fishery. The test fishery indicated that fish were of the appropriate size and were not in spawning condition and the purse seine fishery opened under the management plan conditions on 31 October 1996. The fishery stopped and re-started several times during the year because of concern over the percentage of local fish in the catch and at one point offloading by the seiners was prevented because of a wharf occupation. On 3–4 December, 32% of the catch was spring spawners in a location near the Bras d'Or Lakes. The percentage of spring spawners in the catch in this area is usually 10–25%. Because of concern for the Bras d'Or Lakes herring stock (Claytor, 1997), fishing was restricted to north of Cape Smoky (Fig. 2). There was no additional fishing by the seiners after this date and the season was effectively closed. In 1997, fishing was restricted to north of Cape Smoky, for the entire season but seiners were allowed for the first time to fish in 4T and 4Vn under the same license.

General guidelines

The distribution and degree of mixing among the stocks in the fishery area was critical in determining the exploitation rate that was expected on each stock component. Two dichotomous computer simulation experiments demonstrated the importance of the mixing pattern and were used to derive the general guidelines that directed the development of the decision rules. In the first simulation, fishing occurs where the stocks are randomly mixed in proportion to their relative abundance. In the second, the stocks are not randomly mixed throughout the fishing area and fishing occurs where the small stock is concentrated.

Previous work on mixed stock or species fisheries has concentrated on determining equilibrium fishery yields, exploitation rates, or effort allocation among fisheries for assemblages of stocks or species which are exploited by one fishery, or when several fisheries exploit the same species concurrently or sequentially (Hilborn, 1976; Murawski, 1984; Murawski and Finn, 1986). Lloyd (1996a,b) examined how changes in the percentage that a stock contributes to total fishery landings affects the exploitation rate expected for that stock in constant harvest and fixed escapement managed fisheries. Determining the general guidelines for this fishery adds to previous work by: (i) examining the exploitation rate expected when the stock proportions where fishing occurs, differs from the relative abundance of the stocks; (ii) by introducing a random effect on the probability of capture; and (iii) by examining a fishery in which the target exploitation rates had already been determined for each stock and where the area of the mixed stock fishery may be only one of several places where these stocks are harvested. Thus, the emphasis was on determining how the stock mixing pattern would influence the probability of maintaining exploitation rates within identified limits.

General guidelines simulation: method

For both simulation experiments the allocated catch was based on 4% of the biomass of the larger stock and the simulated purse seine fishery proceeded until this allocation level was reached. This percentage was similar to the exploitation rates of the 4T stock in the 4Vn fishery since 1979, and was consistent with the 4T exploitation rate in the 4Vn fishery being much lower than the overall target fishing mortality of 20% to 25% for 4T autumn spawners. Catches in each purse seine set were 40 t (equal to the average purse seine set in the example fishery). Fish populations in the simulation consisted of representations of a large migratory and a small locally spawning stock. School sizes for the large migratory and small local stocks were 40 t, so that each set caught a complete school of local or migratory fish. Fixing the school sizes at 40 t and the catches for each set at 40 t made the distribution of exploitation rates more discontinuous than they would have been if smaller school sizes relative to set sizes were simulated, but it does not affect the general conclusions concerning relative averages or variability. A random number between 0 and 1 determined the origin of the catch. If this number was less than the probability that the school was a local one, then the school in the set was identified as originating from the local stock, otherwise it was from the migratory stock. Each simulation sequence consisted of a set of purse seine catches until the allocated catch was caught or exceeded. Each experiment consisted of 10 000 sequences.

For the proportionately randomly mixed experiment, the ratio of the large migratory to small local stock varied from 1:1, 2:1, 4:1, 8:1, and 16:1. In these experiments the allocated catch was set at 5% of the large stock. If the small stock was 1000 t and the ratio was 1:1, then the large stock would be 1000 t and the allocated catch would be 50 t. The fishery would proceed to 80 t, however, because the size of the schools and the catch in each set was 40 t. In each case, schools associated with each stock were randomly mixed in proportion to their relative abundance and as described above, the exploitation rate for the small and large stocks should be equal. These experiments simulated the effect that would occur as increasing proportions of the large stock migrated from its home area to the local stock area.

In the second experiment, the ratio of the large:small stock used to set the allocated catch was fixed at 16:1, but the ratio of the large:small stock where fishing occurred varied from 1:1, 2:1, 4:1, 8:1, and 16:1. In this experiment, the allocated catch was based on the overall abundance of the large stock. For example, if the small stock was 1000 t, then the large stock would be 16 000 t and the allocated catch would be 800 t. If fishing occurred where the ratio was 1:1, the 800 t allocated catch would come from an area where the total abundance of the large and small stocks was 2000 t. In this situation, the exploitation rate expected on the small stock would be much higher than it would in the proportionately mixed experiment where the ratio of the stocks was 1:1. These conditions would occur if the small stock concentrates in a particular part of the fishing area for feeding, spawning, migrating, or some other purpose and a small part of the larger migratory stock breaks off from its main group and moves to this area.

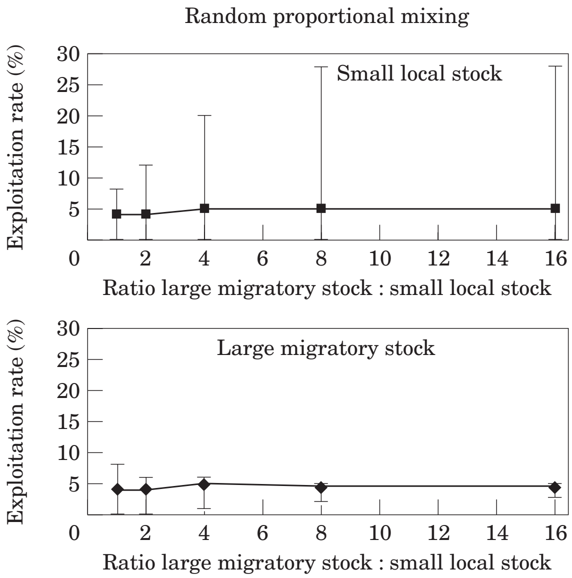

Figure 3. Average exploitation rate (horizontal line) and range around exploitation rate (vertical lines) when fishing occurs where stocks are mixed at random in proportion to their abundance. The ratio of the large migratory stock:small local stock varies from 1:1 to 16:1.

General guidelines simulation: results

The results of the first experiment, when fishing occurred where the stocks were randomly mixed in proportion to their abundance, indicated that the average exploitation rate on both stocks varied from 2% to 4% but variation in exploitation rates on the smaller local stock was greater than for the larger stock. For example, exploitation rates on the small stock ranged from 0% to 16%, but for the large stock they ranged from 0% to 4%, depending on the ratio (Fig. 3). In addition, the variability in exploitation rates on the small stock increases as the ratio of the large:small stock increases (Fig. 3). Most exploitation rates for the local stock were less than the average, indicating that in most cases exploitation rates on small stocks will not exceed the expected value (Fig. 4). Occasionally, however, because of their greater sensitivity to random effects than larger stocks, high exploitation rates will occur (Fig. 4).

The results of the second experiment, when fishing occurs in an area where the effect is to make the small stock more concentrated with respect to the allocated catch than if the two stocks are randomly mixed in proportion to their abundance, indicated that exploitation rates on the small stock are much higher than the expected 2% to 4%. For example, when the true ratio between the stocks is 16:1 but fishing occurs where the ratio is 1:1, the average exploitation rate on the small stock would be about 40%, or eight times higher than expected (Fig. 5). In addition, 95% of the time the

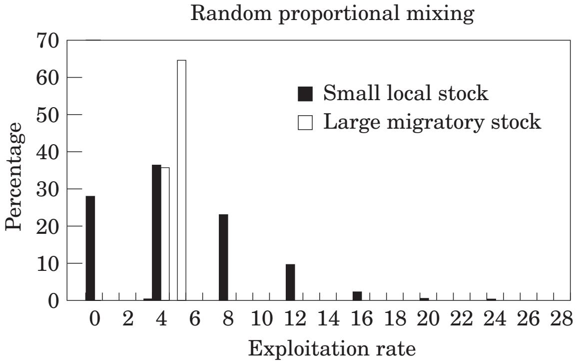

Figure 4. Example of distribution of local and migrating stocks when fishing occurs where stocks are mixed at random in proportion to their abundance. Ratio of large migrating stock:small local stock is 16:1.

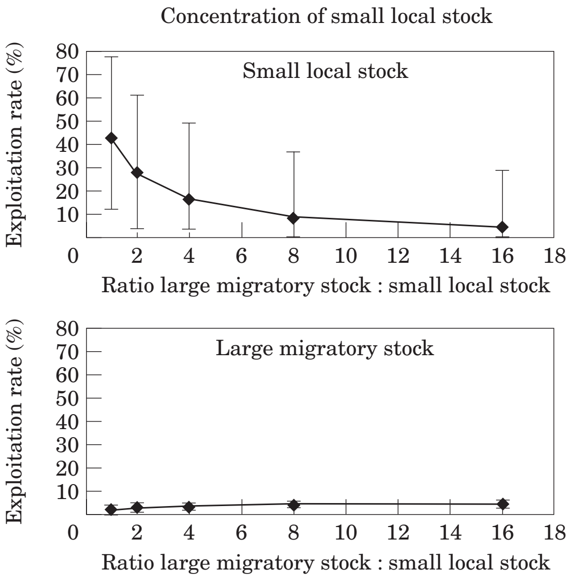

Figure 5. Average exploitation rate (horizontal line) and range around exploitation rate (vertical lines) when fishing occurs where small local stocks are concentrated. The ratio of large migratory stocks:small local stocks is fixed at 16:1 in the management area but varies from 1:1 to 16:1 where fishing occurs.

exploitation rates on the small stock would be above 20% (Fig. 6), which is the level identified as the conservation target for many Atlantic Canadian herring stocks for all fisheries combined (Anon., 1997). The exploitation rate on the large stock, however, was <4%, because of the higher exploitation rate on the small stock (Fig. 6). This result illustrates why mixed stock fisheries are so difficult to manage. The overall exploitation rate may be as expected and within identified limits but one of the stocks may be unknowingly over-exploited.

General guidelines simulation: interpretation

These results produced the following general guidelines. First, if fishing occurs where mixing of schools from stocks is random and proportional to their abundance, then exploitation rates will on average be equal among all stocks, regardless of the number of stocks, but exploitation rates will be more variable on the smaller stock(s). Second, if fishing occurs where small stocks are concentrated, exploitation rates much higher than expected will occur on the small stocks.

Thus, formulating and evaluating decision rules requires understanding the relative sizes of the contributing stocks, the areas where small stocks are concentrated, and differences in biological characteristics so that stock mixtures can be evaluated.

Decision rules

The general guidelines defined above, computer simulations, and data from the fisheries were used to formulate decision rules which controlled: how many fish to catch, the size of fish to catch, when to start fishing and where to fish.

Decision Rule 1: how many fish to catch

Decision rule 1 was formulated in 1997 and relied on a comparison of reported catch levels in the purse seine fishery and the age data of the local stock near where the fishery occurred (Neils Harbour). There was a high proportion of age 11+ year old herring, of unknown stock origin, in northern local coastal autumn fisheries (Neils Harbour) (Fig. 2). Local fisheries have operated in this area since at least 1983 and the continued presence of these local fisheries, suggested that purse seine fishing levels, since 1983, have not been detrimental to local spawning components. While, this was recognized as a weak biological rationale for advice, it was stated that until additional information became available on the 4Vn spawning components, it would form the current advice for catch allocations. On this basis it was concluded that the overwintering catch should not exceed recent average landings.

Decision Rule 1 simulation: methods

Additional information was not available in the next year, 1998, to assess directly fishing mortalities on the Neils Harbour local stock. The general guidelines cited above, however, were used to estimate the effect that various harvest levels in the overwintering fishery may have on these stocks. This analysis used the simulation approach which established the general guidelines but modelled a more detailed and realistic representation

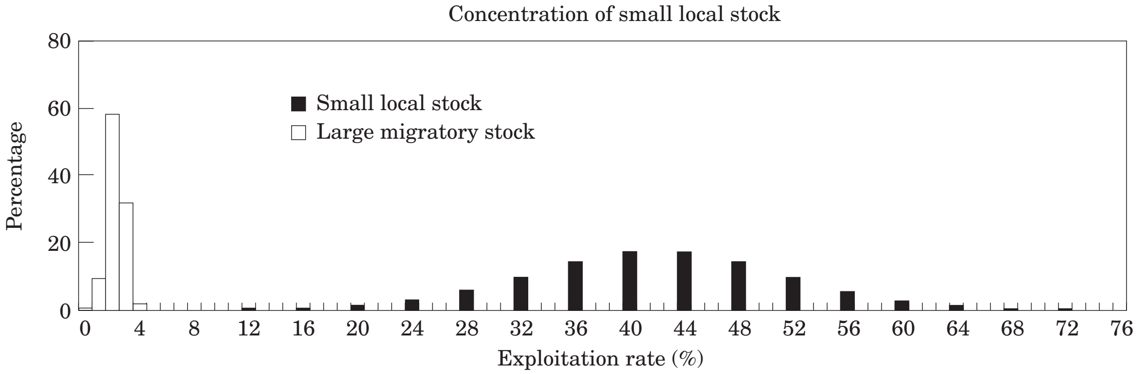

Figure 6. Example of distribution of exploitation rates on small local and large migrating stocks when fishing occurs where ratio of large migratory stock:small local stock is 1:1, but ratio in all areas inlcuding those not fished is 16:1. That is, fishing occurs where local stocks are concentrated.

of the fishery to determine the relative changes in exploitation rate that would result from varying catch levels, migratory situations, and local stock abundance. As before, school sizes and catches were 40 t. The varying levels of the 4T stock that had migrated to 4Vn for the fishery were 20 000 t, 40 000 t, and 120 000 t. Estimates of 4T autumn spawner stock size have ranged from 240 000 t to 350 000 t since 1990 (Claytor *et al.*, 1998). The varying abundance levels of local stocks were 2500 t, 5000 t, 10 000 t, and 20 000 t. These levels represented situations when varying proportions of the 4T stock would have migrated to 4Vn. For example, if 20 000 t of the 4T stock had migrated to 4Vn, that would represent 5% to 8% of the 4T stock, or at 120 000 t, it would represent 33% to 50% of the 4T stock. The schools of 4T and local spawning stocks were assumed to be randomly mixed in the area where the fishery occurred. The catch varied from 3700 t, 4200 t, 4800 t, and 8400 t and did not depend on the size of the 4T stock. The 8400 t level was chosen so that an extreme situation could be examined but each of these levels corresponded to those suggested by industry and management representatives at various times during the development of the decision rules. The simulations proceeded as described above for those used to develop the general guidelines.

Decision Rule 1 simulation: results

Simulation results indicate that when a small proportion of the 4T stock migrates to 4Vn, exploitation rates on the small local stocks range from 10% and 30%. These rates reflect only the overwintering fishery and are additional to exploitation rates from other fisheries (Fig. 7). The simulations described above to investigate the effects of catch levels, stock abundance, and stock mixing are similar to the second experiment used to develop the general guidelines. In both cases, fishing occurs where local or small stocks are concentrated but the allocated catch is based on the overall abundance of the large or migrating stock. The presentation of the results differs because the exploitation rates reported for the large stock in the decision rule simulations are based on the number of fish from the large stock in the fishing area (Figs 7, 8), rather than total abundance of the large stock including those outside the fishing area as in the general guidelines experiment (Fig. 5). This difference has the effect of making the expected exploitation rates equal for each stock and puts the emphasis on comparing the range of exploitation rates expected on the smaller local stock compared to the larger migrating stock. If the reporting of the large stock exploitation rate was based on the total stock size of 240 000 t to 350 000 t, then the exploitation rates on the large stock would have been much smaller and the results would be similar to those in Fig. 5, which show higher exploitation rates and variation on the small compared to the large stock. These presentation differences do not affect any conclusions concerning the general guidelines or the decision rules.

The worst situation developed when the local stock size was smallest (Fig. 7). This result led to investigating the consequences of differing levels of catch assuming the local stock size was 2500 t. A low (20 000 t) and high level (120 000 t) of 4T migration were tested. These results indicated that local stock exploitation rates will exhibit greater variation at low 4T migration levels. At the higher 4T migration (120 000 t), there was little relative difference among the 3700 t to 4800 t catches. Exploitation rates resulting from the 8400 t catch, as expected, were about twice the lower rates (Fig. 8).

The risk of exceeding target fishing levels increases when fishing occurs before the large 4T stock migration is well underway, for example, when 20 000 t of the large

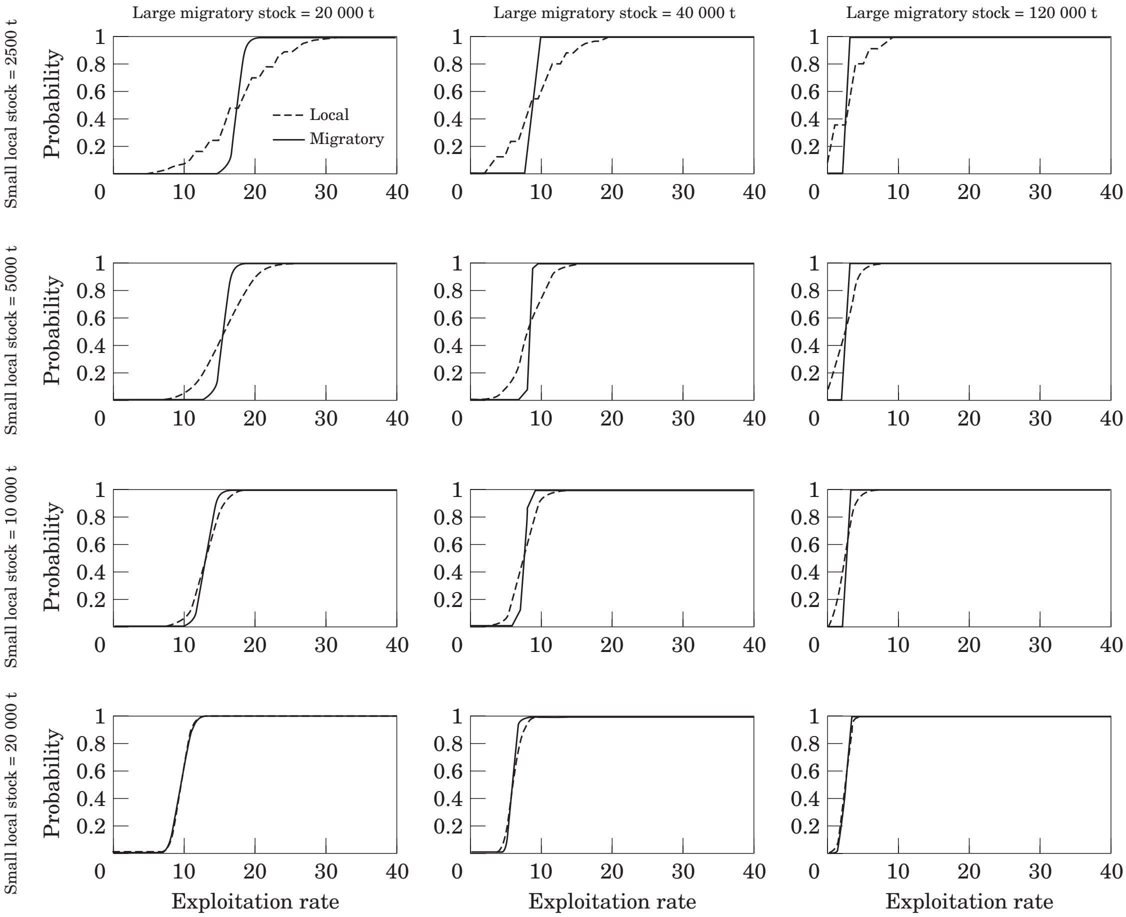

Figure 7. Cumulative probability distributions of exploitation rates simulated by keeping the TAC constant at 4200 t and varying the size of local stocks from 2500 t to 20 000 t and migrating stocks from 20 000 t to 120 000 t. The total allocated catch is 4200 t in all cases. The broken line represents the small local stock and the solid line represents large migratory stock in each panel.

stock have migrated to the fishing area (Fig. 8). When, however, a greater proportion of the large stock, 120 000 t, has migrated to the fishing area, expected exploitation rates on local stocks would be below target fishing levels. In addition, there would be little difference among exploitation rates with catches of 3700 t to 4800 t (Fig. 8). These results were consistent with the continued application of Decision Rule 1 which stated "overwinter catch not to exceed recent averages" and emphasized the importance of determining a starting date that ensured that the 4T migration would consistently represent a high proportion of the stock.

Decision Rule 2: when to start

The general guidelines and the simulation analysis to determine how many fish to catch indicate that the starting date should reflect a time when the migration of the 4T stock has proceeded to the extent that the risk of over-exploitation on smaller stocks is minimized. Results of acoustic and bottom trawl surveys indicated that, since 1984, the migration is well established by 1 November (Table 4, Fig. 9). Major biomass concentrations in 4Vn during October and November were in Aspy Bay and St Ann's Bank. Concentrations in the north were always greatest after 1 November, indicating that the 4T migration has been consistently advanced after 1 November (Fig. 9). In some years, the migration appeared to make an appreciable start by mid-October but in other years this was not the case. Abundance of the 4T stock was at its peak in 1991 and 1992 yet the abundance of herring in 4Vn by mid-October was considerably different (Table 4, Fig. 9). These results indicated that 1 November is an appropriate starting date.

Decision Rule 3: size of fish in catch

In 4Vn, a higher percentage of the immature herring is likely to be of local origin than adults. The reason for

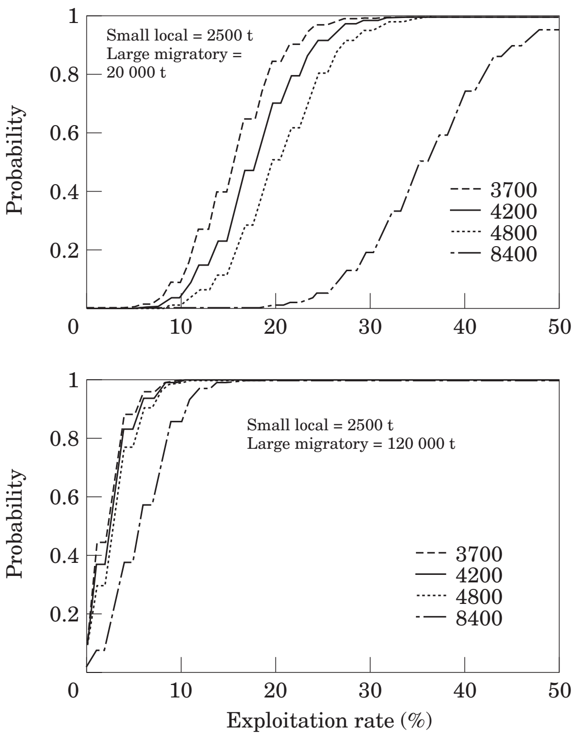

Figure 8. Cumulative probability distributions for exploitation rates simulated if local stocks are kept constant at 2500 t and migrating stock is 20 000 t or 120 000 t and the allocated catch varies between 3700 t to 8400 t.

Table 4. Biomass estimates (t) from bottom trawl and acoustic surveys for years when two or more of these surveys completed, 1984–1997. There were no acoustic surveys in 4Vn in 1989 and 1994, 1997 July bottom trawl survey results were not available (n/a) when Decision Rules were formulated, and the September bottom trawl survey in 4Vn only occurred in 1994 and 1995.

	Bottom trawl Biomass (t)		Acoustic Biomass (t)	
Year	July	Sep	Sep–Nov	Dates
1984	1940		75 724	17–26 Nov
1985	0		106 865	23–26 Nov
1986	230		127 708	1–12 Dec
1987	39 345		443 058	17–24 Nov
1988	81		172 886	21–22 Nov
1989	0			No survey
1990	9		135 249	4–8 Nov
1991	4997		4418	21–23 Oct
1992	0		44 845	14–22 Oct
1993	417		12 512	15–20 Oct
1994	8788	8773		No survey
1995	1773	5201	7295	24–26 Sep
1996	0		21 804	14–16 Oct
1997	n/a		17 463	9–11 Oct

this difference is that 4T immature herring are known to overwinter in 4T, or at least migrate to 4Vn later than 4T adult herring. This differing migration pattern results from anti-freeze proteins in juvenile 4T herring that allow them to live under the ice in the Gulf of St Lawrence during the winter (Chadwick *et al.*, 1990). Thus, a size limit is an additional criterion that can be used to reduce exploitation of local herring.

The size restriction in effect for 1996 was that no more than 10% of the catch by number could be below 24.5 cm fork length. This size restriction is the same as in 4T. This restriction was a change from previous years in 4Vn when the 10% limit was based on 26.5 cm fork length. The 24.5 cm restriction, written into regulations as fork length, converts to about 27 to 27.5 cm total length (Claytor, 1997).

Landings of immature herring in 1996 were 285 tonnes, about 7% of the total catch by biomass and 10% by number. This level was above the average from 1992 to 1995. The maximum size for immature herring in the 1996 catch was 28.5 cm total length but most (70%) were below 27.0 cm total length. Of the herring below 28.5 cm total length, 20% were immature (Fig. 10). The 1996 size limit was effective in keeping the landings of immature herring to $\leq 10\%$ and within the $F_{0.1}$ level indicated by the assessment of the 4T herring stock (Table 5). Even though immature herring caught in 4Vn are likely to be of local origin, maintaining combined catches of juveniles in 4T and 4Vn within the identified $F_{0.1}$ fishing level for 4T alone is consistent with the objective of protecting juvenile herring. A re-evaluation of this size limit in 1997 compared age structures, trends in mean weight, and percentage of fish at 0.5 cm length intervals between the 4T and 4Vn fisheries. The results of these comparisons were consistent with management objectives of protecting local immature fish and did not indicate that the size regulation needed to be changed (Anon., 1998).

Decision Rule 4: where to fish

Fishery location and size of aggregations are two ways in which fishing area can affect the stock composition of the catch. The general guidelines indicate that exploitation rates on small stocks are best minimized by fishing in areas where the large stock predominates and the mixing of stocks is random and in proportion to their relative abundance. It is, however, especially important to avoid areas where the small stock is concentrated.

Purse seiner fishing activity in 4Vn concentrated primarily in the northern portion of the fishing area from 1991 to 1995. During this time, over 90% of the catch comprised autumn spawners. In 1996, a similar percentage of autumn spawners was caught in Aspy Bay to the end of November. When the fishery moved further south a higher percentage of spring spawners occurred in the catch. This pattern was consistent with previous years (Fig. 11). In 1997, fishing took place entirely in the northern portion of the fishing area by regulation.

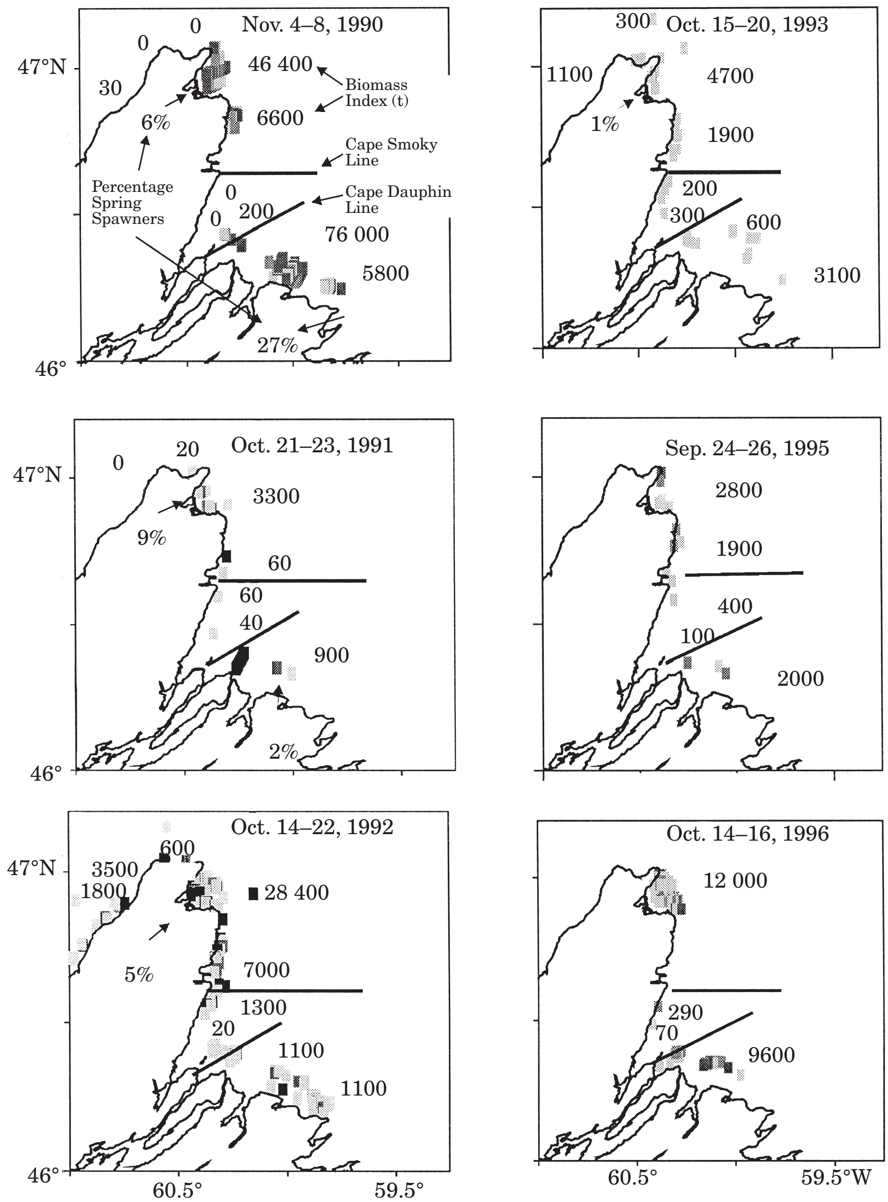

Figure 9. Biomass indices estimated from acoustic surveys in 4Vn from 1990–1996, there was no survey in 1994. Percentages are for spring spawners in indicated areas. Grey scale indicates relative density with darkest being the most dense. For place names see Figure 2. The biomass indices refer to nearest grey scale densities.

This higher concentration of spring spawners could occur for two reasons. Either, it was in an area where 4T spring spawners predominate, or it was in an area where spring spawners from local, primarily Bras d'Or stocks, were concentrated. If the situation was one of concentration of local stocks, high exploitation rates would be expected.

Specific application of the general guidelines in this situation requires that the following questions need to be answered to determine where to fish:

(1) What is the location of the large 4T migrating stock during the timing set by Decision Rule 2: (when to start) for the overwintering fishery? Decision Rule 4 (where to fish) requires that the overwintering fishery be restricted to this area.
(2) What local stocks are in the area of the overwintering fishery and what is their relative size compared with the 4T migrating stock? The general guidelines require this information in order to determine the probability that fishing in a

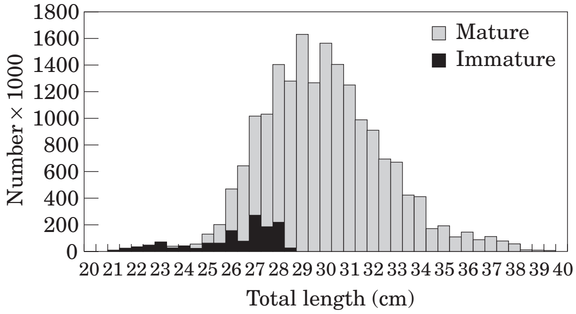

Figure 10. Length frequency distribution of total catch by large seiners in 4Vn, 1996.

Table 5. Catch of immature herring caught in 4T and 4Vn compared with 4T target catch of immature herring in 1996.

	Catch (t)			
Spawning group	4T	4VN	Total	$F_{0.1}$
Autumn	278	256	534	576
Spring	93	29	122	269
Total	371	285	656	845

particular area will be on a random mixture of stocks or in an area where concentrations of small local stocks are likely to be encountered.

(3) What are the biological characteristics of local 4Vn stocks and how do they compare to the large 4T migrating stock? This information will help assess the type of mixture and the effects of all current fishing practices on these populations. This comparison will help determine the probability of mixture type and the probability that these fish make up a large proportion of the overwintering catch.

These questions and issues are dealt with collectively below.

Location of major concentrations during the time of the overwintering fishery

Determining the location of the major concentrations during the overwintering fishery indicates the areas where the large 4T migrating stock is likely to be during the fishery and where the requirement for random mixing is most likely to be met. Historical information from the fishery and acoustic surveys identifies areas where herring are concentrated after the 1 November fishery starting date. Acoustic survey results, using research vessels from 1990 to 1997, and a purse seiner in 1997, indicate two areas of fish concentration, one in Aspy Bay and one off New Waterford-Glace Bay south of the Cape Dauphin Line, with low biomass indices for the St Ann's Bay-Bird Islands area (Fig. 9).

An examination of spawning group identifies areas where mixtures of 4T and local stocks are most likely to occur. The percentage of spring spawners in the surveys has always been less than 10% in the Aspy Bay area but has been as high as 27% south of Cape Dauphin (Fig. 9). The overwintering fishery shows the same pattern. In Aspy Bay, where most of the fishing has recently occurred, the percentage of spring spawners has been less than 10% except for 1996. In 1997, fishing occurred exclusively in Aspy Bay and the percentage of spring spawners was 4% (Table 3). When fishing has occurred in the St Ann's Bay-Bird Islands area, the percentage of spring spawners is higher than in Aspy Bay but is still similar to the percentage of spring spawners in the 4T population (Table 6).

Location of major concentrations at times other than the overwintering fishery

Examinations of major concentrations at times other than the overwintering fishery provides information on the locations and relative sizes of local stocks compared with the larger 4T migrating stock. A comparison of the January, July, and September bottom trawl surveys provides information on the relative size and distribution of the migrating 4T stock compared with local stocks. This comparison is useful because during the January survey the entire 4T stock is in the overwintering area, and during July and September all herring observed are assumed to be of local origin.

January bottom trawl surveys to investigate winter fish distributions generally found herring in distinct concentrations in the north, middle and southern portions of 4Vn. Herring were observed in the July and September bottom trawl surveys only in the St Ann's Bay-Bird Islands area and south of the Cape Dauphin Line. No major concentrations were observed north of Cape Smoky (Fig. 12).

Estimates of minimum trawlable biomass of local 4Vn herring are available from the July and September surveys. While July survey estimates are available from 1970 to the present, comparisons with other surveys have only been possible since 1984 when the acoustic survey began, and with the September survey for 1994 and 1995, the only years it was completed. Biomass estimates in the July survey ranged from 0 to 39 000 t from 1984 to 1996 and from 5000 to 9000 t in the September. In comparison, acoustic survey estimates ranged from 4000 to 440 000 t during 1984–1997 (Table 4).

Ages of autumn spawners in the 4Vn September 1994 and 1995 surveys do not show any sign of the large 1990 year class that was dominant in the 4T population and 4T portion of the September bottom trawl survey in those years. Maturity stages of these fish were greater than 90% spent fish. These maturity stages suggest that

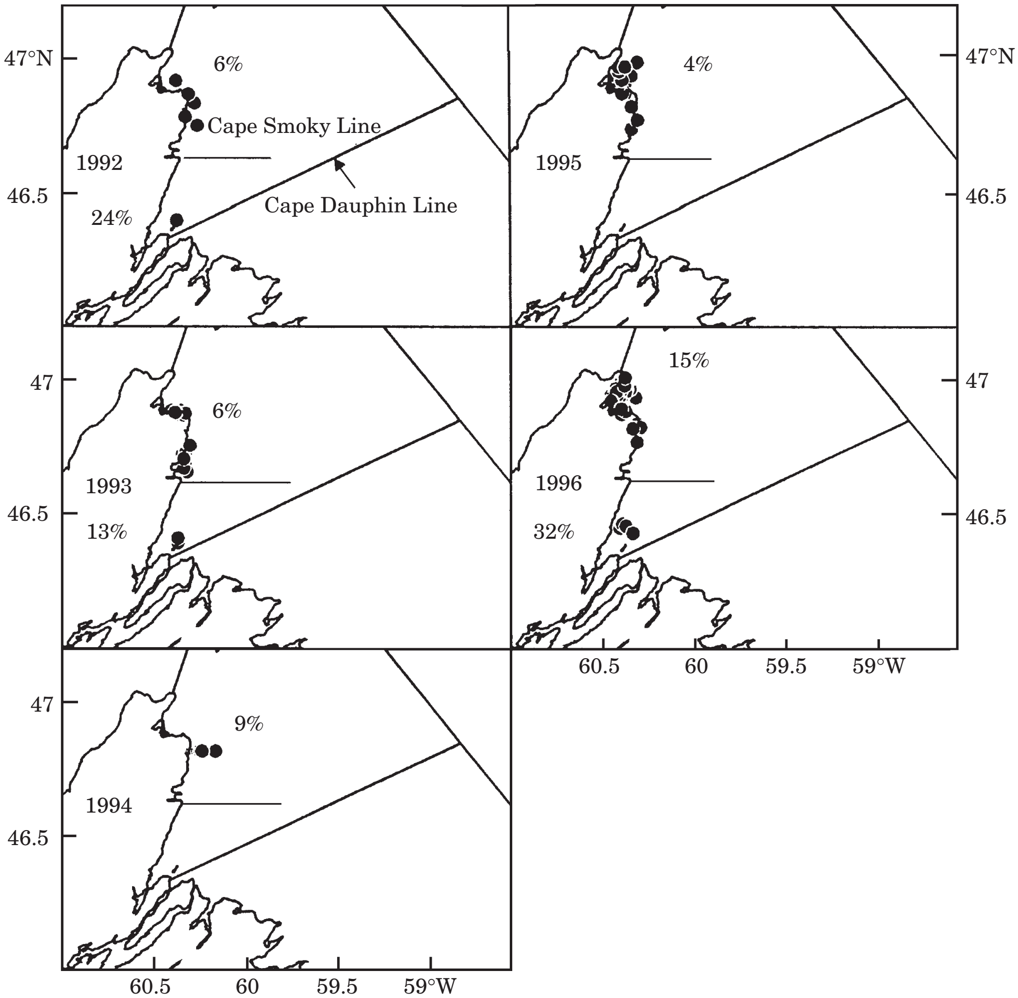

Figure 11. Location of purse seine samples from 1992 to 1996. The percentages refer to spring sapwners in the indicated areas. All fishing in 1997 occurred north of the Cape Smoky Line. For place names see Figure 2.

these fish are of local origin (Claytor and LeBlanc, 1998).

Local fisheries also provide information on the location of concentrations at times other than the overwintering fishery. Catches of herring have occurred in trapnets set in Aspy Bay during May, June and July from 1989 to 1997. Ages of spring and autumn spawners in these trapnets have a similar age distribution to 4T, except for 1995 (Claytor and LeBlanc, 1998).

Table 6. Percentage of spring spawners in 4T overwintering fishery in 4Vn and 4T population.

Year	Purse seine catch		4T Population
	Aspy Bay	Bird-St Ann's	
1992	6	24	29
1993	6	13	35
1994	9		30
1995	4		46
1996	15	32	35
1997	4		27
Ave.	7	23	34

The distribution of lobster licenses indicates that most of the effort for herring as bait is probably south of Cape Smoky (Fig. 2). This situation depends on the assumption that fishing and catch of herring for bait is directly related to the number of lobster licenses in each area. This license distribution is important because the lobster fishery was reported, at a workshop held in Sydney, February 1997, to last about 50 days and requires about 0.15 t/day of bait per license. If this amount were all herring and were harvested locally, then the total herring catch in the bait fishery could be as high as 3500 t and provides some information of the distribution expected for local stocks (Claytor and LeBlanc, 1998).

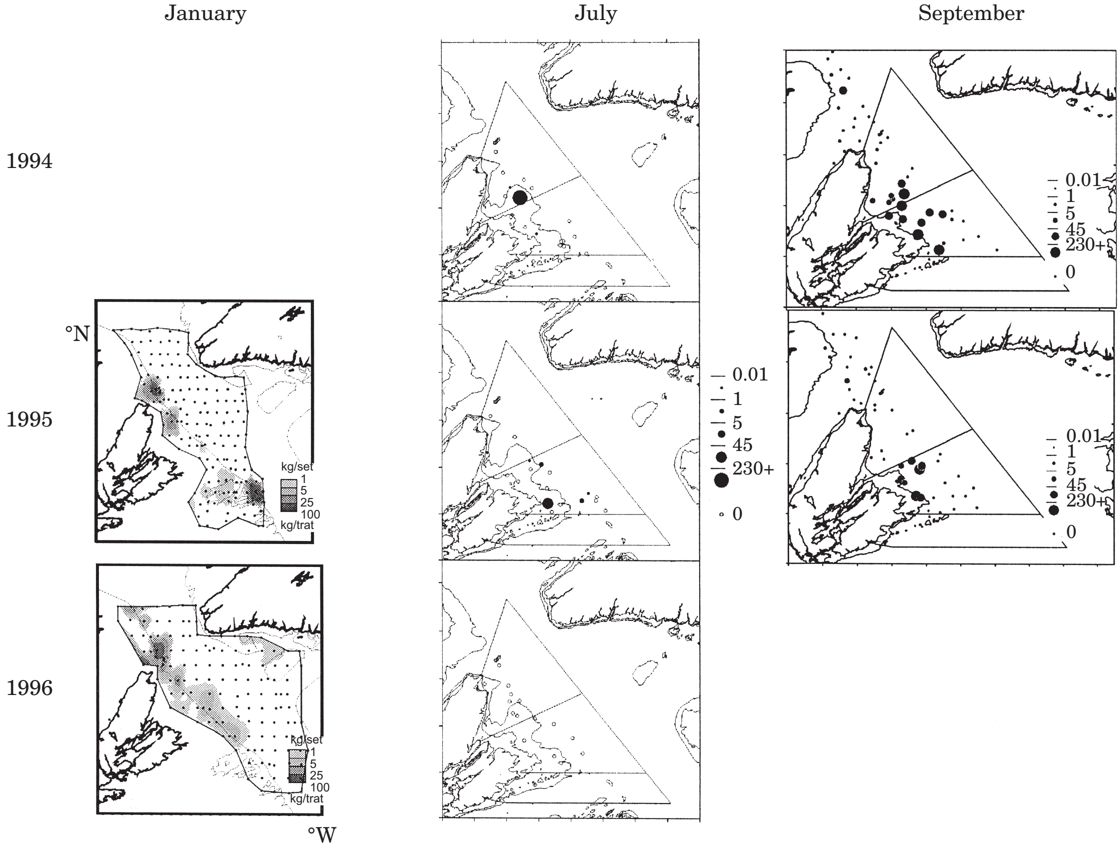

Figure 12. Distribution of herring in bottom trawl surveys in 4Vn during January, July, and September for years in which these surveys overlap. Indices for January are from contouring estimates and kg/tow for July and September. Open circles represent locations where sets were made but no herring were caught. For place names see Figure 2.

Historical tagging studies also indicate areas where local stocks may be vulnerable during the overwintering fishery. From 14 April–1 May 1981, 2975 herring were tagged in St Ann's Bay. Of the 38 tags recovered, eight were recovered from Bras d'Or Lakes during the spring in 1981 and 1982 combined and 26 from the purse seine fishery during October to December of 1981. Although unadjusted for effort, these results indicate the presence of Bras d'Or Lakes herring in the St Ann's Bay area during the time of the overwintering fishery. Thus, an overwintering fishery in St Ann's Bay has the potential for catching local stocks from the Bras d'Or Lakes (Table 7).

A number of points are relevant with respect to the potential impact a fishery in the St Ann's Bay area would have on Bras d'Or Lakes herring. First, the Bras d'Or Lakes spring-spawning component has declined in recent years. Herring have been absent from traditional spawning beds, low larval densities are observed during surveys, and fishing effort in the lake has increased and has become more concentrated in the last two years.

Second, the age structure of spring spawners caught in the St Ann's Bay area in 1996 suggests that 4T spring spawners would predominate in catches from this area. For example, the age structure of spring herring caught in Aspy Bay was similar to those caught in St Ann's Bay-Bird Islands area in 1996. These ages were also similar to those expected from examinations of the 4T spring spawner population age structure. Dominant year classes of spring spawners in the overwintering catch, with considerations for gillnet mesh sizes were different

Table 7. Number, location and timing of tags recovered from St Ann's Bay experiment (Simon and Stobo, 1983).

Recovery location	1981–1982		1981	
	Apr–June	July–Sep	Oct–Dec	Total
4Vn	1		25	26
Bras d'Or	8			8
4Wa		1		1
4T	2	1		3

from those in the Bras d'Or Lakes population (Anon., 1997).

Third, herring have occasionally been taken under the ice in Bras d'Or Lakes, indicating that not all Bras d'Or Lakes herring overwinter in 4Vn.

These similarities and differences, while suggesting a predominance of 4T spring spawners in the St Ann's Bay-Bird Islands area catch in 1996, do not guarantee a reduction in the risk to local spring stocks from fishing in this area.

The general principle of fishing in areas where stocks are randomly mixed is most likely to be met in northern areas of 4Vn. Risk of fishing in areas where small vulnerable local stocks are concentrated is greater between Cape Smoky and Cape Dauphin, than north of Cape Smoky. Fishing below Cape Smoky increases the proportion of spring spawners in the catch. Therefore, given the declining situation in the Bras d'Or Lakes, the Cape Smoky line (Fig. 2) is appropriate at this time.

Process used to develop decision rules

The decision rules were developed over a two-year period using workshops and stock assessment review meetings to develop the general guidelines and explain the analyses that would be used to formulate the decision rules. In retrospect the sequence seems logical, although at the time, the mode of operation was one of high stress because of the need for continual crisis management caused by extremely belligerent stances taken by one fleet against another and against all Department of Fisheries and Oceans personnel. Nevertheless, this combination of workshops and reviews provided a mechanism for developing the decision rules and resolving the crisis.

The need for decision rules was identified in two meetings held in the late summer and early autumn of 1996. In the first meeting a new departmental management plan was communicated to local 4Vn fishers and the Gulf purse seine fleet. In the second meeting, representatives of local fishing groups expressed their vehement opposition to the plan. This opposition led to a series of four workshops held during and immediately after the fishery to explain the results of analyses on the test and regular fisheries.

The general guidelines to formulate these decision rules were developed and presented at a workshop attended by members of the 4T, 4Vn, and 4WX fleets in February, 1997. Shortly after this meeting, another workshop was held with these industry members to explain the data and analyses that would be used to derive the decision rules. These analyses were then organized into a working paper that was presented at the stock assessment review meeting for Atlantic herring stocks in March, 1997. The final decision rules for 1997 were developed at the meeting from the data presented during the stock assessment review. This review also identified additional analyses to be conducted over the next year. These analyses were completed and presented at workshops prior to the March, 1998 stock assessment meeting. As before, the decision rules were finalized by the group of industry representatives, managers and scientists attending the stock assessment review meeting. At the end of the second year, all industry parties accepted the decision rules as a basis for managing the fishery and there have been no additional requests from either the seiners or local interests to change the rules.

The key to this process was the frequency of the workshops. Whenever work was completed on a specific issue, a workshop attended by industry, managers and scientists was held. Industry representatives could see the effect that additional data and analyses had on the decision rules because of the interactive nature of the workshops and the immediacy of the response to questions and concerns.

The workshops served two major purposes. First, they established the basis for, and obtained agreement on, the general guidelines. Second, they established the requirement that each rule had to have a basis in the general guidelines. Acceptance of the general guidelines by industry was achieved because they were as specific and as quantitative as possible. Qualitative terms such as precautionary and safe, even though they were at the heart of the decision rules, were not used in the general guidelines. As a result, the general guidelines were successful in focusing concerns and providing a rationale for the rules. Acceptance of the general guidelines meant that the decision rules could be stated simply and without interpretation.

Accountability was a major aspect of the workshops. Science staff conducted analyses and presented results that arose from fishers' concerns, while industry had to keep their statements consistent from one workshop to the next. For example, industry could not claim at one meeting that the Bras d'Or Lakes were in trouble as a way of stopping the seiner fishery and then argue at another meeting that the stock was in good shape so that this local fishery could expand. This accountability was achieved by taking and circulating minutes for each workshop (for example see Anon., 1997a, Anon., 1999, Chouinard 1999). Statements made without data were noted, but an attempt was made to determine if data existed that could be used to verify or falsify the statements. If it was determined that the data existed, then a commitment was made by science staff to present it at the next workshop. If it did not exist, a method of gathering the data or investigating the problem in some other way was determined. When data were weak or unavailable computer simulations became a valuable tool for focusing attention on the most important aspects of the issue.

The stock assessment review meetings were also attended by industry representatives, scientists, and managers. Science staff presented the information used to develop the rules at these meetings but all of the participants jointly formulated the decision rules based on the data and analyses presented. The workshop process was crucial to the development of the decision rules. Without the prior preparation and openness of the workshops, it is doubtful that the decision rules could have been developed at the stock assessment review meetings.

Discussion

Common complaints and fears expressed by members of the fishing industry, including fishers, processors and union representatives at stock assessment and review meetings are that it is not clear why various decisions about the fishery are made and how they can be changed. These complaints have been recorded by industry during meetings on a wide variety of species including Atlantic salmon, gaspereau, herring and groundfish. Uncertainty is also expressed by industry regarding how emerging management ideas such as the precautionary approach will affect their fisheries (for example see: Chadwick, 1987; Claytor *et al.*, 1995a; Claytor *et al.*, 1995b; Anon., 1997; Anon., 1999; Chouinard, 1999). These uncertainties can lead to an atmosphere of non-cooperation between the fishing industry and fishery's managers and scientists. As a result, many crises in fisheries management develop because it is not clear to industry who made the decisions, why they were made or what alternatives were considered. This lack of clarity and accountability makes decisions open to the criticism that they are political in nature and, consequently, political solutions are sought by those who do not like the decisions. The situation is exacerbated when industry does not recognize that their concerns have been addressed as part of the decision. This perception of an opaque and political process leads to confrontational and crises management even when fish stocks are not in decline. When resources are scarce the intensity of the crisis increases.

While many of the specific data requirements and analyses described above are exclusive to the 4Vn overwinter fishery there is much about the decision rule process that is transferable to other fisheries. One of the most important aspects is the requirement for accountability. In this example, scientists were accountable to industry for responding to their questions and concerns. Industry was accountable for being consistent and willing to back up their statements with data or projects that would test their statements. As a result, it was made clear from the beginning that the process for establishing and changing the rules would have a data and analytical basis and that these data and analyses would be reviewed by all parties. The workshop and review meetings made the process transparent and easily understood.

The decision rules were not developed with a formal definition of the precautionary approach or risk aversion (Francis, 1993), or one of optimal harvesting strategy as defined by Walters and Hilborn (1976); Horwood (1993); and Walters and Parma (1996). They did, however, correspond to a general consensus of the conditions that would be safe enough to allow the fishery to continue uninterrupted through a season with a post-season evaluation of the effectiveness of the decision rules. In this sense, they were consistent with the use of introducing decision algorithms and the participation of the fishing industry in risk evaluation and fisheries management as described by Wilimovsky (1985). The process that developed the decision rules provides a model, based on the biological aspects of fisheries management, that could provide a template for a more integrated approach that would include socio-economic considerations as suggested by Lane and Stephenson (1998). The full-scale implementation of management frameworks will not occur overnight, particularly in fisheries where there has been a tradition of conflict and suspicion. The decision rule framework presented here provides a first step for industry, managers and scientists alike in gaining some experience in codifying decision algorithms for fisheries management.

It is in facilitating this first step that the decision rules described above improved the management of the 4Vn fishery. They achieved this result because they were simply stated and did not require interpretation. This approach worked because scientific analysis was seen as neutral and was used as a tool to delineate the consequences of actions and of non-compliance in achieving targets. The scientific analysis was, however, only one reason why the decision rules were successful. The process that lead to their development was equally important. The participants in the workshop and assessment review meetings had responsibility for the decision rules. There was no delay or barrier caused by additional consideration by a second group that was removed from those most directly affected by the management of the fishery. The process worked because it increased accountability, broke down barriers, and required specific and quantitative general guidelines as the basis for the decision rules. Searching for ways to improve and incorporate the decision rule process into more fisheries management decisions will lead to fewer conflicts and better managed fisheries.

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I would like to thank Mike Sinclair for suggesting this approach to the resolution of this problem in 4Vn and the many people from industry that participated in the development of these rules in a positive manner including Jeff Brownstein, Greg Egilsson, Robert Haché and Greg Organ. Geoff Evans, Nora Macnee, Jake Schweigert, Alan Sinclair, Mike Chadwick and two anonymous reviewers provided valuable comments on earlier versions of the manuscript.

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