POPULATION DYNAMICS AND BIOLOGICAL CHARACTERISTICS OF THE NEWFOUNDLAND WEST COAST HERRING STOCK

JOHN A. MOORES

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by

J.A. Moores, B.Sc.

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Department of Biology
Memorial University of Newfoundland

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ABSTRACT

Atlantic herring (*Clupea harengus harengus* L.) occurring along the west coast of Newfoundland were examined. Based on tagging results and spawning type (spring-spawners and autumn-spawners) composition a fisheries management unit encompassing the area from Cape Anguille to Cape Norman was proposed. Several spawning areas have been identified in this area indicating that there are several herring populations in the area such that the fishery exploits a stock-complex. Several biological characteristics including maturity rate, growth and feeding were examined. A comparison of growth rates from samples taken at two spawning sites and from the fall fishery did not indicate any differences and the populations were, therefore, treated as a unit stock for an analysis of its population dynamics. These analyses indicate that recruitment in recent years has generally been poor particularly among autumn-spawners which have steadily declined in abundance during the period covered by the analysis (1966-78). Recruitment to the spring-spawning component has been poor with the exception of the exceptionally strong 1968 year-class and the moderately strong 1974 year-class. However, no stock and recruit relationship could be established. In terms of $F_{0.1}$ management strategy the stock is currently underexploited.

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INTRODUCTION

The Atlantic herring, Clupea harengus harengus, occurs throughout the north Atlantic from as far south as Cape Hatteras in the western Atlantic and north as far as Greenland and south as far as Gibraltar in the eastern Atlantic (Leim and Scott, 1966). Herring fisheries have existed in the western Atlantic long before European settlement and since their arrival herring have been exploited extensively as a source of food and bait (Scattergood and Tibbo, 1959). In Newfoundland, several areas have been noted historically as important herring fishing areas, particularly Fortune Bay and the Bay of Islands (Templeman, 1966).

Herring catches along the west coast of Newfoundland have been highly variable. In the late 1940's average catches of 15,000 metric tons (mt) were reported (Templeman, 1966). These large catches were in response to markets created by the United Nations Relief Association (UNRA) aid programs. In the 1950's catches declined sharply and did not increase until the late 1960's and they further expanded in the 1970's. In the late 1940's the fishery was concentrated in the Bay of Islands and Port-au-Port Bay areas (Fig. 1). Bonne Bay became the primary fishing area in the 1960's. During the late 1960's and early 1970's the center of fishing activity gradually shifted northward concentrating in Hawkes Bay in 1971 and 1972, then shifting to St. John Bay in 1973. The fisheries of the late 1960's and early 1970's were primarily purse seine fisheries occurring in the late fall and early winter. Gillnet fisheries occurred throughout the year but until recently took only small quantities of fish. As the abundance of the

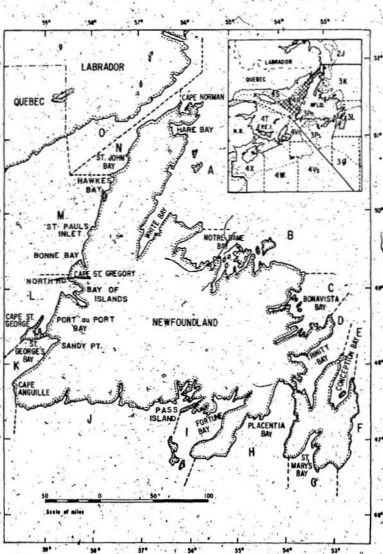

Fig. 1. Map of Newfoundland showing Newfoundland statistical areas and place names referred to in the text. Inset shows ICNAF areas and indicates the west coast of Newfoundland herring stock area (hatched area).

southern Gulf of St. Lawrence herring stock declined in the early 1970's (Winters and Hodder, 1975) catches from the spring herring fishery along the southwest coast of Newfoundland declined. To offset their reduced catches along the southwest coast, vessels from the purse seine fleet increased the area searched and by 1973 they had begun to move into the St. George's Bay area where they found concentrations of herring. The fishery in St. George's Bay expanded as pre-spawning concentrations were found off Sandy Point in 1975. Since 1975 two major herring fishing seasons have developed on the west coast with a spring fishery south of the Bay of Islands and a fall fishery north of the Bay of Islands.

With the expansion of the west coast herring fishery there was a need for information regarding the biology of herring in this area. These herring have been examined by several authors (Tibbo, 1956; Olsen, 1961; Hodder, 1966), who characterized them as spring-spawners. Several spawning areas including St. George's Bay, Port-au-Port Bay and St. Paul's Inlet were identified. Additional information has been collected in investigations conducted on the southern Gulf of St. Lawrence herring stock (Parsons and Hodder, 1971; Winters and Parsons, 1972; Parsons, 1973).

The present study was directed towards establishing the stock relationships of the herring found along the west coast of Newfoundland, examining certain biological characteristics of these herring and describing their population dynamics, particularly with regard to the implications concerning the management of the fisheries.

The management of a fish species is generally conducted on a stock basis. However, many definitions of what constitutes a stock exist. Larkin (1972) defined a stock as a group of organisms sharing a common environment and a common gene pool. This definition is close to the classical biological definition of a population. Templeman (1962) considered a stock to be a recognizable unit where most of the fish have a similar area occupying and migratory pattern while Ricker (1975) defined a stock in more succinct terms as the exploitable biomass. As all management schemes relate to particular fisheries they must encompass all fish which are being exploited in that fishery. Also if the fish are being exploited in several different areas during the course of migrations all these fisheries must be managed jointly. Thus the definition of a stock from a management perspective encompasses both the definition of Templeman (1962) and Ricker (1975). While Larkin's definition of a stock (1972) would constitute a desirable unit for the management of the resource he admits that generally what is defined as a stock is the result, at least partially, of arbitrary decisions made for human considerations. The term stock, in this study, will be used in the general sense incorporating the definitions of Templeman (1962) and Ricker (1975) and is equivalent to a management unit while the term population will be used to describe sub-units of the stock which have distinct spawning behaviour either in time (spring-spawning and autumn-spawning) or in location (St. George's Bay, Port-au-Port Bay, etc.).

Stocks which are composed of more than one population have also been referred to as stock-complexes and in the literature these terms have been used interchangeably. The multi-population stock concept has been utilized for herring on both sides of the Atlantic for such areas as the southern Gulf of St. Lawrence (Winters and Hodder, 1975; Ware and Henriksen, 1978), Nova Scotia and George's Bank (Stobo et al., 1978; Anthony, 1972 and 1977) in the western Atlantic and in the North Sea stock (Cushing and Bridger, 1966) and the Atlanto-Scandian stock (Anon., 1979) in the eastern north Atlantic. The utilization of the stock-complex as the smallest management area indicates the degree of difficulty in evaluating the relative contribution of each population to the catch in a given year thereby preventing a detailed analysis of the population dynamics of each component of the complex. Treating the complex as a unit for management considerations represents a conservative approach aimed at reducing the possibility of over-exploitation of any particular component. It would, therefore, be expected that any defined stock area along the west coast of Newfoundland would encompass several populations.

Many techniques have been employed for stock separation and they can be broadly categorized into indirect and direct methods. Stock separation of herring through the use of indirect means (meristics, morphometrics, biochemical characteristics and parasites) has, generally, not proven to be successful for herring in the western Atlantic. Meristic and morphometric characteristics of various Atlantic herring stocks have been extensively examined by several authors (Messieh and Longmuir, 1978; Parsons, 1973, 1975) and have only been useful in confirming the stock boundaries, demonstrated through tagging results, of the southern Gulf of St. Lawrence stock. Biochemical characteristics of herring in the western north Atlantic were examined by Odense and Allen (1969) but this method was ineffective in discriminating between stocks. Parsons and Hodder (1971) examined herring for the presence of the larval nematode Anasakis sp.; finding differences between southern Nova Scotia and the Gulf of St. Lawrence, but no clear differences between other areas. Data available for the west coast of Newfoundland (Parsons, 1973, 1975; Parsons and Hodder, 1971) include meristic and morphometric data and nematode incidence, none of which enables a subdivision of the stock.

Tagging experiments provide direct information on the movements of fish. Herring tagging experiments were conducted along the southwest coast of Newfoundland and at Hawkes Bay during the early 1970's (Winters and Parsons, 1972). These experiments utilized metal, internal tags which were recovered from herring meal processing plants. The results of those studies indicated a high degree of mobility in the herring stocks along the west coast. Recoveries from the Hawkes Bay tagging were reported as far south as the southwest coast of Newfoundland, and as far west as the Gaspé coast. Fish tagged along the southwest coast (Winters, 1975) were recaptured primarily in the southern Gulf and southwest Newfoundland and also on the west coast of Newfoundland as far north as St. George's Bay. The results of those experiments must be viewed carefully, however, due to the nature of the fishery at that time. The fishery was a high volume purse seine fishery with all the catch being converted to herring meal. With the large fleet and high volume, a plant could have landings from several areas in its holding facilities at any given time. In addition, the tags were recovered from magnets in the meal processing plant. This leads to problems in ascertaining precisely where an individual fish was recaptured. Also, the stock in the southern Gulf of St. Lawrence was extremely large at that time (Winters, 1975) and was experiencing some expansion in its range.

As the indirect techniques generally give inconclusive results, it would appear that tagging experiments provide the most useful information for the separation of herring stocks in the western Atlantic. An initial part of this study, therefore, was to conduct tagging experiments along the west coast of Newfoundland.

Once the stock area has been defined, various biological parameters of the herring occurring within the area can be measured. In addition to providing a basis for comparison with other herring stocks, knowledge of the biological characteristics are essential to the development of the population models and their interpretation and can also help explain why current fishing patterns exist. These parameters must be measured separately for the two spawning components (spring-spawners and autumn-spawners) due to the possible variation caused by the difference in their time of birth and initial growth (Winters, 1975). In addition to the two spawning components, three spawning sites have been identified along the west coast of Newfoundland, each of which may represent a discrete spawning population, as was postulated by Ware and Henriksen (1978) for the southern Gulf of St. Lawrence herring stock-complex. Where possible the biological characteristics of each population should be examined to see if there are significant differences which could influence any generalized conclusion made regarding the stock-complex and therefore influence the management strategy used to regulate the exploitation of the stock.

Biological data and commercial fisheries data are available for this area since 1966 providing a broad data base for incorporation into analytical models to evaluate the population dynamics of herring in the west coast area. Two basic types of models have generally been employed to assess the status of various stocks in the northwest Atlantic. The surplus production model (Schaefer, 1954) utilizes data regarding catch levels and catch-per-unit of effort. The data from the most recent year are compared to the historical relationship to ascertain the current status of the stock. This model does not require a detailed biological data base.

The second group of models are the sequential population models (virtual population analysis (Fry, 1957) is sometimes used as a synonym) which require data regarding the removals-at-age in the catch, estimates of fishing (F) and natural (M) mortality. Variations of this model have been presented by Fry (1949, 1957), Gulland (1965) and Jones (1961, 1968), but all have been based primarily on the Baranov catch equation $C = \frac{FaN}{Z}$ (Baranov, 1918);

where C = number of individuals in the catch

F = instantaneous rate of fishing mortality

a = rate of annual mortality

N = number of individuals in the population

Z = instantaneous rate of total mortality

Pope (1972) developed an approximation to the method of Gulland (1965) which he called cohort analysis. This method facilitates the computational procedures of sequential population analysis and is usable up to values of, at least, M = 0.30 and F = 1.20.

The errors associated with cohort analysis (Pope, 1972) are reduced the further back in time the analysis progresses, thereby providing a reliable estimate of the historical stock picture. The greatest error is associated with the most recent years, but can be calibrated with commercial catch-per-unit-effort or effort data. As sufficient data exist for the west coast of Newfoundland herring to perform sequential population analysis, which provides greater detail regarding the population dynamics of the stock than Schaefer-type models, this method was used to examine the population dynamics of the area. Of the methods available cohort analysis was selected for the analysis for its ease of computation without loss of resolution. Once the current stock status has been established projections can be performed. These projections help provide a basis for the establishment of catch levels while permitting an examination of the effect various management options will have on the stock.

METHODS AND MATERIALS

A. Tagging

Tagging experiments were conducted along the west coast of Newfoundland from 1975 to 1978. All herring tagged were obtained from commercial fishermen using either purse seines or herring traps. Both gears are non-selective, with regard to size, and provide fish in excellent condition. Fish were transferred from the commercial gear to a holding pound (18' x 18' x 18') by attaching the headropes together, and depressing the headropes such that the herring could be rolled from the commercial gear into the holding pound. The herring were tagged from a small boat. Herring were transferred, with a dipnet, from the holding pound into a plastic tub filled with seawater placed in the bottom of the boat. From 20-30 herring at a time were placed in the tub. The water in the tub was changed after every second lot of fish were tagged. A tagging team consisted of two men, one of which held the fish while the second man inserted the tag into the musculature below the dorsal fin. The fish was then released over the side of the boat.

Four types of external tags were used in these experiments: anchor (Floy FD-68), short anchor (Floy FD-68D), dart (Floy FT-2) and streamer (Floy FTSL-73). Two colors of short anchor and streamer tags were used: yellow and international orange. All other tags were yellow. Each tag was individually numbered and bore the return address of the Newfoundland Biological Station.

Tag recaptures were returned either through collectors located at particular plants or by being sent directly to St. John's. The information requested with each return was: date caught, gear used and location of capture. A reward of $3.00 was paid for each tag returned.

B. Biological sampling

Herring samples have been collected annually from the commercial fishery occurring along the west coast of Newfoundland since 1966. Sampling was spread over the entire year and encompassed most gear types and areas. Additional samples were also available from research studies. The sampling intensity varied from a low of 7 samples in 1966 to a high of 88 samples in 1977 averaging 37 samples per year. Each sample was composed of 50 fish collected randomly from commercial and research gears and examined fresh or after being frozen for several weeks. Each sample was assigned a number and date of capture, location of capture and gear of capture were recorded. Sampling data collected for each fish included length, weight, sex, maturity stage, and gonad weight. Otoliths were taken for subsequent aging. The following definitions apply:

Length: Total length was measured in millimeters from the tip of the snout to the end of the lower lobe of the tail.

Weight: Both round weight and a gilled and gutted weight were measured to the nearest gram.

Sex: Sex was determined by gross examination of the gonads.

Gonad weight: Gonad weight was measured to the nearest gram.

Age: Ages (age-group) were determined from the sagittal otoliths which had been removed and placed in a depression in a plexiglass tray and adhered with dichloro-ethane. Each tray had sufficient depressions to hold the otoliths for an entire sample and was labeled with the sample number. All otoliths were read using a binocular microscope with the otoliths immersed in 80% ethanol. The assignment of age-group and year-class was based on the conventions proposed for herring by Hunt et al. (1973). All fish age 11 and older were grouped together as age-group 11+.

Spawning type: Spawning type was assigned on the basis of maturity stage in relationship to the annual maturity cycle or on the basis of otolith characteristics for immature specimens.

Degree of stomach fullness: The degree of stomach fullness was subjectively determined using a 5 point-classification system where 0 = empty, 1 = 1/4 full, 2 = 1/2 full, 3 = 3/4 full, and 4 = full.

C. Catch and effort data

Statistical information and log records were supplied by the Economics and Intelligence Branch of Fisheries and Oceans, Canada. Catch data were broken down by statistical area, year, month and gear type.

RESULTS

A. Stock separation along the west coast of Newfoundland

A1. Tagging results:

Six tagging experiments were conducted along the west coast of Newfoundland between 1975 and 1978. The tagging experiments covered all seasons and included the entire west coast (Fig. 2). A total of 34,750 tags were applied with 874 tag recaptures being reported (Table 1A). Recaptures were almost exclusively (99.3%) made along the west coast. Four tags were returned from the east coast of Newfoundland, one from southern Nova Scotia (4W) and one from the Quebec North Shore (4S). Of the 874 recoveries 638 (73%) were recovered during the year of tagging with 216 tags (25%) recovered in the following year and 20 tags (2%) recovered during the third year of release. The recaptures were spread throughout the west coast area with recaptures being reported in at least one statistical area in addition to the area in which the tagging occurred. This pattern was observed both in initial recoveries (year of release) and subsequent recoveries (more than 1 year of release).

In conjunction with the west coast taggings an experiment was conducted in the southern Gulf of St. Lawrence. Of 3,800 fish tagged along the "edge" (Fig. 2) in May 1976 only 1 of 179 recaptures was reported along the west coast of Newfoundland (Table 1B).

Fig. 2. Herring tagging sites along the west coast of Newfoundland from 1975-78 and tagging sites in adjacent areas from which tag recaptures were reported from the west coast of Newfoundland:

1. Reef Hr. (July '75), St. John Bay (Dec. '76)
2. St. Paul's Inlet (May '78)
3. Port-au-Port (May '77)
4. St. George's Bay (Apr. '76), Sandy Pt. (Apr. '77)
5. the "edge" (May '76)
6. Hare Bay (June '76)
7. Sop's Arm (Oct. '76)
8. Laurenceton (June '77)

Table 1. Results of herring tagging experiments conducted between 1975 and 1978 with returns from the west coast of Newfoundland. Recaptures by year and Newfoundland statistical areas and ICNAF Divisions.

A. Tagging experiments conducted along the west coast of Newfoundland.
B. Tagging experiments conducted in the southern Gulf of St. Lawrence.
C. Tagging experiments conducted along the east coast of Newfoundland.

					Area of Recapture									
			Recaptures		Nfld. Stats. Areas							ICNAF Areas		
Location Tagged	Date Tagged	No. Tagged	No.	Year	K	L	M	N	A	B	O	S	T	W
A. WEST COAST OF NEWFOUNDLAND														
Reef Hr. (N)	July '75	2,350	10	1975				8						
				1976	1					1				
St. George's Bay (K)	April '76	6,400	151	1976	99	1								
				1977	46			1						
				1978	3	1								
St. John Bay (N)	Dec. '76	10,000	169	1976				11						
				1977	114	11		12	3				1	1
				1978	13		1	2						
Sandy Pt. (K)	April '77	7,500	417	1977	384	11	1	3						
				1978	18									
Port-au-Port (L)	May '77	2,000	18	1977		6		5						
				1978	5			2						
St. Paul's Inlet (M)	May '78	6,500	109	1978			104	5						
TOTAL		34,750	874		683	30	106	49	3	1			1	1

Table 1. Cont'd.

Location Tagged	Date Tagged	No. Tagged	Recaptures No.	Recaptures Year	Area of Recapture: Nfld. Stats. Areas K	L	M	N	A	B	O	ICNAF Areas S	T	W
B. SOUTHERN GULF OF ST. LAWRENCE														
Edge (T)	May '76	3,800	179	1976									142	
				1977		1							26	1
				1978									7	2
TOTAL		3,800	179			1							175	3
C. EAST COAST OF NEWFOUNDLAND														
Sops Arm (A)	June '76	5,600	402[1]	1977	1									
Hare Bay (A)	Oct. '76	5,000	221[1]	1978	1									
Lawrenceton (B)	June '77	5,000	86[1]	1977							1			
TOTAL		15,600	709		2						1			

[1] all recaptures, other than those listed, were from the east coast stock areas.

Numerous tagging experiments have also been conducted along the east coast of Newfoundland (Winters and Moores, 1979) from which only 3 returns have been reported from western Newfoundland (Table 1C). These recaptures were from three different tagging sites (Fig. 2) located in Notre Dame Bay and White Bay. In these three tagging experiments a total of 15,600 tags were applied with 609 tags being returned.

The recent tagging results indicate a fairly marked separation between the west coast areas and both the southern Gulf of St. Lawrence and the east coast of Newfoundland. The degree of movement along the west coast appears to be extensive, particularly between the major west coast fishing areas: St. George's Bay and St. John Bay. Due to the limited effort along the Quebec North Shore and southern Labrador the scarcity of returns from these areas should not be interpreted to mean that the herring from the west coast do not migrate into these areas.

A2. Migration pattern:

Based upon the tagging results and the seasonal distribution of fishing effort a pattern of migration can be proposed. The fishery commences in the spring of the year in the St. George's Bay area. The lack of fisheries in more northern areas and the presence of herring tagged in St. John Bay and Port-au-Port Bay indicates that overwintering probably occurs in the St. George's Bay area. As spring progresses the spring-spawners move northward with the various spawning populations branching off to their inshore spawning areas. The arrival of these spawning schools coincides with increased gillnet catches. With the completion of spawning, inshore catches of spring-spawners decline rapidly and is probably related to a dispersion of these herring into the northern Gulf of St. Lawrence for feeding. Purse seiner activity resumes during the late fall when large schools form in the St. John Bay area. Coincidently there is an increase in the proportion of spring-spawners taken by gillnets. Searching activity in other areas at this time has failed to find concentrations of herring. The presence of herring tagged in other areas suggests that these schools are a forerunner of the overwintering concentrations. These schools move south during the winter months to be exploited again in the spring of the year in the St. George's Bay area. A similar north-south migration of spring-spawning herring has been observed on the east coast of Newfoundland (Tibbo, 1956; Winters and Moores, 1977).

From catch data the autumn-spawners do not appear to move as extensively as the spring-spawners. Incidental catch data from shrimp trawlers indicate that autumn-spawners are present in the Esquiman Channel during the winter and spring months, disappearing in the summer and fall when they are caught in coastal areas. The presence of primarily mature fish in the gillnet catches indicates that the inshore fishery exploits the spawning migration of the autumn-spawners.

There would, therefore, appear to be a localized onshore-offshore movement of autumn-spawners rather than a south-north pattern as proposed for spring-spawners.

A3. Delineation of the stock area:

The tagging data show that the herring occurring along the west coast of Newfoundland are reasonably discrete in their distribution. On the basis of the tagging studies, in conjunction with additional data, a Newfoundland west coast herring stock area can be established which delineates it from the adjacent southern Gulf of St. Lawrence and east coast of Newfoundland herring stock areas. The Newfoundland west coast herring stock (management unit) is defined as having the following boundaries:

Southern Boundary: Prior to 1977 the southern Gulf of St. Lawrence stock area extended from Pass Island, Bay d'Espoir to North Head, Bay of Islands and included all of the Gulf of St. Lawrence south of Anticosti Island (Anon., 1972). The inclusion of the southwest coast of Newfoundland and part of western Newfoundland in the southern Gulf stock area was based upon tagging studies (Winters and Parsons, 1972; Winters, 1975) which indicated that southern Gulf herring were overwintering and being exploited in these areas.

However, the tagging data presented here indicate that both the St. George's Bay and the Port-au-Port Bay fisheries do not exploit southern Gulf fish. If both the present and the historical (Winters and Parsons, 1972; Winters, 1975) studies were accurate then a change in the pattern of migration or exploitation has occurred. Winters (1975) showed that the majority of fish overwintering along southwest Newfoundland were autumn-spawners and that autumn-spawners were also dominant along the "edge" during the spring as these fish migrated back into the Gulf of St. Lawrence. The present fishery in St. George's Bay exploits primarily pre-spawning concentrations of spring-spawners thereby making a comparison of the spawning type composition of the catch from St. George's Bay (Area K) and the "edge" (Area T), an indicator of possible changes in exploitation pattern. Comparing the period 1973-76 (Table 2) shows that prior to 1975 the catch composition was similar indicating that the southern Gulf stock was being exploited in both areas. Since 1975 there has been a marked difference in the two areas suggesting that the fleet has been exploiting two different stocks. An examination of purse seine fleet activity, based on log records, indicates that prior to 1975 the fleet operated primarily south of Cape Anguille but since then has operated along the north shore of St. George's Bay from Sandy Point to Cape St. George.

These data suggest that herring from the southern Gulf of St. Lawrence stock have been present in that portion of statistical Area K south of Cape Anguille while north of Cape Anguille the west coast stock has been exploited. On this basis, Cape Anguille is a reasonable point of demarcation between the two stocks. Extending a line from

Table 2. Percentage of spring- and autumn-spawners occurring in purse seine samples taken in St. George's Bay (Area K) and the "edge" (Area T) during the spring fisheries from 1973 to 1976.

Year	% Autumn-spawners		% Spring-spawners	
	K	T	K	T
1973	45	44	55	56
1974	50	64	50	36
1975	16	76	84	24
1976	4	55	96	45

Cape Anguille to Anticosti Island effectively delineates the Newfoundland west coast stock from the southern Gulf of St. Lawrence stock and acts as the southern boundary for the west coast management area.

Northern Boundary: When licenses were issued for purse seiner activity along the east coast of Newfoundland in 1975, the area was bounded in the north by Cape Norman. This northern limit corresponds to the northern extreme by the White Bay statistical area (Area A). While this designation is somewhat arbitrary it effectively delineates the east coast area as little herring fishing occurs north of Hare Bay. St. John Bay has historically been the northern limit of herring fishing activity along the west coast. The existing boundary of Cape Norman can therefore be used as the boundary for the west coast herring stock effectively delineating the two stock areas.

Western Boundary: The herring fishery along the Quebec North Shore and southern Labrador is relatively small (< 1000 mt) and has not been extensively studied. The data from these areas indicate that the bulk of the catch is autumn-spawners. This fishery occurs in the summer months and therefore is similar to the St. John Bay area where the summer fishery also exploits primarily autumn-spawning fish. These fish are all mature and represent pre-spawning schools, and as such most probably represent local populations. Due to the limited knowledge of the area and the minimal tag return data, it is reasonable at the present time to consider the mainland shore as distinct from

from the Newfoundland area and for convenience a line can be drawn down the middle of the Esquiman Channel to indicate a western boundary.

All herring occurring in the area with these boundaries (Fig. 1) shall be designated as belonging to the Newfoundland west coast herring stock.

B. Biological characteristics

B1. Feeding:

Herring are planktivorous feeders consuming primarily copepods, chaetognaths and euphausiids (Paulmier and Decamps, 1973). Data on degree of stomach fullness from commercial sampling has been collected in the course of normal sampling procedures. The data were qualitatively classified into 5 categories with 0 = empty to 4 = full and examined on a monthly basis with the data from all years combined. A very low proportion of fish taken in commercial gears have food in their stomachs (Fig. 3). This may be attributable to the manner in which the commercial fishery exploits the schooling behaviour of herring in the west coast area. The fishery exploits primarily overwintering, pre-spawning and spawning concentrations in near shore situations. Thus the main commercial fisheries do not exploit the stock during the primary feeding period of summer and early fall. Research cruises along the coast of Newfoundland and Labrador indicate that herring schools are generally small and dispersed during the

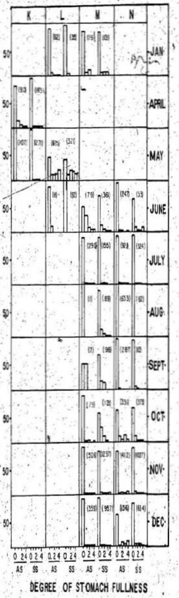

Fig. 3. Frequency of occurrence of stomach fullness for spring- (SS) and autumn-spawning (AS) herring from the Newfoundland west coast herring stock by month and statistical area. Number of fish in brackets.

summer months which may result from feeding activity. This dispersal accounts for the lack of purse seine activity in the Newfoundland area during the summer. It was therefore apparent that commercial gears primarily exploited non-feeding herring and could at best provide only limited information on the food and feeding of herring in the west coast stock area.

B2. Maturity by age and length:

Due to the nature of the fisheries, which tend to concentrate on larger fish, the smaller sizes and younger age-groups were generally poorly represented in the samples. In order to have a reasonable representation of younger age-groups in the analysis, samples were combined for the entire west coast area for the years 1975-78. While this was unsatisfactory for evaluating changes in maturity within the stock, it provides a generalized picture of the recent period.

Specimens were classified into mature and immature groups, on the basis of maturity stage, both by age-group and 1 cm length intervals. This process was performed separately for spring- and autumn-spawners but with sexes combined in both cases. Maturity ogives were constructed (Fig. 4) with the 50% maturity point being determined by Probit Analysis (Bliss, 1952). For spring-spawners, 50% maturity was achieved at an age of 3.29 years and a length of 27.49 cm while autumn-spawners achieved 50% maturity at 3.86 years of age and a length of 27.18 cm. Both spawning components display 100% maturity by age 6 and at a length of 32 cm.

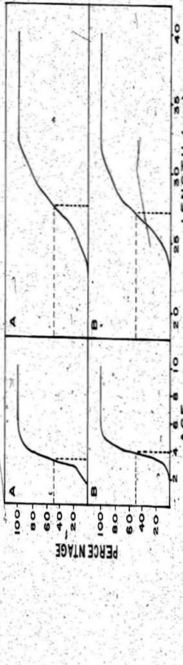

Fig. 4. Maturity ogives by age-group and length (cm) for (A) spring- and (B) autumn-spawning herring from the Newfoundland west coast herring stock combined for the years 1975-78.
—— spring-spawners; - - - autumn-spawners

B3. Length-weight relationship:

Data from the fall (Oct.-Dec.) purse seine fishery were combined for the period 1966-78 to construct general length-weight curves for both spring- and autumn-spawners (Fig. 5). Purse seine catches were used as they are non-selective and, therefore, should in general not be biased towards faster growing fish. The fall period was selected on the basis of the tagging results which indicate at this time the various populations of the west coast area all contribute to the catch. Data from this fishery should, therefore, most accurately reflect the general situation within the stock. The two curves were very similar in the left-hand portion of the curve (fish < 30 cm), diverging in the older lengths with autumn-spawners showing a lower weight at length. These differences are not biologically meaningful. The exponents of length were higher for spring-spawners but both are slightly below the theoretical level (3.0) for isometric growth (Ricker, 1968).

B4. Back-calculated growth:

Samples of spring-spawners were available from spawning grounds in St. George's Bay (Area K) and St. Paul's Inlet (Area M) for 1978. Twenty-five fish from the 1968 and 1969 year-classes were selected randomly from both of these areas and the otoliths examined to back-calculate length at age. Otoliths were measured using the technique described by Moores and Winters (1978). An annulus was defined as including an opaque zone (summer growth) and a translucent zone

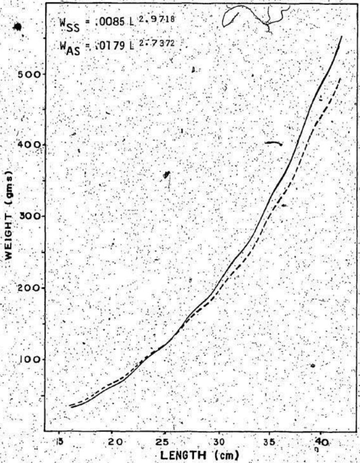

Fig. 5. Length-weight relationships of spring- and autumn-spawning herring from the Newfoundland west coast herring stock. Data from the fall purse-seine fishery combined for the years 1966-78.

— spring-spawners; --- autumn-spawners.

(winter growth), thereby representing the growth increment in a given year. All annuli were measured on each otolith. Average values of annulus width and total observed length were calculated for each area and year-class. These values were used to back-calculate an average length at age using the direct proportionality technique (Lea, 1919). Power curves were fitted to these points and are shown in Fig. 6A and 6B. For both the 1968 and 1969 year-classes the growth curves were similar for both areas. This suggests that even if these are discrete spawning populations, the growth rates are similar.

Empirical average length at age data were available for these year-classes from the fall purse seine fishery. These values when plotted (Fig. 6A and 6B) showed a different growth curve than those derived from back-calculation. This difference was attributable to the point in the annual growth cycle to which the length increment refers. The back-calculated length for any given age (ℓ_n) indicates the length at the start of the year while the empirical length values for the same age-group, as they were collected in the October to December period, represent the length at the end of the year. As the empirical values include one additional growth season they more accurately represent the back-calculated length for the next year (ℓ_{n+1}). When the empirical values were increased by one age-group to standardize the growth interval represented the curves showed good agreement. Data related to growth can, therefore, be applied generally over the entire area.

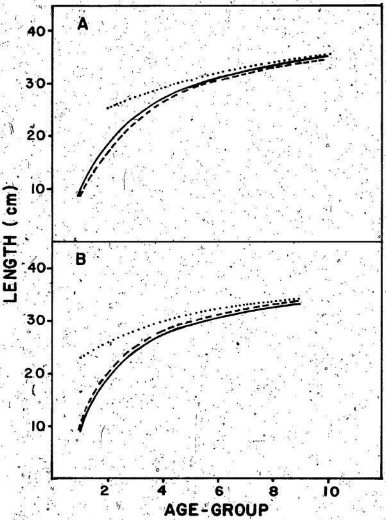

Fig. 6. Age-length relationship of spring-spawning herring derived by back-calculation from otoliths of fish taken from spawning areas in St. George's Bay (Area K) and St. Paul's Inlet (Area M) and from measurements taken during the fall purse-seine fishery.
A. the 1968 year-class; B. the 1969 year-class.
—— St. George's Bay; --- St. Paul's Inlet;
.... fall purse-seine.

C. Population dynamics

C1. Landing information:

Detailed landing information was available for the west coast stock area since 1966 (Tables 3 and 4). Catches in St. George's Bay prior to 1975 have been grouped with the Southern Gulf stock on the basis of spawning type composition (Table 2) and the area in which the catches were made and, therefore, have been excluded. Landings from the west coast stock have been highly variable both in total catch and area of capture. The main gear component in this fishery is the purse seine, fished from vessels in excess of 25 m overall length. In the period 1966-74 most of the fishery occurred north of the Bay of Islands as a fall-winter fishery. Detailed catch data (Table 4) show a general northward trend in the fishery with the bulk of the catches coming from Bonne Bay (Area M) in the late 1960's, shifting to Hawkes Bay (Area M) in 1971 and 1972, then into St. John Bay (Area N) in 1973. In 1975, the fleet began exploiting pre-spawning concentrations in St. George's Bay (Area K) and off the Port-au-Port Peninsula (Area L). This fishery occurs in the spring of the year and marks a return to the fishing pattern of the 1940's when these areas were major herring fishing grounds (Templeman, 1966). Purse seine landings have varied from a low of 2,000 mt in 1972 to a peak of 10,000 mt in 1978.

With increased prices and improved handling facilities, there has been a rapid increase in inshore effort with catches increasing from

Table 3. Herring landings (mt) from the Newfoundland west coast herring stock by statistical area for the years 1966-78.

Year	Area K	Area L	Area M	Area N	Total Catch
1966		103	5529	18	5650
1967		66	5540	13	5619
1968		59	3978	11	4048
1969		46	2549	40	2635
1970		27	3473	301	3801
1971		2424	1076	1963	5463
1972		862	1544	3628	6034
1973		2862	2067	9222	14151
1974		856	942	2842	4640
1975	3613	113	242	1027	4995
1976	6565	2067	226	1251	10109
1977	5569	2203	156	4358	12286
1978	6808	1984	365	6453	15610

Table 4. Herring landings (mt) from the Newfoundland west coast herring stock by gear type for each west coast statistical area for the years 1966-78. (Fixed gear is primarily gillnet but also includes traps and bar seines.)

Year	K		L		M		N		Total		
	Purse Seine	Fixed Gear	Purse Seine	Fixed Gear	Purse Seine	Fixed Gear	Purse Seine	Fixed Gear	Purse Seine	Fixed Gear	Combined
1966				103	5490	39		18	5490	160	5650
1967				66	5464	76		13	5464	155	5619
1968				59	3776	202		11	3776	272	4048
1969				46	2344	205		40	2344	291	2635
1970			12	15	2939	534		301	2951	850	3801
1971			2239	185	725	351	356	1607	3320	2143	5463
1972			727	135	1330	214	-	3628	2057	3977	6034
1973			2740	122	1763	304	3453	5769	7956	6195	14151
1974			756	100	439	503	1071	1771	2266	2374	4640
1975	3495	118	-	113	-	242	-	1027	3495	1500	4995
1976	6067	498	1955	112	-	226	184	1067	8206	1903	10109
1977	5289	280	2008	195	-	156	2167	2191	9464	2822	12286
1978	6252	556	1037	947	-	365	2636	3817	9925	5685	15610

160 mt in 1966 to 5,600 mt in 1978. The main inshore (non-mobile) gear is the gillnet with the major gillnet fishery occurring in summer and fall in Area N.

C2. Spawning type composition of the catch:

The contribution of each spawning type to the catch was variable with regard to location and time of catch and gear used. This variability is shown for the years 1976-78 in Table 5. The catch in St. George's Bay (Area K), during the spring, exploits primarily spring-spawners with the fixed gear catch being 100% spring-spawners and the purse seine catch in excess of 90% spring-spawners. In Port-au-Port Bay the fixed gear catch was similar to St. George's Bay but the purse seine catch varied from 76-24% spring-spawners. In Area M the gillnet catch fluctuated from 86-100% spring-spawners. In St. John Bay (Area N) the purse seine catch was predominantly spring-spawners but the gillnet catch varied from 2-79% spring-spawners.

While this variability is large it does conform to the migratory hypothesis presented. The gillnet catches from Areas K, L and M occur primarily during the spring of the year exploiting spring-spawners as they approach or are on the spawning grounds. Once spawning is completed and the spring-spawners disperse to feed catches deline. In St. John Bay (Area N) the gillnet fishery is more protracted taking primarily autumn-spawners during the summer as they prepare to spawn. As spring-spawners start to shoal up into overwintering concentrations,

Table 5. Percentage of spring-spawners occurring in the purse seine and gillnet fisheries of the west coast of Newfoundland by statistical area for the years 1976-78.

Year	Month	Area K P. Seine	Area K Gillnet	Area L P. Seine	Area L Gillnet	Area M Gillnet	Area N P. Seine	Area N Gillnet
1978	April	83		76				
	May		100			100		
	June					100		12
	July							34
	Aug.							
	Sept.							
	Oct.							
	Nov.						87	79
	Dec.						85	
1977	April	96						
	May	99		24				
	June					86		70
	July					98		33
	Aug.							2
	Sept.							28
	Oct.						49	57
	Nov.						92	79
	Dec.					86		
1976	April	94						
	May	99	100	53	100			
	June					100		
	July							8
	Aug.							
	Sept.							
	Oct.							
	Nov.						90	75
	Dec.							

they become more abundant in the near shore area and represent an increasing proportion of the gillnet catch.

The purse seiners exploit mainly spring-spawners in both the spring and the fall of the year. The proportion of autumn-spawners in their catch may be influenced by the time at which they initiate fishing activity with autumn-spawners being more prevalent during the beginning of the seasonal fisheries. The earlier the fishery commences in the spring the greater the likelihood that exploitation will occur on mixed schools as the spring-spawners would not have segregated into schools moving into the spawning areas. In the fall the earlier the fishery starts the more post spawning autumn-spawners will be taken as not all of the spring-spawners have arrived to form the overwintering schools.

The pattern of fishing in this stock, concentrating on spring-spawners, while reflecting the present abundance of the two spawning components, does create a situation where differential exploitation of the two spawning components can occur.

C3. Age composition of the catch:

The catch composition from the west coast herring stock (Fig. 7) shows two distinct patterns. The spring-spawning component shows one year-class dominating the catch for several years, a pattern which has been commonly seen in herring (Winters, 1975; Stobo et al., 1978). Prior to 1970, the 1959 year-class was dominant but was

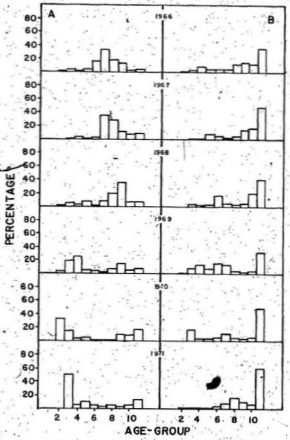

Fig. 7. Age frequency of (A) spring- and (B) autumn-spawning herring in landings from the Newfoundland west coast herring stock area for the years 1966-78.

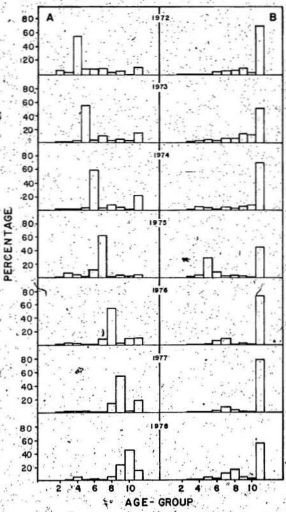

Fig. 7. Cont'd.

replaced in 1970 by the 1968 year-class as age-group 2. The 1968 year-class has dominated the fishery since 1970 and in 1978 was still the dominant year-class contributing between 40-50% of the total catch of spring-spawners. The second largest year-class has been the 1969 year-class, however, its increasing contributions in recent years may be partially due to errors in aging as the fish become older. Apart from these year-classes only two year-classes have appeared in any reasonable strength, the 1972 and 1974 year-classes. While the 1972 year-class showed strongly in St. John Bay (Area N) in 1975, it did not contribute significantly in future years. In 1978 the 1974 year-class appeared in St. John Bay but whether it will follow the course of the 1972 year-class or instead develop into a major year-class has yet to be determined.

The autumn-spawners have shown no major recruitment with the bulk of the catch coming from age-group 11+. Between 1966 and 1978, this segment of the stock has contributed between 40-90% of the catch. The failure of the autumn-spawners to produce significant year-classes in recent years indicates that its abundance has been declining.

C4. <u>Numbers-at-age in the catch</u>:

Catch data were available from 1966-78 for each of the four statistical areas (Areas K-N) broken down by gear and month. The number of individuals taken was calculated for each of these units of catch (eg., May, gillnet, St. George's Bay) then summed over the entire west coast area. The total number of individuals in the catch was derived by dividing the catch weight by the average weight of the sample with the individuals being assigned to spawning type on the basis of the percent occurrence of each spawning type in the sample. Within each spawning component the catch numbers were partitioned according to the age frequency to produce the catch-at-age. When no samples were available for a particular catch unit the weight and frequency from the closest sample were used; for example, if purse seine catches were made in St. George's Bay in both April and May but samples were only available for May, then the May frequency and weight would be applied to the April catches to generate the numbers-at-age in the April purse seine catch. This procedure was followed in each year (1966-78) to generate a catch matrix (Tables 6 and 7) for each of the spawning components.

C5. Effort data:

Effort data were available from log records for the northern fall fishery for the period 1966-73 and for the St. George's Bay spring fishery for 1975-78. Landing slip data for the northern area were available for 1977 and 1978. These effort data (Table 8) present several problems in interpretation due to changes in the pattern of exploitation on this stock. The historical effort data (1966-73) are consistent both in fleet composition and mode of operation. During this period the fishery occurred primarily during the late fall in the Cape Gregory to Cape Norman area and exploited schools forming overwintering concentrations.

Table 6. Removals-at-age (in thousands) of spring-spawners from the Newfoundland west coast herring stock for the years 1966-78.

	Year												
Age	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
2	173	1	101	212	3377	1	405	211	62	117	509	11	1
3	358	9	359	1109	1565	3076	265	98	113	951	994	666	45
4	280	338	200	1525	386	282	6332	764	26	525	983	538	2012
5	551	60	475	341	545	589	751	16215	201	293	230	530	222
6	1932	264	128	318	237	289	806	1270	5548	1541	332	305	703
7	3890	3392	561	176	195	150	940	2873	146	8410	2820	364	248
8	2032	2704	1231	441	240	307	208	1311	773	235	15555	4226	2241
9	1575	1162	2237	963	988	92	499	1404	484	366	777	16452	8479
10	292	769	416	368	952	315	135	806	58	138	2858	934	16460
11+	482	853	430	445	1680	797	1094	4272	2041	701	3229	5666	5164
Total	11565	9552	6138	5898	10165	5898	11435	29224	9452	13277	28287	29692	35575

Table 7. Removals-at-age (in thousands) of autumn-spawners from the Newfoundland west coast herring stock for the years 1966-78.

	Year												
Age	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
2	111	1	1	17	1	30	12	1	1	1	1	1	1
3	195	29	228	299	770	1	81	292	12	94	63	3	10
4	632	51	131	531	141	2	93	466	141	183	51	61	30
5	273	542	206	272	145	55	69	628	110	1188	119	118	407
6	271	314	1050	613	214	343	248	585	57	350	338	298	296
7	273	119	295	517	468	950	326	973	117	83	462	727	1018
8	996	332	224	157	177	2058	422	1040	58	112	105	373	1608
9	1091	953	292	119	129	1093	893	2223	195	70	157	207	482
10	914	1151	1219	168	239	714	256	2016	205	59	50	95	298
11+	2749	3217	2538	1254	2122	7583	6265	8975	2161	1842	3742	6926	5018
Total	7505	6709	6184	3947	4406	12829	8665	17199	3057	3982	5088	8809	9168

Table 8. Catch-per-unit-effort and total effort (in operating days) from the Newfoundland west coast herring stock during the spring fishery (Areas K+L) and the fall fishery (Areas M+N) based on purse seiner log records for the years 1966-78.

Year	Total Catch (mt)	Catch/op. day		Effort		Adj. K+L	
		K+L	M+N	K+L	N+M	Catch/op. day	Effort
1966	5650		62.3		89.4		
1967	5619		67.5		86.5		
1968	4048		65.4		61.9		
1969	2635		47.8		55.1		
1970	3801		38.3		99.2		
1971	5463		38.6		141.5		
1972	6034		31.7		190.4		
1973	14151		53.0		267.0		
1974	4640		-		-		
1975	4995	92.6	-	53.9	-	45.8	109.1
1976	10109	89.5	-	113.0	-	44.3	228.2
1977	12286	79.8	70.2[1]	154.0	175.0	39.5	311.0
1978	15610	68.5	89.0[1]	227.9	175.4	33.9	460.5

1 from landing slips

To reduce the amount of time spent by the purse seine vessels in transporting herring to the processing plants in the Bay of Islands area, a system of carriers (vessels used to transport herring but not engaged in catching fish) was used. This increased the amount of time that a purse seiner spent actively engaged in the fishery, essentially increasing the efficiency of each fishing unit. Since 1975, the fishery has undergone several changes: in St. George's Bay the fleet has been expanded and exploits primarily pre-spawning concentrations of herring while in the northern area improved handling facilities have eliminated carriers and reduced steaming time to and from off-loading ports.

While both recent data sets are inconsistent with the historical data set, they are also inconsistent with each other. The St. George's Bay data (1975-78) show a steady decline in catch-per-operating day while the St. John Bay data show an increase from 1977 to 1978. The differences between these two areas may in part be due to differences in fleet composition. As many as 25 vessels take part in the spring fishery but generally not more than 6 vessels operate in the fall fishery. In order to produce a consistent effort series a correction factor was generated to bring recent St. George's Bay (Areas K+L) effort data into line with the historical time series for the fall fishery (Areas N+M). This was done by using the ratio of 5+ biomass (from trial runs of cohort analysis) in 1973 (last year of historical fall fishery) to the 5+ biomass in 1975 (the first year of the spring fishery). This ratio (0.86) was applied to the 1973 calculated effort to generate an adjusted effort in 1975. The effort data from the spring fishery in subsequent years were adjusted on a proportional basis:

$$\frac{\text{Effort year n+1}}{\text{Effort year n}} = \frac{\text{adj. effort year n+1}}{\text{adj. effort year n}}$$

C6. Assumptions of natural mortality rate:

Values of natural mortality have been variously calculated and assumed for different fish stocks (Pinhorn, 1975; Winters, 1978). The natural mortality rate (M) applied to different herring stocks has varied between 0.10 and 0.20. Cushing and Bridger (1966) calculated M to be equal to 0.20 for North Sea herring. For the two components of the Atlanto-Scandian herring stock natural mortality has been estimated at 0.10 for the Icelandic component and 0.16 for the Norwegian component (Anon., 1979). In herring stocks in the Northwest Atlantic M has generally been assumed to be equal to 0.20 (Winters et al., 1977; Stobo et al., 1978) with the exception of the fall-spawning component of the west coast of Newfoundland stock (Moores, 1979). For this component M was assigned to be equal to 0.15 due to the large numbers of fish age 11 and older in this component which suggested a value of natural mortality lower than that occurring in the spring-spawning component for which M has been assumed to be equal to 0.20. For the following analysis M for spring-spawners was assumed to be 0.20 while for autumn-spawners two options of M (0.20 and 0.15) were assumed to examine whether a reduction in M is valid for this component.

C7. Average weight-at-age:

As the population structure produced by this cohort analysis reflects the stock status as of January 1, weight-at-age data from only the first and second quarters were used to calculate biomass levels for this population structure. All samples from this period were combined without respect to gear to calculate average weight-at-age values. This process was done separately for spring- and fall-spawners (Table 9). Only 1978 data were utilized so that the 1978 biomass was the most accurate with all previous years being expressed in terms of 1978 weight. While this may introduce some bias in terms of the absolute biomass for a particular year by not incorporating yearly variation in growth it provides a relative measure of biomass and permits examination of years for which only minimal weight data were available.

C8. Partial recruitment rates:

Not all age-groups are equally susceptible to the fishing effort either through differences in schooling behaviour or through gear selectivity (Paloheimo and Dickie, 1964; Ricker, 1975). To account for the reduced fishing mortality on these age-groups a partial recruitment vector must be calculated for spawning type in the stock. Two techniques were employed to estimate the partial recruit rate.

A genearl partial recruit rate can be calculated from the F matrix (F at age by year) generated by the cohort analysis. The two most recent years were omitted as they are substantially influenced by the input

Table 9. Partial recruitment rates (PR) and average weight values used in cohort analysis for spring- and autumn-spawning herring of the Newfoundland west coast herring stock.

		Age-group									
		2	3	4	5	6	7	8	9	10	11
Spring-spawners	PR	.10	.25	.40	.55	.70	.90	1.00	1.00	1.00	1.00
	Wgt.	121	161	219	243	265	270	286	310	315	364
Autumn-spawners	PR	.01	.10	.15	.30	.50	.80	.95	1.00	1.00	1.00
	Wgt.	112	162	205	249	253	291	299	302	313	383

partial recruitment rate. Using a trial run of cohort analysis, initiated with previously calculated partial recruitment rates, F values were averaged over the period 1971-75 for each age-group. The average F was then expressed as a percentage of the largest value and used to construct a partial recruitment curve (Fig. 8).

Partial recruitment rates can also be derived empirically (Winters, 1978). This technique compares the percentage at age in the total catch to the percentage at age in the St. John Bay purse seine catch and assumes that the population was randomly mixed in St. John Bay and that the purse seines were non-selective. The ratio of these percentages by age provides a measure of the relative selectivity pattern (Table 10) and by setting the highest value at 1.0 (fully recruited) all other values can be expressed in terms of this value to generate a partial recruitment rate directly or plotted to produce an ogive (Fig. 9).

Both techniques have biases. If partial F values are utilized they may reflect the historical era but not necessarily the last year. The empirical technique assumes that one gear type will reflect the population through random mixing and non-selectivity which may not be true, especially for younger age-groups and is sensitive for small year-classes whose abundance may be masked by dominant year-classes. As the second technique is most influenced by sampling biases the average F method was selected as most appropriate. The partial recruit rates used are presented in Table 9.

These recruitment rates indicate that full recruitment does not occur until several years after full sexual maturity has been reached. This would, however, be expected due to increasing catches made by

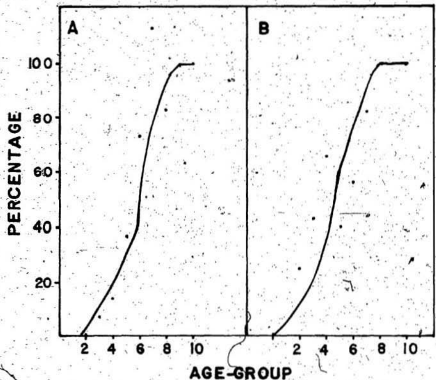

Fig. 8. Recruitment ogives for (A) spring- and (B) autumn-spawning herring of the Newfoundland west coast herring stock derived from the F matrix for 1971-75 generated from trial runs of cohort analysis. (standardized to age 9 and fitted by eye)

Table 10. Empirical estimation of selectivity factors (partial recruitment) for spring- and autumn-spawning herring of the Newfoundland west coast herring stock.

% = per cent-at-age
SJB = St. John Bay purse seine catch which is assumed to be representative of the population.
T = total catch
SF = selectivity factor ie. %T/%SJB

Age	Spring-spawners			Autumn-spawners		
	% SJB	% T	SF	% SJB	% T	SF
2	-	>0.0	-	-	>0.0	-
3	0.2	0.1	0.50	0.7	0.1	0.14
4	18.7	5.7	0.30	1.6	0.3	0.19
5	0.3	0.6	2.00	19.5	4.4	0.23
6	2.8	2.0	0.71	3.4	3.2	0.94
7	0.5	0.7	1.40	5.9	11.1	1.88
8	5.3	6.3	1.19	12.0	17.5	1.46
9	13.2	23.8	1.80	2.5	5.3	2.12
10	41.8	46.3	1.11	3.1	3.3	1,06
11	16.7	14.5	0.87	51.4	54.7	1.06

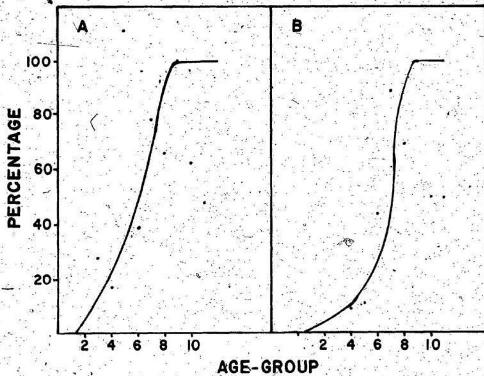

Fig. 9. Recruitment ogives for (A) spring- and (B) autumn-spawning herring of the Newfoundland west coast herring stock derived from a comparison of the age frequency in landings in the fall St. John Bay purse seine fishery to that observed in the total landings during 1978. (fitted by eye)

gillnets which in this area range in size from 2 1/2" to 2 3/4" mesh. The spring-spawners are fully recruited at a younger age than autumn-spawners and are more heavily exploited at younger ages which would be expected due to their heavy exploitation by the relatively non-selective purse seine fishery. The autumn-spawners, which are the main contributor to the gillnet fishery and not as heavily exploited by the purse seine fleet, show a lower partial recruit rate for the younger age-groups.

C9. Trial runs of cohort analysis:

The population structure for both spring- and autumn-spawners of the Newfoundland west coast herring stock was calculated for each fishery year using cohort analysis (Pope, 1972). Cohort analysis is based on the following formula:

$$N_i = C_i e^{M/2} + N_{i+1} e^M$$

where N_i = population of a cohort at the i^{th} year

C_i = catch of a cohort at age i

N_{i+1} = population size at the beginning of the (i+1)th. year

M = instantaneous rate of natural mortality

$N_{i+1} = N_t$ where t represents the last age-group of a year-class for which catch data are available. N_t was calculated from the Baranov (1918) catch equation.

Trial runs of cohort analysis were conducted with a range of terminal F values from 0.05 to 0.40 with M = 0.20 for spring-spawners and M = 0.15 and 0.20 for autumn-spawners. The partial recruitment rates and average weights-at-age used are given in Table 9. From each cohort run a population matrix and an F matrix were produced and total (age-groups 2+) biomass, adult (age-groups 5+) biomass, total number of individuals, number of adults, and a weighted adult fishing mortality (F_{5+}) were calculated.

C10. <u>Selection of fishing mortality in the terminal year (F_T)</u>:

From the various options of F_T the one most accurately representing the stock picture must be selected. This process essentially entails selecting the most appropriate terminal F value. This can be achieved by either examining the relationship of F to effort (Rothschild, 1977) or biomass and catch-per-unit-effort (CPUE) (Ricker, 1975).

A weighted F_{5+} was calculated for each year and each spawning type under each option using the formula:

$$F_{5+} = (-\ln N_{5+}/N_{5+}) - M$$

where F_{5+} and N_{5+} are for year N

and N_{5+} is for year N+1

The effort series used was the historical time series including the adjusted K+L effort for the period 1975-78. A plot of F_{5+} vs. effort for both spring- (Fig. 10a) and fall-spawners (Fig. 10b, 10c) shows a wide scatter in the data points particularly during the earlier years for spring-spawners and during the recent period for fall-spawners.

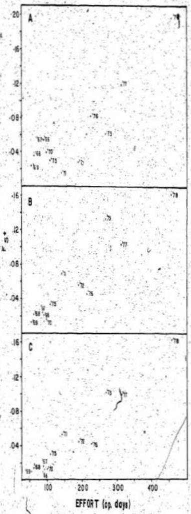

Fig. 10. Relationship of effort (in operating days) to F_{5+} (from cohort analysis) for the Newfoundland west coast herring stock.

A. spring-spawners M = 0.20
B. autumn-spawners M = 0.15
C. autumn-spawners M = 0.20

The data for biomass 5+ and CPUE were plotted for both spring- and autumn-spawners (Fig. 11). It was apparent from the plots that the data could be classified into two discrete periods, one representing the historical time period 1966-72, and another for recent years 1973-78. While this may indicate an inappropriate adjustment of the area K+L CPUE there are two alternative explanations. The break in the data coincides with the recruitment of the strong 1968 year-class of spring-spawners to the adult population and also marks the commencement of the spring purse seine fishery in St. George's Bay. Whatever the cause it is apparent that the data cannot be examined as a time series from 1966-78 but must be analyzed on the basis of a "recent" and a "historical" period. When using the two periods the nature of the fishery must be considered such that as the spring fishery exploits primarily pre-spawning concentrations of spring-spawners the data for K+L can only be applied to the spring-spawning component while for the fall period which exploits both autumn- and spring-spawners the data should be combined.

For the historical period 1966-73 the biomass 5+ of autumn-spawners and spring-spawners were added and regressed against CPUE for that time period. With M = 0.20 for both autumn- and spring-spawners the best correlation was achieved at F_T = 0.20 (linear regression r = 0.91, power curve r = 0.94). When M = 0.15 was used for autumn-spawners the correlation coefficients increased with increasing F_T but the correlation coefficients were lower than those achieved with M = 0.20.

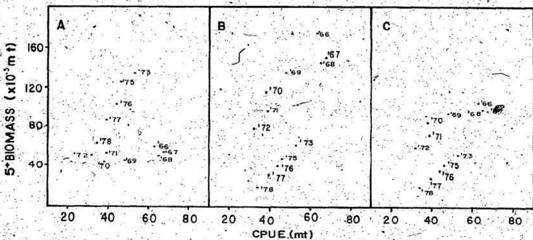

Fig. 11. Relationship of CPUE (tons/operating day) to 5+ biomass for the Newfoundland west coast herring stock.

A. spring-spawners M = 0.20
B. autumn-spawners M = 0.20
C. autumn-spawners M = 0.15

The recent period was examined using the actual K+L effort and CPUE data. The regression of F_{5+} for spring-spawners on effort for this period showed a peak of $F_T = 0.20$ ($r = 0.99997$) however the r^2 values for F_T values from 0.05 to 0.30 were all greater than 0.99. The predicted F_{5+} for 1978 indicated that F_T was below 0.20. The relationship of 5+ biomass and CPUE for the 1975-77 period showed an increasing trend with F_T but the correlation coefficients were again very close.

Between year mortalities were also calculated according to the method of Paloheimo (1961) given by the formula:

$$P_Z = -\ln\left[{}^{C_2}/_{f_2} \Big/ {}^{C_1}/_{f_1} \right]$$

where P_Z = Paloheimo Z value

C_1 = catch in numbers year n ages 5+

C_2 = catch in numbers year n+1 ages 6+

f_1 = effort year n

f_2 = effort n+1

By subtracting natural mortality of 0.20 a value of F can be obtained. The following values were obtained:

Year	1975/76	1976/77	1977/78
P_Z	0.97	0.59	0.71
F	0.77	0.39	0.51

The values of F generated by the Paloheimo method are substantially higher than those generated by cohort analysis and also display a differing pattern. While the F values generated by cohort show an increase in recent years the Paloheimo values are variable but highest in the 1975/76 period. The variability in the F values derived from the Paloheimo method do not reflect the increasing catch levels observed in the stock which when coupled with poor recruitment should produce an increasing trend in F and therefore cannot be used to determine the terminal F level.

The analysis of both the "historical" and "recent" periods suggests that a terminal F of 0.20 in 1978 is the most appropriate to use. Due to the better correlations achieved with an M = 0.20 for autumn-spawners this value of natural mortality was selected.

C11. Results of cohort analysis (F_T = 0.20; M = 0.20):

a. Population size: The population matrices for F = 0.20 and M = 0.20 are given in Tables 11 and 12. The west coast herring stock reached a peak in 1971 with a 2+ biomass of 285,000 mt with peak numbers of 1,170 million individuals in 1972 (Table 13). The trend in the two components of this stock have been very different. The autumn-spawners have shown a decline for the entire period covered by the analysis. Its biomass has been reduced from a high of 201.5 thousand mt in 1966 to 21.5 thousand mt in 1978. The spring-spawners increased from a low of 74.7 thousand mt in 1966 increasing to a peak biomass of

Table 11. Results of cohort analysis of spring-spawning herring of the Newfoundland west coast herring stock (F_T = 0.20; M = 0.20). Population numbers (N) are in thousands and biomass (B) is in metric tons.

	Year												
Age	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
2	14657	44148	145277	44171	715279	238382	48260	6966	17223	6635	44478	1255	56
3	39136	11844	36144	118851	35973	582565	195170	39145	5513	14045	5326	35955	1017
4	21866	31718	9689	29268	96304	28036	474181	159552	31961	4411	10638	3461	28835
5	52356	17649	25662	7751	22582	78498	22699	382497	129939	26144	3136	7821	2347
6	56302	42367	14395	20581	6038	17996	63736	17905	298490	106203	21140	2360	5923
7	48712	44348	34448	11670	16562	4729	14472	51453	13510	239363	85557	17007	1656
8	38480	36362	33240	27696	9395	13384	3736	10998	39527	10929	188364	67497	13595
9	19564	29666	27324	26101	22277	7475	10680	2870	7818	31662	8735	140145	51438
10	7826	14593	23237	20347	20498	17345	6037	8292	1080	5963	25592	6449	99854
11+	4083	9050	17889	32908	42865	49495	53718	47811	41339	32829	30920	40246	31329
N_2+	302982	281745	367305	339344	987773	1037905	892689	727489	586400	478184	423886	322196	236050
N_5+	227323	194035	176195	147054	140217	188922	175078	521826	531703	453093	363444	281525	206142
B_2+	74679	69171	76680	75777	156642	183523	193254	177722	153409	129924	113930	93246	71764
B_5+	61816	54976	51160	44887	43211	54746	52147	135635	143439	125894	105361	86547	65278
F_5+	.054	.054	.035	.023	.039	.015	.028	.061	.019	.029	.081	.118	.197

Table 12. Results of cohort analysis of autumn-spawning herring of the Newfoundland west coast herring stock (F_T = 0.20; M = 0.20). Population numbers (N) are in thousands and biomass (B) is in metric tons.

Age	Year 1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
2	53801	19219	8655	7121	12077	16607	39981	21886	8075	14223	1675	681	552
3	94617	43948	15734	7085	5815	9887	13570	32723	17918	6610	11644	1371	557
4	23273	77289	35955	12676	5530	4064	8094	11037	26527	14659	5327	9476	1119
5	36290	18482	63233	29319	9898	4400	3326	6543	8614	21591	11836	4315	7703
6	38603	29465	14642	51584	23758	7972	3553	2660	4788	6953	16602	9583	3426
7	41004	31360	23840	11037	41679	19258	6217	2684	1649	3869	5376	13287	7576
8	211630	33325	25568	19251	8569	33700	14908	4795	1317	1244	3092	3984	10220
9	148572	172367	26983	20731	15620	6855	25729	11823	2985	1026	917	2437	2924
10	55103	120653	140260	21828	16865	12672	4624	20257	7669	2267	777	609	1808
11+	50218	82916	162716	244656	216891	189247	157810	127088	110693	94765	76277	55856	30441
N_2+	753111	629024	517586	425288	356702	304662	277812	241496	190285	167207	133523	101599	66326
N_5+	581420	488568	457242	398406	333280	274104	216167	175850	137715	131715	114877	90071	64098
B_2+	201486	177838	159290	140659	119659	101606	85988	73118	59172	51617	42537	33117	21535
B_5+	175362	152722	148401	136115	116231	97311	77652	63103	49927	45948	39371	30876	21154
F_5+	.013	.015	.014	.009	.012	.053	.044	.109	.024	.029	.042	.098	.162

Table 13. A summary of 2+ and 5+ population numbers and 2+ and 5+ biomass of autumn- (AS) and spring-spawning (SS) herring from the Newfoundland west coast herring stock for the years 1966-78 as derived from cohort analysis. (N = population numbers in thousands; B = biomass in metric tons)

		Year												
		1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
N_2+	SS	303.0	281.7	367.3	339.3	987.8	1037.9	892.7	727.5	586.4	478.2	423.9	322.2	236.1
($x10^{-6}$)	AS	753.1	629.0	517.6	425.3	356.7	304.7	277.8	241.5	190.2	167.2	133.5	101.6	66.3
TOTAL		1056.1	910.7	884.9	764.6	1344.5	1342.6	1170.5	969.0	776.6	645.4	557.4	423.8	302.4
N_5+	SS	227.3	194.0	176.2	147.1	140.2	188.9	175.1	521.8	531.7	453.1	363.4	281.5	206.1
($x10^{-6}$)	AS	581.4	488.6	457.2	398.4	333.3	274.1	216.2	175.9	137.7	131.7	114.9	90.1	64.1
TOTAL		808.7	682.6	633.4	545.5	473.5	463.0	391.3	697.7	669.4	584.8	478.3	371.6	270.2
B_2+	SS	74.7	69.2	76.7	75.8	156.6	183.5	193.3	177.7	153.4	129.9	113.9	93.2	71.8
($x10^{-3}$)	AS	201.5	177.8	159.3	140.7	119.7	101.6	86.0	73.1	59.2	51.6	42.5	33.1	21.5
TOTAL		276.2	247.0	236.0	216.5	276.3	285.1	279.3	250.8	212.6	181.5	156.4	126.3	93.3
B_5+	SS	61.8	55.0	51.2	44.9	43.2	54.7	52.1	135.6	143.4	125.9	105.4	86.5	65.3
($x10^{-3}$)	AS	175.4	152.7	148.4	136.1	116.2	97.3	77.7	63.1	49.9	45.9	39.4	30.9	21.2
TOTAL		237.2	207.7	199.6	181.0	159.4	152.0	129.9	198.7	193.3	171.8	144.8	117.4	86.5

193.3 thousand mt in 1972 with the recruitment of the strong 1968 and moderate 1969 year-classes. Since 1972 this component has been declining and in 1978 approached the biomass levels observed in 1966. With the exception of the period from 1970 to 1972 the stock has been showing a general decline (Fig. 12a).

The trends in population numbers are similar to that observed for the biomass. Prior to 1970 the autumn-spawners were the dominant component in the stock representing 70% of the total number of individuals. Since 1970 there has been a reversal in spawning type with spring-spawners accounting for approximately 75% of the stock (Fig. 12b). This reversal of spawning type dominance appears to be a return to the historically observed stock composition. Studies by Olsen (1961) indicated the west coast of Newfoundland to be primarily spring-spawners. This pattern has also been observed by Winters et al. (1977) for the southern Gulf of St. Lawrence stock. In the mid 1950's this stock was decimated by a fungus disease, Icthyosporidium hoferri (Sinderman, 1966; Tibbo and Graham, 1963). The stock was characterized during the 1960's as being primarily autumn-spawning with the production of the large 1958 year-class of autumn-spawners. With improved recruitment to the spring-spawning component this was reversed in the early 1970's.

b. Trends in F: An examination of the weighted F_5+ values generated on this stock (Table 11 and 12) indicate a relatively low level of exploitation. The fishing mortality was higher on spring-spawners from 1966 to 1970 when spring-spawning stock size was low and from 1975 to 1978 with the commencement of the spring fishery in St. George's Bay.

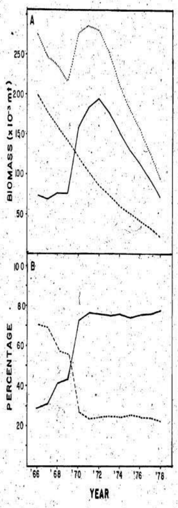

Fig. 12A. Trend in 2+ (thousands of metric tons) biomass of spring- and autumn-spawning herring and both combined for the Newfoundland west coast herring stock during the period 1966-78.

Fig. 12B. Trend in spawning type composition of the Newfoundland west coast herring stock for the period 1966-78. 2+ population numbers expressed as a percentage.

— spring-spawners; - - - autumn-spawners; .... total

c. Trends in recruitment: Recruitment to the autumn-spawning component has been poor for the entire period covered by the analysis, with this component being represented primarily by the 1958 year-class (Table 12). Recruitment, at age 2, for the year-classes 1964-76 has averaged 1.6×10^7 individuals.

The spring-spawning component has shown a better recruitment pattern (Table 11) with the strong 1968 year-class and the moderate 1969 year-class. Since 1969 recruitment has generally been poor, with the exception of the 1974 year-class. Average recruitment, at age 2, for this component has been 1.0×10^8 individuals. While this appears to be much higher than for autumn-spawners the average is strongly influenced by the 1968 and 1969 year-classes.

C12. Calculation of the $F_{0.1}$ fishing mortality rate:

Yield-per-recruit curves were generated separately for both spring- and autumn-spawners using the method of Thompson and Bell (1934) and incorporated the average weights-at-age and partial recruitment rates utilized in the cohort analysis (Table 9) with M = 0.20. The resultant curves generated by plotting the yield at various levels of fully recruited fishing mortality are shown in Fig. 13. These yield curves are relatively flat topped and do not produce an asymptotic level that would correspond to a maximum sustainable yield (MSY) level. However, the fishing mortality required to give the "optimum yield" ($F_{0.1}$) can be derived from

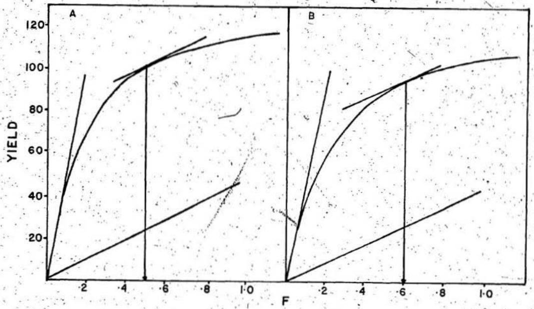

Fig. 13. Yield-per-recruit curves for (A) spring- and (B) autumn-spawning herring from the Newfoundland west coast herring stock showing derivation of the $F_{0.1}$ level of fishing mortality. (see text for explanation)

these curves. The $F_{0.1}$ level is that level at which an increase of one unit of fishing effort produces only one-tenth the yield derived by adding an additional unit during the initial phase of the fishery (Gulland and Borema, 1973). The initial yield can be described by a line tangential to the yield curve at the left-hand limb and was approximated by passing a straight line through the yield-per-recruit value generated at F = 0.0 and F = 0.05. The point at which a line, with 1/10 the slope of the tangent at initial yield levels, is tangential to the yield curve is the $F_{0.1}$ yield-per-recruit with the F required to generate this yield being equivalent to the $F_{0.1}$ level of fishing mortality.

The $F_{0.1}$ level for autumn-spawners was 0.60 and for spring-spawners it was 0.50 (Fig. 13). The higher $F_{0.1}$ for autumn-spawners is due to the lower partial recruitment rates which necessitate a higher fully recruited F to generate the optimum yield. If an average F is calculated for fully mature age-groups (5+) the resultant F values are much lower and equal to 0.44 for spring-spawners and 0.48 for autumn-spawners. The average F for ages 2+ for both components was 0.35.

C13. <u>Stock projection:</u>

While cohort analysis provides a detailed picture of the historical stock situation, it does not provide information regarding the future of the stock or appropriate catch levels. Accepting the 1978 population structure generated with an F_T = 0.20 the stock was projected to 1985 assuming M = 0.20, that partial recruitment pattern and average weights would remain unchanged from 1978 and assuming a pattern of poor recruitment (numbers of recruits at age 2 = 1.0×10^7) and $F = F_{0.1}$.

Under these assumptions the 1979 catch would be 24,000 mt (Table 14) declining steadily to 2,000 mt in 1985. The catch levels for 1980 onward should be considered as minimum estimates due to the very conservative levels of recruitment which have been assumed. Recruitment has been assumed to be equivalent to the lowest observed which for spring-spawners is 1/70 of the strong 1968 year-class. The production of one large year-class or several moderate year-classes would increase the projected catch levels.

Also, the 1978 population structure which is derived from cohort analysis, is inherently the most inaccurate of the cohort time series (1966-78) and its use as the basis for projection introduces a possible error, whose direction and magnitude are both unknown.

Due to the variability in year-class strength observed in herring stocks, the lack of abundance data independent of commercial information and the assumption that the exploitation pattern will remain the same, long term projections of yield for herring stocks are very suspect. However, short term projections of one to two years provide a reasonable basis for formulating advice on catch levels as they incorporate the best estimate of the population status and are not highly dependent upon incoming recruitment.

Table 14. Results of a stock projection of the Newfoundland west coast herring stock. 1978 population structure derived from cohort analysis and projection performed assuming M = 0.20. The catch is at the $F_{0.1}$ level with a constant recruitment of 1.0×10^7 recruits for each spawning component. (AS = autumn-spawners; SS = spring-spawners)

Year	5+ Number			5+ Biomass			Catch (mt)		
	AS	SS	Total	AS	SS	Total	AS	SS	Total
1978	64100	206141	270241	21154	65278	86432			
1979	45151	160390	205541	15026	52909	67935	5826	18289	24115
1980	21982	83155	105137	7441	28345	35786	3031	10031	13062
1981	10536	42496	53032	3659	14585	18244	1644	5566	7210
1982	9573	25103	34676	2899	8303	11202	1054	3245	4299
1983	10137	16716	26853	2787	5272	8059	873	2101	2974
1984	10863	12734	23597	2926	3767	6693	896	1549	2445
1985	11295	10791	22086	3015	3056	6071	928	1294	2222

C14. Stock and recruit relationships:

Recruitment in pelagic stocks in highly variable and along the west coast of Newfoundland has varied by as much as 100 times (Fig. 14). Since 1964 the spring-spawners have shown much stronger recruitment than the autumn-spawners. Of particular significance have been the 1966 and 1968 year-classes of spring-spawners. In recent years, recruitment has been poor in both spawning groups particularly in autumn-spawners. The 1974 year-class of spring-spawners appears, however, to be promising.

The causes of fluctuations in year-class strength has been an area of intensive investigation for many stocks. The stock and recruit relationship for west coast herring was examined in terms of both adult (5+) population numbers and adult (5+) population biomass for both spawning components (Fig. 15). In neither case was there a clearly definable stock and recruit relationship. Stock and recruit relationships have been postulated for several European stocks (see Proceedings of the Symposium on the Biological Basis of Pelagic Fish Stock Management (in press)) and the relationships have been utilized to establish minimum spawning biomass levels for these stocks. The principal of minimum stock biomass has then become the key management consideration for these stocks. As stock and recruit relationships have not been demonstrated for the northwest Atlantic herring stocks, the $F_{0.1}$ level remains the primary reference point for management consideration.

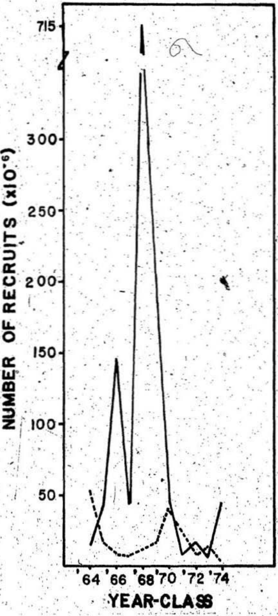

Fig. 14. Variability in year-class size of spring- and autumn-spawning herring of the Newfoundland west coast herring stock.

— spring-spawners; - - - autumn-spawners

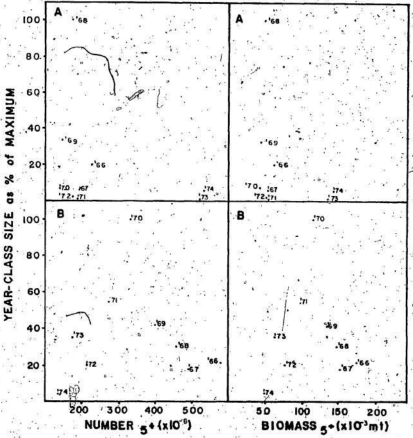

Fig. 15. Relationship of year-class size (as a per cent of largest observed) to adult (5+) population numbers and biomass for (A) spring- and (B) autumn-spawning herring of the Newfoundland west coast herring stock.

DISCUSSION

The Newfoundland west coast herring stock has been defined primarily on the basis of tagging studies. These studies indicated that this management unit is independent of the adjacent southern Gulf of St. Lawrence and east coast Newfoundland herring stocks. The presence of several known spawning sites within the area suggests that several populations are present such that the west coast stock is in reality a stock-complex. While the tagging data indicate an extensive intermix within the stock area, the experiments were not designed to assess the relative contribution of particular populations to the total catch. If it were possible to determine the relative contribution of each population to the fishery, then a separate analysis of the population dynamics of each could be performed as has been done for the two spawning types. While the management area would have to remain the same due to the fishing pattern, a more precise evaluation of how the fishing pressure was being distributed over the stock could be undertaken. This would allow for a more detailed management strategy and help optimize the yield. In the North Sea stock three component stocks have been identified yet have to be managed as a unit as no means can be found to calculate the removals from each component in areas where mixing occurs (Burd, 1978).

Due to a lack of knowledge as to what extent the progeny of the various spawning sites contribute to each of the fisheries, it is difficult to examine any of the biological characteristics in any terms other than a general stock approach.

Hubold (1978) suggested that for North Sea herring the onset of maturity is length dependent. Studies on spring-spawners in Fortune Bay, Newfoundland, support this view showing a relatively stable length at 50% maturity while age at 50% maturity showed greater variability (Moores and Winters, 1978). The average values of 50% maturity for Fortune Bay during the period 1968-76 were 3.13 years and 27.09 cm which compares closely to the values derived for spring-spawners from the west coast of Newfoundland where the average values from 1975-78 were 3.29 years and 27.18 cm.

Similarity in growth rates were found between year-classes and spawning areas along the west coast of Newfoundland. These rates also agree with empirical data derived from the fall mixed fishery and suggest a uniformity in growth throughout the area. Tibbo (1957) found this consistency in growth occurring in the various herring stocks along the Atlantic coast of Nova Scotia as did Saville (1978) for herring in the North Sea. Ware and Henriksen (1978), however, in an examination of larval growth of herring in the Gulf of St. Lawrence used differences in growth rate to identify four spawning populations (2 spring-spawning groups and 2 fall-spawning groups). Saville (1978) suggested that similarity in growth observed over a wide geographical area may indicate general environmental control over growth. The same results, however, would be observed if juveniles of the component populations occupy the same feed grounds.

Having defined the Newfoundland west coast management area, and as similar growth patterns were found throughout the stock area, the population dynamics of these herring were assessed as a unit stock. The analysis represents an average picture of the herring populations within the area without attempting to assess the relative contributions from each spawning site and the possible differential exploitation rates exerted on each of these components. However, sub-allocation of the total allowable catch (TAC) over the stock both by both area and season, should reduce the potential for over-exploitation of any particular spawning population.

As with all models the use of cohort analysis and commercial catch data to evaluate the population dynamics of a pelagic fish stock has certain weaknesses. One of the major concerns has been the use of CPUE and effort data derived from purse seine vessels as a measure of abundance (Rothschild, 1977; Ulltang, 1977). Herring form dense schools and a reduction in abundance would be reflected in a reduction in the number or size of schools. The density within a given school would remain relatively constant. Changes in stock abundance would affect the amount of time spent searching for schools but once a school is encountered catch rates would remain fairly constant irregardless of population size. If fishing effort is concentrated during seasons when schools are most dense searching time would be minimal. Thus, commercial effort data may not reflect changes in population abundance.

In this study catch rates were found to be variable depending upon the season, limiting the value of the time series available. In addition, the calculation of total effort (total catch/CPUE purse seine) may be biased due to the variability in the relative proportion of fixed gear catch. With a rapidly changing component in the fishery the relationship between CPUE and biomass appears to be a more reliable indicator of abundance than total effort and fishing mortality. Ulltang (1977) has suggested that where possible independent estimates of abundance, such as research vessel catch rates or acoustic estimates of biomass, should be used to evaluate commercial catch rate data for calibrating the estimate of terminal fishing mortality.

In spite of the problems inherent in such stock assessment work the methods used to assess the status of the west coast herring stock should provide reasonable estimates of the stock size and its dynamics, particularly for the historical period covered (Pope, 1972). These estimates can, therefore, provide a sound basis for advice upon which management strategies can be formulated. As the data base is improved the models should be refined to incorporate environmental and spawning population influences. As with most pelagic stocks a wide variation in abundance was observed in the Newfoundland west coast herring stock. This variation is attributable, primarily, to fluctuations in year-class strength. In addition to affecting total abundance the relative strength of year-classes of the two spawning components affects the stock composition such that a complete reversal of the predominant spawning type component in the stock has occurred. While this variability in year-class strength has been observed no stock and recruit relationship was observed. However, if a stock and recruit relationship does exist it may have been masked by environmental factors as was indicated by Moores and Winters (1978) for the southern Gulf herring stock. No comprehensive data on environmental factors is currently available for the west coast of Newfoundland with the closest stations being at Entry Island in the southern Gulf of St. Lawrence and Station 27 off St. John's, Newfoundland.

The fishery exploiting this stock has also been very dynamic. Catches along the west coast have increased steadily since the mid-seventies first in the purse seine sector then in the inshore component. These changes have created difficulty in interpreting the CPUE and effort series and have also changed the partial recruitment rates related to an expansion in the fixed gear effort. If expansion continues in the fixed gear component a further reduction in the partial recruitment rates will be required to reflect the increasing proportion of older fish taken by gillnets with subsequent changes reflected in the $F_{0.1}$ level.

The period covered by the analysis shows an improving pattern in the Newfoundland west coast spring-spawning component with a continual decline in autumn-spawners. The extent to which this pattern continues depends upon recruitment. Total allowable catch levels of

12,500 mt set in 1977 would appear to have been conservative, based on these analyses, and the higher $F_{0.1}$ catch level reflects a more detailed evaluation of partial recruitment rates and recruitment.

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