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Canadian Stock Assessment Secretariat
Research Document 99/63

Secrétariat canadien pour l'évaluation des stocks
Document de recherche 99/63

A Proposed Acoustic Survey Design for 4WX Herring Spawning Components

by

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ISSN 1480-4883
Ottawa, 1999
Canada

Abstract:

Over the past several years the 4WX herring stock complex has been assessed using input from industry based acoustic surveys and fishing excursions. Unfortunately, the data have been collected in somewhat of an *ad hoc* manner. The results, while providing valuable information on the abundance of herring on specific spawning grounds, are not comparable from year to year due to restricted coverage and only provide a minimum biomass of the fish observed on the day surveyed. To overcome this problem, data from the fishery are used to identify potential survey areas from the distribution of catches during the spawning season. The survey coverage area is further reduced by isolating the locations which contains more than 90% of reported landings. Thereafter, standard random transects are selected within the survey area and a protocol recommended for instances when fish are observed beyond the survey boundaries. Standarization of the survey area provides a means to compare observations from year to year and forms the basis for an index of abundance in years to come.

Résumé :

Au cours des dernières années, le complexe de stocks de hareng de 4WX a été évalué à l'aide des résultats des relevés acoustiques et des sorties de pêche de l'industrie. Malheureusement, les données ont été recueillies de façon plutôt ponctuelle. Les résultats obtenus, qui constituent une source d'information valable sur l'abondance du hareng dans certaines zones de frai, ne peuvent cependant être comparés d'année en année à cause de la couverture limitée et ne permettent d'obtenir qu'une biomasse minimale du poisson observé le jour du relevé. Pour résoudre ce problème, les données de la pêcherie sont utilisées pour définir des zones potentielles de relevé à partir de la distribution des captures pendant la saison du frai. La zone de couverture du relevé est de plus réduite en isolant les lieux où l'on retrouve plus de 90 % des débarquements signalés. Ensuite, des transects aléatoires normalisés sont choisis dans la zone de relevé et un protocole est recommandé pour les occasions où du poisson est observé au-delà des limites de la zone du relevé. La normalisation de la zone de relevé constitue un moyen de comparer les observations de d'année en année et forme la base d'un indice d'abondance pour les années suivantes.

Introduction:

Over the past two years industry based acoustic surveys of herring spawning grounds in NAFO Sub-division 4WX have become a common event and an integral aspect of assessment and management (Anon 1997, Melvin et. al. 1998a, Stephenson et. al. 1998). This new approach to assessing the abundance of fish in a limited area has evolved since 1995 when biomass estimates of the stock complex declined dramatically and the annual quota was reduced accordingly. The 4WX herring Total Allowable Catch (TAC) was reduced from 151,000t to 80,000t in 1995 and further reduced to 50,000t due to continuing negative signs in 1996. The primary concern, given such a low stock biomass, was systematic erosion of the individual spawning components within the stock complex if a large proportion of the TAC was taken from an individual component.

To address this concern the Department of Fisheries and Oceans (DFO) and the herring industry implemented a protocol, now known as the "Survey, Assess, then Fish", to provide a second level of protection for the individual spawning grounds. Initially, industry based surveys (i.e., those conducted using commercial fishing vessels) were undertaken to establish a rough estimate of fish biomass, prior to opening the area to fishing during the spawning season. The process involved using standard acoustic hardware aboard the purse seiners to survey a fishing area and the captain's experience to estimate quantity. Upon completion of a survey, a consensus was reached between the participating vessels and the DFO observer on the tonnage and biological characteristics of herring observed. The results were then immediately reported to a Working Group consisting of representatives from DFO Science, DFO Management, Herring Associations and processors. If sufficient quantities of fish were observed the fleet was then allowed to remove a portion (up to 20%) of the documented biomass. If a small biomass was reported, the area remained closed to fishing until more fish were documented for the area. (i.e. another survey was undertaken).

While the above approach served to provide a second level of protection for individual spawning components, it became apparent that a more quantitative and defensible sampling approach was required for assessment purposes. To meet this requirement an automated acoustic logging system was developed, in conjunction with Femto Electronics Inc., for deployment aboard commercial purse seiners (Melvin et. al.1998b). The system was designed for simple operation (an on/off switch) and to utilise the vessel's existing acoustic hardware (i.e. sounder and sonar) and navigation instruments to log the distribution and abundance of fish from the commercial vessel. The sounder/transducer was also calibrated, using a tungsten-carbide ball, for echo integration and subsequent biomass estimates.

The automated logging systems have been used to document herring distribution and abundance during standard fishing operations and during structured surveys since 1997. The structured surveys are used to document the abundance of herring on the individual spawning grounds prior to fishing (i.e., in-season management). In this way fishing effort on the individual spawning components, was restricted within the TAC. Unfortunately, the surveys were established to cover only the area where the fleet observed herring. Coverage

area changed from night to night and from year to year. The result was that while the surveys provided an estimate of abundance for the area covered, they could not be compared from year to year in that they reflected a minimum biomass estimate of the survey area. On several occasions herring were observed and captured outside the survey area by non-participating vessels.

Both the survey program and the automated logging systems have been well received by industry and DFO, and the data collect by the recorders incorporated into the stock assessment process (Melvin et. al. 1998a). During the 1998 Regional Assessment Process (RAP) biomass estimates from the acoustic surveys were weighted heavily in assessing the 4WX stock status (Anon 1999, Stephenson et al 1998). Estimates from industry and DFO surveys were combined to produce a minimum biomass estimate for the spawning stock. It was however recognised that the data could not be directly compared from year to year, that the biomass estimates could not be used as an index of abundance and that some standardisation of survey approach was required.

The purpose of this report is to describe a survey approach which will incorporate standard acoustic protocol (i.e. randomly selected transects) and pre-defined strata into the industry surveys. In this way the area covered will be consistent from survey to survey, year to year and will allow for the inter-annual comparison of the data and its possible use as an index of abundance sometime in the future (5-7 years).

Methods:

To address the problem of where the surveys are to be conducted to represent a spawning area and to be comparable from survey to survey, the landing statistics for each of the major spawning components were examined to identify herring distribution during the spawning season. It was assumed that the reported landings are representative of fish distribution and that over a 4-5 week period the fishery would cover most of the areas where herring occurred. Figure 1 displays the location of the three 4WX spawning areas discussed in this report; German Bank, Trinity Ledge and Scots Bay.

The initial step in the process was to identify from sampling data the appropriate time of the year when fish were aggregated on the grounds for spawning. Historical data indicates that the approximate spawning season for Scots Bay was July 20 - August 20, for Trinity Ledge August 15 - September 15 and for German Bank September 10 - October 10. Examination of herring catches over several years (1995 to 1998) for each spawning area during the defined spawning season indicated a rather broad geographical distribution (Figures 2a, 3a, and 4a). The spawning grounds were further contracted using sites which contained ripe and running fish, to isolate the area which best represents the actual potential spawning locations. The proposed boundaries for each spawning ground are described in Table 1 and shown in figures 2b, 3b, and 4b).

Evident from the data are areas at each spawning location which over time consistently represent the majority of catches. Therefore, survey effort for all three spawning components could be vastly reduced by concentrating vessel time in the areas (i.e., strata) which for 1995-98 comprise the largest portion of reported landings. For the purpose of

this report it was decided that the survey must cover an area from which 90% of the reported landings were taken (Table 2). Using this approach the actual survey area was reduced by 85.9% on German Bank, 67.5% on Trinity Ledge and 73.7% in Scots Bay (Table 3). German Bank was further sub-divided into 3 strata to encompass some observed inter-year variability. However, for any given survey priority would be given to surveying stratum 2 where the majority (>90%) of past landings have been reported (Figure 4a). In the event fish are observed or thought to occur outside the primary stratum, pre-define survey strata which encompass 99% of reported landings, are available for the survey vessels. This does not preclude the possibility of surveying (protocol to be established) outside the defined strata, but it does require that the primary stratum be surveyed first to ensure herring are not present. In this way the data collected from the main strata within each spawning area can be compared for consistent location from year to year, thereby allowing annual biomass estimates from each component to track trends in the stock.

For each of the above described strata a series of 12 randomly selected transects, complete with start/stop positions and the distance from the southwestern boundary, were generated (Table 4-6, Figures 2-4). Protocol requires that the main stratum be covered each time a survey is undertaken. Thereafter, additional areas or strata (e.g. German Bank) may be surveyed. The procedure to be followed is that each vessel taking part in a survey selects a transect in sequence, beginning with transect 1 and ending with transect 12. Because most vessels participating in these surveys have sonar equipment capable of observing fish up to 500m either side of the vessel a minimum distance of 0.5 km between transects may be used to eliminate transects in close proximity. This distance (km) from the southwest corner of a strata is provided with each series of transects. If two transects in the sequence are found to be closer than 0.5 km the latter is simply rejected and the next line in the series is used. To obtain a reasonable estimate of error a minimum of 4 transects must be completed in each strata before a survey is considered valid.

In some instances a large aggregation of fish may be found confined to a small section of the survey area. If this occurs it is imperative that the initial 4 transects have been run their full length to provide coverage of the entire stratum. However, upon completing these transects the remaining lines can be shortened to concentrate on that portion of the stratum where fish were observed. Although this will save time and fuel for survey participants, it is important that the shortened lines be the random transects. Alternatively, fish may be observed outside the predefined survey area. In this event the spawning component strata should be surveyed first for year to year comparison. Thereafter, a series of transects can be established to delineate the fish. A new series of random transects can be generated for each designated survey or they can remain fixed for the year.

Discussion

Hydroacoustic surveys are used to estimate biomass of several pelagic fish stocks in eastern Canada (Carscadden 1997; McQuinn and Lefebvre 1997; Wheeler 1998) and throughout the world (Simmonds et. al. 1997; Vilhjalmsson et. al 1997). The approach used in the survey design is to cover most, if not all, of the geographical distribution of the target species with one or more dedicated research vessels. Unfortunately for 4WX herring, the potential distribution area is large and prohibitive and research vessel time limited.

Current initiatives under the "Survey, Assess, then Fish" protcol (Melvin et. al 1998a; Stephenson et. al 1998) using commercial fishing vessels and the automated logging system to survey individual spawning components have provided minimum biomass estimates. However, because the coverage is restricted, no comparisons can be made from year to year or in many cases from night to night. Therefore, stock trends are not reflected in the biomass estimates from these surveys.

The approach described above provides a method for annual comparison of biomass from each of the three major spawning components within the 4WX stock complex. In addition, it removes the ambiguity of how/where a survey should be conducted and it provides detailed survey instructions for the vessel captains, including specific transects to be run by the vessels involved in the survey. Transects are simply followed in sequence after removal of lines which fall within the minimum separation distance (recommended 0.5 km). Biomass estimates are based on standard acoustic protocol and error estimates are consistent with sampling theory.

The standardisation of industry based structured surveys means that the results can be compared either intra or inter yearly for each of the three main spawning components and a biomass estimate determined which encompasses most of the spawning area. Unlike the situation where fishing excursions documented distribution and abundance for a restricted area, the size of the spawning component can now be estimated and compared to investigate stock trends. For cases of multiple surveys in a single spawning season, the biomass estimates can be considered cumulative assuming sufficient time had elapsed between surveys (Stephenson et al. 1998; Paul 1998).

The defined spawning area, dates of the spawning season and the time series of landings used to determine the most appropriate area to survey are open for discussion given the limited time series of data (1995-98) used in this analysis. It is however unlikely that the inclusion of more years of data will alter the proposed strata by any significant amount. Additional years of data will be examined during 1999 to confirm this assumption. Furthermore, the survey design is flexible enough to account for changes in actual spawning location in that other areas of the bank can be surveyed after the predefined strata have been evaluated.

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Table 1. Latitudinal and longitudinal boundaries for German Bank, Trinity Ledge and Scots Bay spawning components in degrees and minutes. This represents the maximum area within which ripe and running herring would be associated with an individual spawning ground.

Location	Southwest		Northwest		Northeast		Southeast	
	Lat	Long	Lat	Long	Lat	Long	Lat	Long
German Bank	43 10	66 40	43 40	66 40	43 40	66 10	43 10	66 10
Trinity Ledge	43 50	66 25	44 10	66 25	44 10	66 10	43 50	66 10
Scots Bay	45 00	65 20	45 15	65 20	45 20	64 50	45 12	64 40

Table 2. Coordinates of strata within each spawning component for German Bank, Trinity Ledge and Scots Bay in degrees, minutes and decimal minutes.

Location:	Latitude		Longitude	
	Min	Max	Min	Max
German Bank				
Strata 1	43° 14.0'	43° 34.0'	66° 24.0'	66° 14.0'
Strata 2	43° 14.0'	43° 30.0'	66° 30.6'	66° 24.0'
Strata 3	43° 17.0'	43° 34.0'	66° 14.0'	66° 09.6'
Trinity Ledge				
Strata 1	43° 55.0'	44° 05.0'	66° 25.0'	66° 15.0'
Scots Bay				
Strata 1	45° 02.0'	45° 20.0'	65° 12.0'	64° 42.0'

Table 3. Comparison of proposed spawning component strata, spawning season landings, landings, area of coverage and percent of reported landing for 1995-98. The survey strata represent only a fraction of the area of the spawning component. Primary strata are those with boldface percentages.

Location	Area (km^2)	Percent Area	Total Landings (t)	Percent Landings
German Bank	3353	100	47,518	100
Strata 1	302	9.0	2,433	5.1
Strata 2	474	**14.1**	44,547	**93.7**
Strata 3	170	5.1	102	0.2
Trinity Ledge	741	100	4.385	100
Strata 1	241	**32.5**	4,074	**92.9**
Scots Bay	2708	100	19,437	100
Strata 1	712	**26.3**	17,926	**92.2**

Table 4. A series of 12 randomly selected transects for each of the three stratum on German Bank. Co-ordinates are in degrees, minutes and decimal minutes. Distance is measured from the south-western boundary of each box. The primary strata is boldfaced.

Location/ Strata	Transect Number	Start Lat	Start Long	End Lat	End Long	Distance (km)
German Bank						
Strata 1	1	4314.00	6630.34	4330.00	6630.34	0.35
	2	4314.00	6629.22	4330.00	6629.22	1.86
	3	4314.00	6627.94	4330.00	6627.94	3.58
	4	4314.00	6624.32	4330.00	6624.32	1.86
	5	4314.00	6626.95	4330.00	6626.95	4.91
	6	4314.00	6624.32	4330.00	6624.32	8.32
	7	4314.00	6624.72	4330.00	6624.72	7.92
	8	4314.00	6630.38	4330.00	6630.38	0.29
	9	4314.00	6626.93	4330.00	6626.93	4.94
	10	4314.00	6625.86	4330.00	6625.86	6.38
	11	4314.00	6629.65	4330.00	6629.65	1.28
	12	4314.00	6630.23	4330.00	6630.23	0.50
Strata 2	1	4314.00	6618.94	4334.00	6618.94	4.53
	2	4314.00	6617.63	4334.00	6617.63	7.76
	3	4314.00	6622.79	4334.00	6622.79	0.83
	4	4314.00	6617.31	4334.00	6617.31	8.20
	5	4314.00	6620.00	4334.00	6620.00	4.58
	6	4314.00	6615.51	4334.00	6615.51	10.62
	7	4314.00	6614.95	4334.00	6614.95	11.37
	8	4314.00	6620.42	4334.00	6620.42	4.01
	9	4314.00	6616.78	4334.00	6616.78	8.91
	10	4314.00	6621.16	4334.00	6621.16	3.02
	11	4314.00	6617.70	4334.00	6617.70	7.67
	12	4314.00	6615.06	4334.00	6615.06	11.23
Strata 3	1	4317.00	6610.43	4334.00	6610.43	3.32
	2	4317.00	6613.14	4334.00	6613.14	4.29
	3	4317.00	6611.58	4334.00	6611.58	0.46
	4	4317.00	6609.70	4334.00	6609.70	4.53
	5	4317.00	6610.71	4334.00	6610.71	2.53
	6	4317.00	6613.38	4334.00	6613.38	5.87
	7	4317.00	6609.88	4334.00	6609.88	6.29
	8	4317.00	6609.61	4334.00	6609.61	2.22
	9	4317.00	6611.92	4334.00	6611.92	4.93
	10	4317.00	6610.21	4334.00	6610.21	1.67
	11	4317.00	6610.14	4334.00	6610.14	4.24
	12	4317.00	6612.49	4334.00	6612.49	6.21

Table 5. A series of 12 randomly selected transects for the stratum on Trinity Ledge. Co-ordinates are in degrees, minutes and decimal minutes. Distance is measured from the south-western boundary of each box.

Location/ Strata	Transect Number	Start Lat	Start Long	End Lat	End Long	Distance (km)
Trinity Ledge Strata 1	1	4355.00	6616.39	4405.00	6616.39	11.49
	2	4355.00	6620.82	4405.00	6620.82	5.60
	3	4355.00	6623.54	4405.00	6623.54	3.58
	4	4355.00	6615.61	4405.00	6615.61	12.54
	5	4355.00	6622.73	4405.00	6622.73	3.04
	6	4355.00	6618.01	4405.00	6618.01	9.33
	7	4355.00	6619.72	4405.00	6619.72	7.06
	8	4355.00	6616.13	4405.00	6616.13	11.84
	9	4355.00	6617.07	4405.00	6617.07	10.59
	10	4355.00	6619.57	4405.00	6619.57	7.26
	11	4355.00	6623.90	4405.00	6623.90	1.49
	12	4355.00	6623.41	4405.00	6623.41	2.15

Table 6. A series of 12 randomly selected transects for the stratum in Scots Bay. Co-ordinates are in degrees, minutes and decimal minutes. Distance is measured from the south-western boundary of each box.

Location/ Strata	Transect Number	Start Lat	Start Long	End Lat	End Long	Distance (km)
Scots Bay Strata 1	1	4504.15	6512.00	4513.53	6443.71	4.03
	2	4509.24	6512.00	4518.62	6447.72	13.44
	3	4505.11	6512.00	4514.94	6444.47	5.80
	4	4503.18	6512.00	4512.56	6442.94	2.22
	5	4507.91	6512.00	4517.29	6446.68	10.99
	6	4511.11	6512.00	4520.49	6449.20	16.91
	7	4508.07	6512.00	4517.45	6446.80	11.27
	8	4511.37	6512.00	4520.75	6446.82	17.39
	9	4511.22	6512.00	4520.60	6449.28	17.11
	10	4505.81	6512.00	4515.19	6445.02	7.09
	11	4509.33	6512.00	4518.71	6447.79	13.61
	12	4506.81	6512.00	4516.19	6445.81	8.95

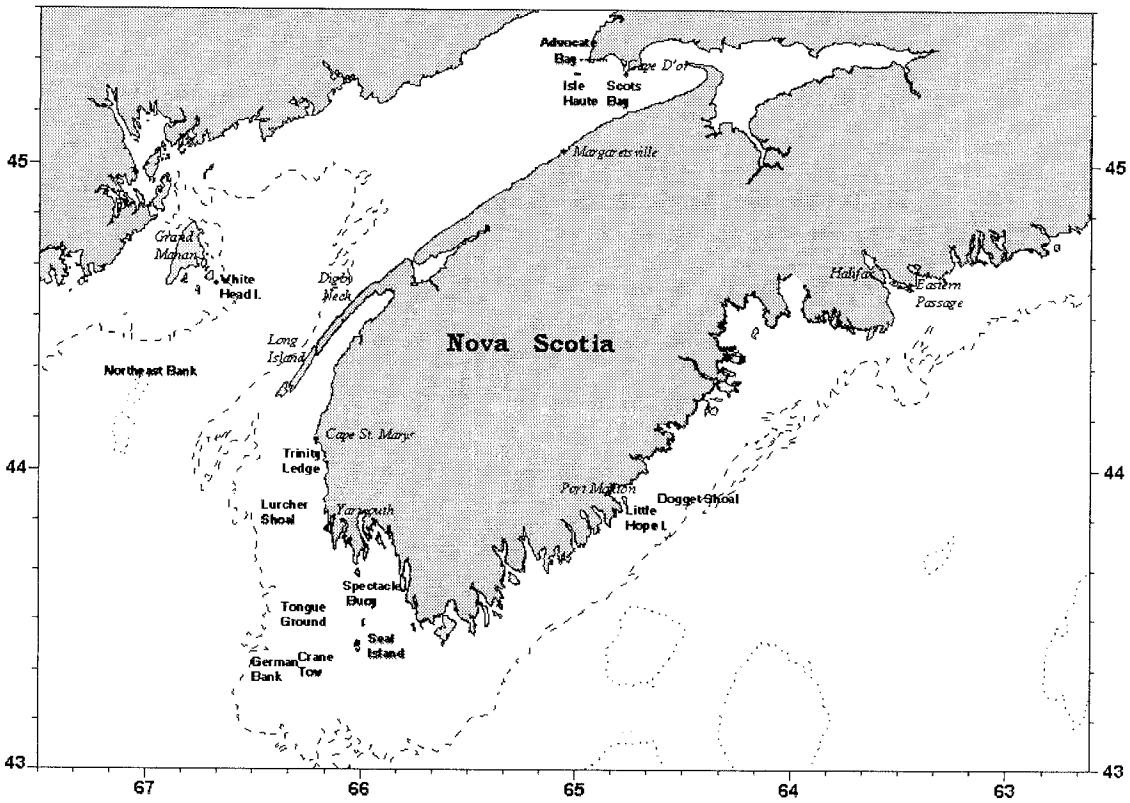

Figure 1. Location of main herring fishing areas off Nova Scotia and in the Bay of Fundy.

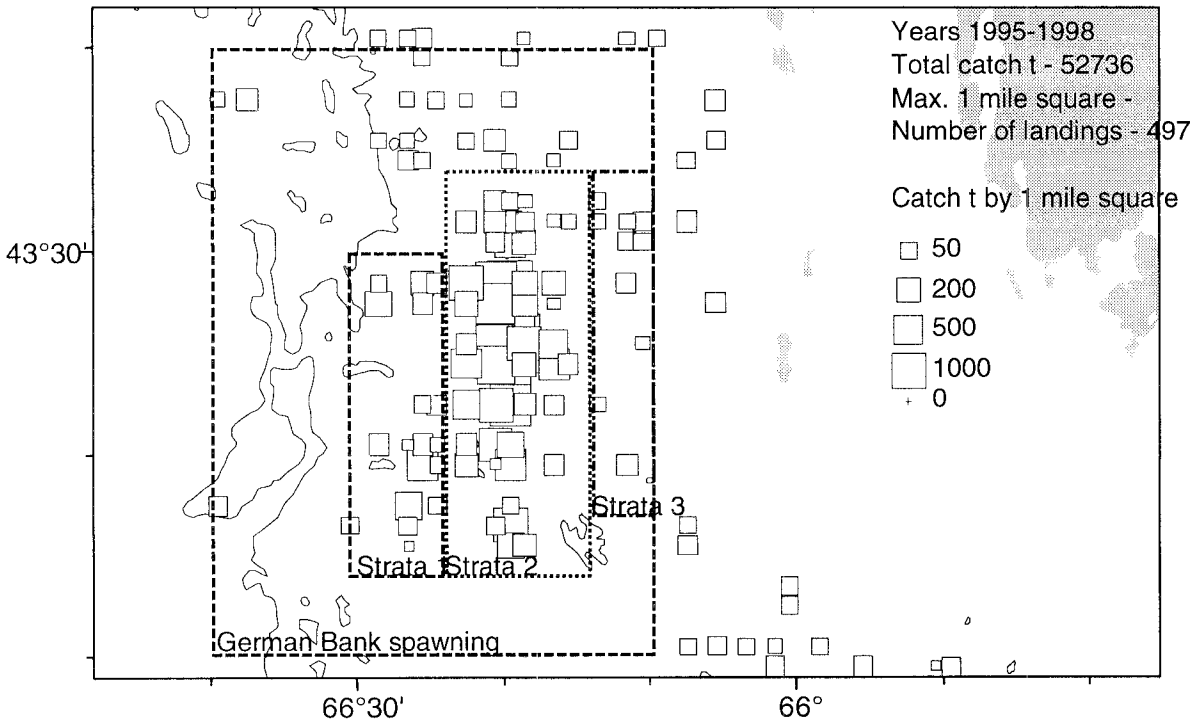

Figure 2a. German Bank purse seine combined catches for 1995-98 (Sep. 10-Oct. 10 only)

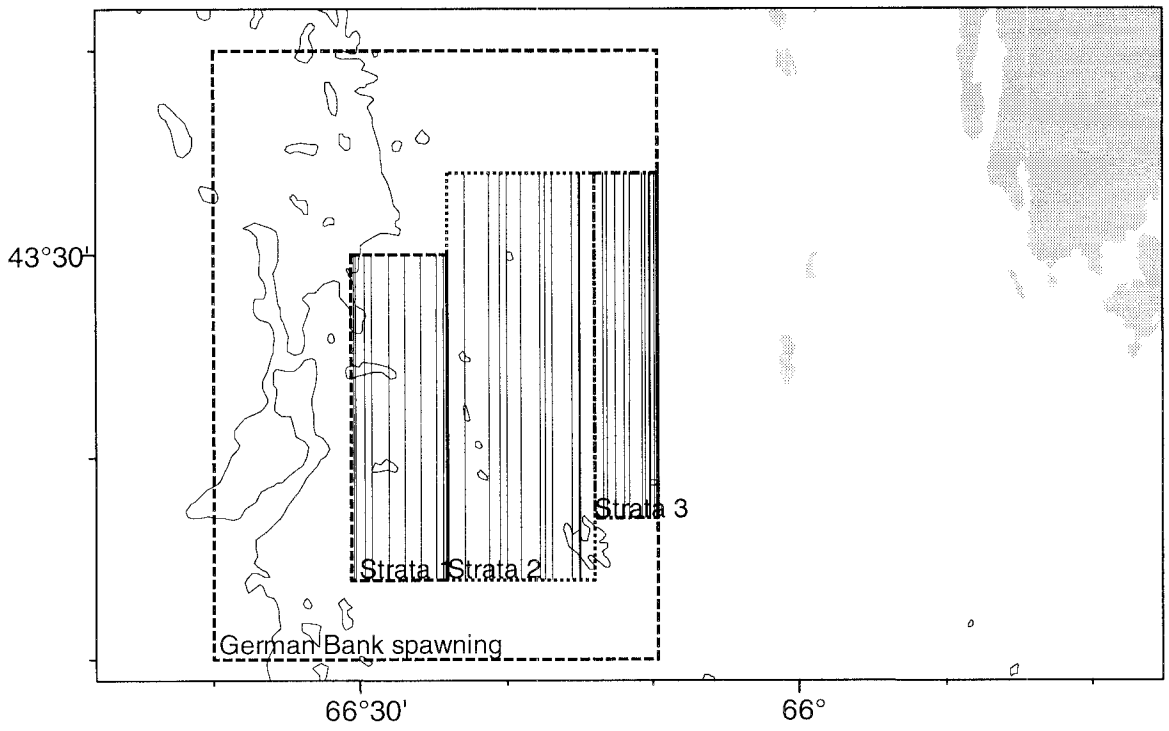

Figure 2b. German Bank spawning area boundaries, strata and random

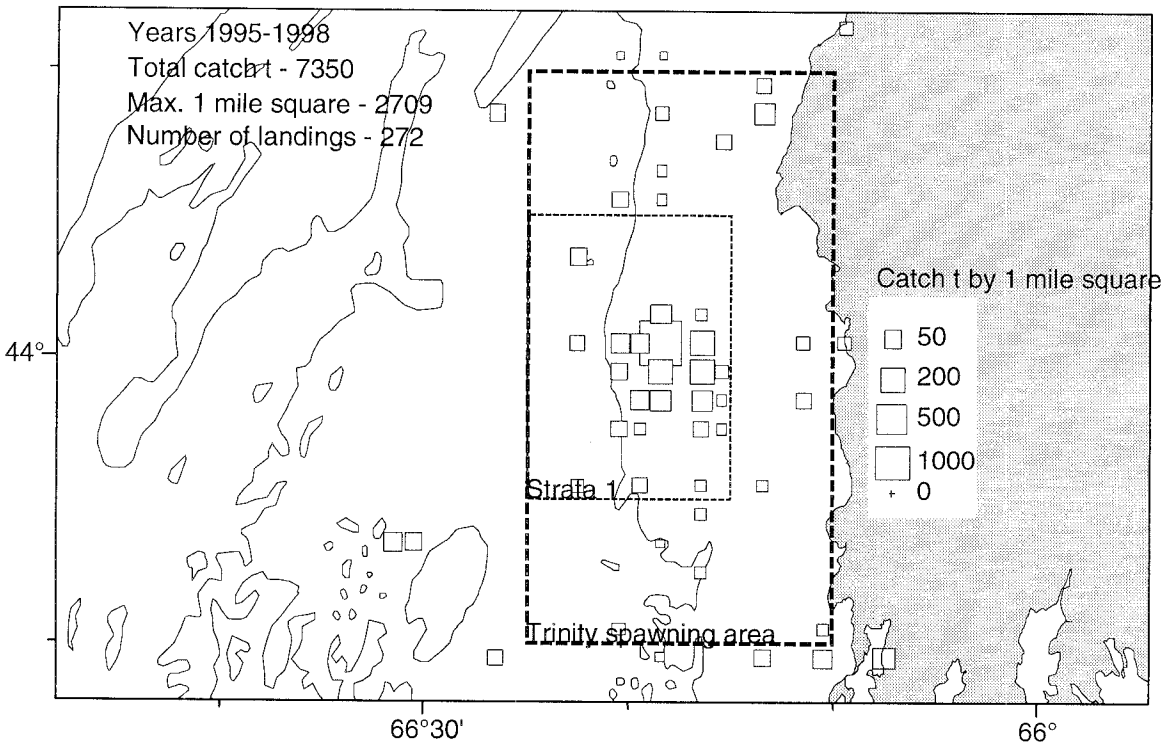

Figure 3a. Trinity Ledge area herring catches for 1995-98 (Aug 1-Sept 15 period

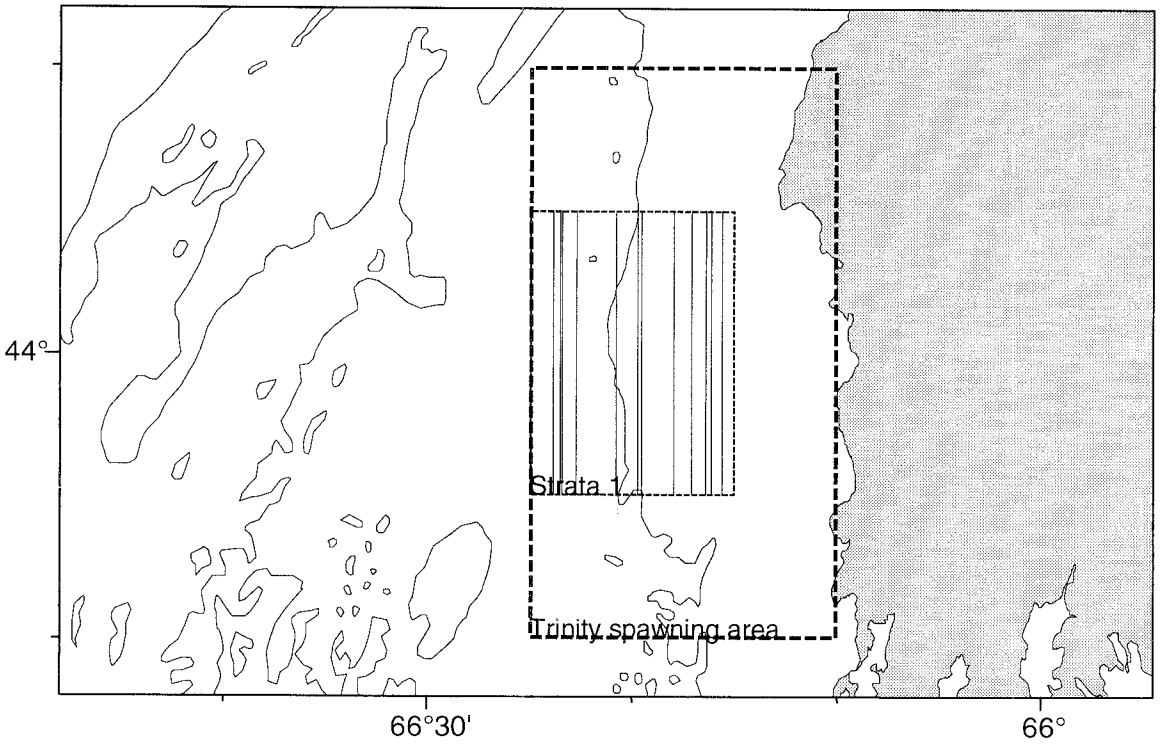

Figure 3b. Trinity Ledge spawning area boundaries, strata and random

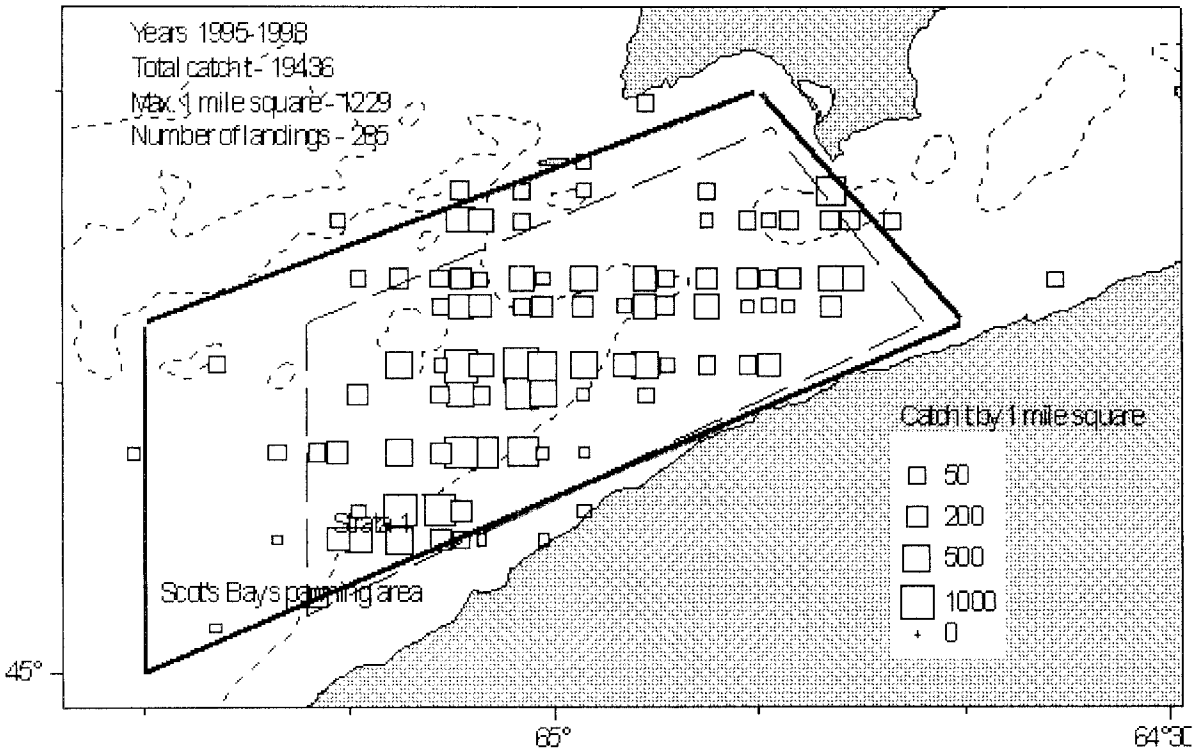

Figure 4a. Scot's Bay purse seine catches for 1995-98 (Jul 20-Aug 20 period only)

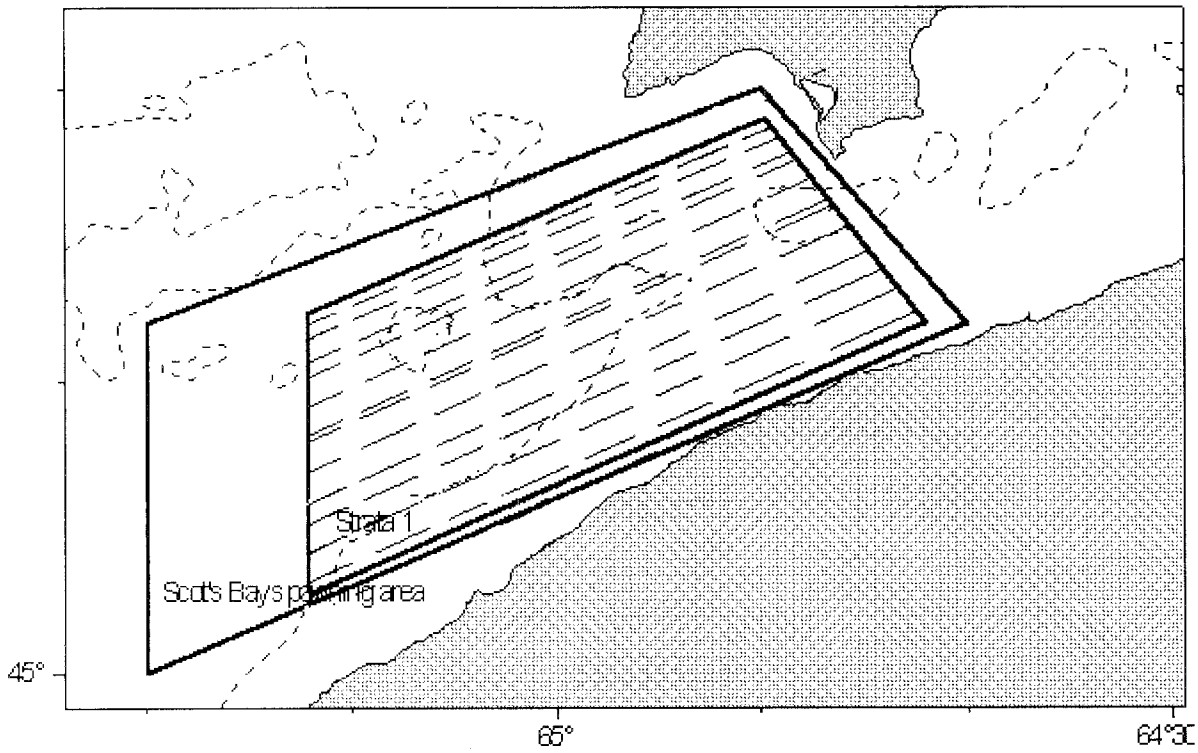

Figure 4b. Scots Bay spawning area boundaries, strata and random transects.