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The Design and Application of Aerial Surveys to Estimate Inshore Distribution and Relative Abundance of Capelin

by

Brian S. Nakashima

Fisheries Research Branch, Department of Fisheries and Oceans
P. O.Box 5667, St. John's, Newfoundland, Canada A1C 5X1

Abstract

Aerial photographic surveys along a survey track in Trinity and Conception bays in Division 3L were conducted during the spawning period and time of the inshore commercial fishery from 1982-84. The number of schools, mean school size, and total school surface area were measured from photographs. Trends in these parameters on a daily and annual basis were compared to fixed gear landing statistics. In most cases the trends were similar. Differences were probably due to inadequate coverage by the aerial survey due to bad weather or to landings which tended to reflect market conditions rather than inshore abundance. More than three years of data are required to produce a firm analysis. However, the total surface area index of relative abundance followed the same trends in abundance as C/day for fixed gear and mature biomass projections from hydroacoustic surveys. These results indicated that serial surveys of capelin schools can describe the distribution and changes in distribution during the spawning period and that there is potential for its use as an index of relative abundance which is independent of the commercial fishery.

SPECIAL SESSION ON BIOLOGICAL SURVEYS

Introduction

Remote sensing of fish by airborne sensors has been conducted using indirect and direct detection methods. Most methods have been restricted to pelagic species because they occur near or at the water surface. Indirect sensing measures surface water temperatures, chlorophyll concentrations, or some other factor which is related to fish abundance. Use of indirect detection methods assume that distribution and/or production of fish are correlated to water temperatures and/or food availability (Kemmerer 1979; Yentsch 1973). Direct detection techniques have employed low light sensors (eg. Hampton et al. 1979; Roithmayr 1971) and aerial photography (eg. Benigno and Kemmerer 1973; Kemmerer 1979). Two useful summaries of remote sensing methods along with research examples applied to fisheries problems were written by Kemmerer (1979) and Vanselous (1977). The choice of method is very much dependent on the schooling behaviour of the target species and local weather patterns.

In the Newfoundland region capelin (Mallotus villosus) form schools of varying sizes and shapes along the coastline in shallow water (<60 m water depth) during the spawning season in June and July. These schools are descernible to the human eye. Consequently they are amenable to aerial photography. Schools can be distinguished from kelp beds and dark rock formations with reasonable accuracy and consistency due to their greyish tones and distinct shapes. The near-absence of pelagic species other than capelin along beaches in June and July supports the assumption that all schools observed were composed of capelin. Logbook records indicated that the bycatch of species other than capelin were negligible (Nakashima and Harnum 1985). The logbook survey provided a method to ground-truth the aerial survey results (for logbook survey design see Nakashima 1984).

Capelin abundance is assessed annually from data gathered on offshore hydroacoustic surveys (see Anon. 1982, 1983). Catch/effort trends calculated from logbooks completed by inshore fishermen are the only measures of inshore abundance of mature fish. Inshore research vessel surveys have been unsuccessful in estimating abundance because the vessel cannot cover the survey area (especially shallow depths) and the time required to cover the extent of the distribution is too long in comparison to the rapid changes in distribution and abundance which occur during the spawning season.

A photographic aerial survey was chosen as a method which could take advantage of the beach spawning behaviour of capelin to provide an independent estimate of relative abundance and to describe distribution patterns. Survey flights could potentially cover a large area in a few hours and give an almost instantaneous picture of the location of all capelin schools in shallow water. Finally the photographic results could be compared to logbook data and landing statistics for verification. Thus the focus of this report is to present in detail the methodology developed for the photographic aerial survey of capelin and to discuss some findings with respect to its goal of describing distribution and estimating relative abundance.

Materials and Methods

Preliminary aerial surveys were first flown in 1981 to choose an appropriate method to record and measure capelin schools. A low light sensor similar to the one described by Roithmayr (1971) was tested and rejected as being unsuitable (Nakashima 1983). Success from photographs utilizing a 70 mm camera and aerocolour negative 2445 film which penetrates water to a depth visible to the naked eye encouraged us to proceed in future surveys with daylight photographic techniques employing the 2445 film type. To improve the resolution and measurement of capelin schools, a large format camera (RC-10 type) using 228 x 228 mm film has been employed on all surveys since 1982.

Pertinent details of aerial surveys from 1982-84 are given in Table 1. All surveys employed fixed-wing aircraft. Two observers along with a pilot and navigator/photographer were present on all flights. One observer spotted capelin schools and directed the survey while the other recorded information. The 1982 survey was experimental in design. Photographs were taken at different times of the day to find the optimal time for colour photography. Runs at a variety of altitudes from 152 to 610 m above sea level were conducted to choose the best altitude to efficiently resolve capelin schools from other features in the water. From these altitude tests and more recent flights, optimal photographic conditions existed between 0900-1100 and 1400-1630 NDT on sunny, light wind days. These time periods minimized glare, reduced the effect of land shadows along the coastline, and increased visibility and therefore the reliability of observers to locate capelin schools. The optimal flying altitude was set at 457 m (1500') above sea level. All flights were along the coastline following a defined survey track along Conception and Trinity bays (Fig. 1.). Conception and Trinity bays were chosen as the study site because the fishery has high landings in this area (Nakashima and Harnum 1985) and they are within one hour of flying time from Torbay airport. The choice of starting point and order of coverage were left to the daily decision of observers because of variable local weather and sea conditions. Since the distribution and abundance of capelin may vary somewhat within and between bays (unpublished data in the logbooks) the survey track was subdivided into four survey transects. These were organized to closely adhere to the statistical sections in the Newfoundland Region for comparison to reported landings of capelin along the survey track. One transect on the outside of Trinity Bay encompassed the route from the Horse Chops to Gooseberry Cove including Southwest Arm (Statistical Sections 15, 16). A second transect on the inside of Trinity Bay ran from Gooseberry Cove to Hopeall (Statistical Section 17). A third on the outside portion of Conception Bay included the shoreline from Capelin Cove to Harbour Grace Islands (Statistical Section 20, 21). The last transect on the inside of Conception Bay went from Harbour Grace Islands to Portugal Cove (Statistical Sections 22, 23). It was impractical to survey the entire coastline of both bays (Fig. 1) within the optimal time period. Thus difficult areas to survey, areas with the least landings, and places with no or little fixed gear fishing were excluded from the survey track. The flight path given in Figure 1 represented the maximum area which could be covered on an ideal day under optimal photographic conditions when capelin were abundant and widely dispersed inshore.

When weather conditions were suitable for colour photography, flights were arranged to cover the 0900-1100 and 1400-1630 windows. We attempted to complete at least one transect on each flight. Flights generally alternated between bays. When a school was observed, it was photographed and information on location, altitude, ground speed, and time of day were recorded. Frames overlapped 10-20% and contained some shoreline as a reference point for later identification of specific location. The frequency of flights was increased subject to weather to cover the peak periods of capelin abundance inshore.

When contact prints were developed, each photograph was scanned to identify capelin schools against background noise from kelp beds and rock formations. Generally capelin schools were a greyish colour and their shapes were distinctive. School surface area was measured using a compensating polar planimeter. Each school was measured three times and the average of the three measurements was accepted as the estimated school size. The scale of the photograph at an altitude of 457 m was 1:3000. Only complete transects were included in this analysis. The total observed surface area was calculated per transect and assumed to represent a minimum estimate of available school surface area. No accurate density or school depth measurements were available. Thus it was assumed that all schools were of uniform density although this was not necessarily true in all situations.

The daily total school surface area (m^2) was compared to total landings (t) from fixed gear (capelin traps, beach seines) along each of the transects from 1982-84 to examine trends in distribution on a daily basis and among transects. The highest daily school surface area in each of the four transects in each year were added together to produce an estimate of the highest total school surface area for each year. These values were then compared to catch/effort (C/day) data from capelin traps (Nakashima and Harnum 1985) and to projections of offshore biomass of capelin (Anon, 1982, 1983) to examine preliminary abundance trends among these indices.

Results

The parameters of number of schools and mean school size were estimated daily and were related to each other and to the total surface area. In most cases coverage was complete except for the outside transects of Trinity and Conception bays surveyed in 1982 which were less frequently surveyed than in other years and than other transects (Tables 2a, b, c, and d). School shapes varied from circular to highly irregular with no consistent shape being observed. Instead, configuration of schools was unrelated to bottom topography or nearness to the beach spawning area. No further work has been done on the shape of schools observed during the survey flights. In general both mean school size and number of schools observed followed the trend established by total school surface area, i.e. large daily total surface areas were associated with high numbers of schools and large mean school size for all comparisons (Tables 2a, b, c, and d). The second noteworthy observation was the tendency towards more schools and larger mean school size on transects inside Trinity and Conception bays compared to transects on the outside. Discernible peaks of total school surface area occured at similar times on the inside and outside transects of a bay in any given year implying that the timing of capelin migration inshore on this scale was similar within bays. However yearly comparisons indicated that there were variations among years in the same area.

Transects which were not surveyed completely due to deteriorating weather conditions were not included in the analysis resulting in gaps in coverage frequency. The obscuring of schools due to sun glare or land shadows was problematic in a few earlier surveys in 1982-83. These were interpreted with caution prior to analysis. The number of schools photographed was a reliable estimator of schools observed along a transect, however, it does represent only capelin schools in shallow water close to the shoreline (within 70 m of the shore). Schools in deeper water were not susceptible to the aerial survey techniques utilized in this study. Changes in mean school size can be utilized to measure daily and regional differences in schooling behaviour. Schools increased to a peak then declined in size which corresponded to similar fluctuations in total surface area. Mean school size was largest in 1983 and smaller in 1982 and in 1984 on all survey transects (Table 2a, b and c) except for the inside transect of Conception Bay where the largest mean school size was observed in 1982 (Table 2d). School size estimates excluded capelin caught in traps (Table 2c and d) although the surface areas were included in the total surface area estimates. The mean school size is used cautiously in this report since the standard deviations are often larger than the means.

For all survey transects and in most years the patterns of capelin distribution and relative abundance from aerial surveys was similar to those reflected by fixed gear landings collected by Fishery Statistics Branch (Fig. 2a, b, c, d, e, and f). For all graphs the aerial survey data are lagged one day ahead since the landings more accurately describe the previous day's activity. Declines in landings on Sundays (small arrows on the x-axes) should be interpreted cautiously since these probably indicate reduced fishing activity rather than reductions in abundance. In 1982 only the inside transect of Conception Bay showed similar trends to the landings (Fig. 2b). The inside Trinity Bay aerial survey index peaked approximately six days after the commercial landings (Fig. 2a). Insufficient data were collected to make any inferences from the outside transects in Trinity and Conception bays (Fig. 2a and b). In 1983 the aerial survey and commercial landings corresponded to each other (Fig. 2c and d). The total surface area estimated along the outside transect in Trinity Bay and the landings in the same area were low with small peaks while both indices for the inside of Trinity Bay peaked at the same time (Fig. 2c). Weather delays resulted in the aerial survey missing the ascending part of the spawning season in Conception Bay. From the graphs the survey along both transects commenced on the day when peak landings were reported for the commercial inshore fishery (Fig. 2d). In 1984 the trends in the aerial survey and landing data were similar for all of Trinity Bay with both indices rising in early July (Fig. 2e), whereas the aerial survey index declined in early July in Conception Bay when the landings were increasing (Fig. 2f). The general impression from these comparisons suggested that changes in total school surface area generally corresponded to the variations in availability of marketable capelin during the spawning season. However, there were some poor relationships which may have been due to lack of good coverage by the aerial surveys (Fig. 2a and b) or inaccuracy in landings from purchase slip data (Nakashima 1984) and poor market conditions.

Discussion

Results from aerial surveys conducted in Trinity and Conception bays from 1982-84 indicated that this survey technique may be used as an independent method to evaluate the distribution and relative abundance of capelin inshore during the spawning season. Utilizing total school surface area and to a lesser degree the mean school size and number of schools observed, the patterns were similar patterns compared to those found using daily commercial landings. Some differences in trends between these two indices may have resulted from less than adequate coverage by the aerial surveys and/or biased commercial data which reflected market requirements for capelin product rather than abundance of capelin. Despite these differences, there was good agreement between the two methods when we examined trends in daily relative abundance and compared inshore distribution among the four study sites. Intuitively the aerial survey should be a more reliable method in determining inshore distribution since one can cover a large area in a short time and record the entire school surface area for later measurement. The former is important when one considers how dynamic mature capelin schools are during the spawning period. As an example on June 26, 1982 a morning and an afternoon flight were conducted on the inside transect of Conception Bay. The number of schools declined from 34 to 20 from the morning flight to the afternoon flight, the total surface area almost doubled, and the mean school size tripled (Table 2d). The magnitude of changes occurring in this short time frame suggested that vessel surveys would have been inefficient at mapping distribution changes during this time.

To consider the utility of school surface area as an index of relative abundance of inshore capelin we compared this index to two other abundance indices (Table 3). A catch rate index (C/day) derived from logbook data recorded by capelin trap fishermen (Nakashima and Harnum 1985) was chosen to represent a commercial fishing index. Assuming catch rates are unbiased estimators of abundance, then the C/day should approximate inshore capelin abundance since it incorporates landings and discards into the catch and the days the trap was fishing into the effort. Thus the C/day from logbooks represented the best measure available of inshore catch rates. The second index was based on mature biomasses reported in NAFO Scientific Council Reports (Anon. 1982, 1983) which were derived from offshore hydroacoustic surveys. No single 1982 projection was accepted, however there were two projections given in Anonymous (1982) (346,000 t from the USSR survey; 834,000 t from the Canadian survey). As noted in Anonymous (1982) the discrepancy between the two numbers was largely due to the high estimate of three-year-olds (1978 yearclass) in the Canadian survey. The Canadian acoustic survey design was changed between the 1981 and 1982 surveys which resulted in a different alignment of survey blocks and cruise tracks in the area adjacent to the Avalon Peninsula in Division 3L (Miller and Carscadden 1983; Miller et al. 1982). This change may have resulted in a reduction in the number of mature three-year-olds which would have been observed during the June surveys when mature capelin are moving inshore to spawn. Subsequent surveys have continued with the survey design initiated in 1982. Thus the change in survey design and very high numbers of three-year-olds in the 1981 Canadian survey have led us to assume that the projected mature biomass of capelin in 1982 was probably closer to 346,000 t than to 834,000 t. In Table 3 we infer that the projection lies somewhere near but was greater than 346,000 t. The final index was the school surface area which represented the maximum amount of capelin observed along the survey track. As explained earlier, each annual estimate was an aggregate of the highest value for each of the four transects. These did not necessarily occur on the same day.

The three indices follow the same trend, i.e. low in 1982, highest in 1983 and than a decline in 1984 (Table 3). Even considering the difficulty in defining the 1982 projection for mature biomass, it was encouraging to see such correspondence among all three indices. All indices had assumptions which may or may not have been violated. However, we have assumed that the C/day and the offshore hydroacoustic estimate were the best available for commercial and research indices of relative abundance, respectively. The comparison in Table 3 demonstrated that there is potential for using the aerial survey as a reliable index of relative inshore abundance, at least as reliable as the other two.

The total school surface area method does have some limitations. The surveys included only schools visible to the eye which ignored deep schools or those further off the coastline. Weather was a significant factor influencing coverage during the spawning period. Photographs must be carefully screened to include all schools including those which may be partially obscured by glare, shadows, or turbulence. Much of this effect can be reduced during the field survey. Finally we assumed peak abundance occured once when school surface area was greatest although successive waves of capelin may come to a particular beach resulting in a mixture of old and new arrivals.

The technique described herein assumes that all schools have the same density. However this is not always true since school colour does vary and may be influenced by bottom depth. In an earlier paper Nakashima (1983) noted that one goal of the study was to combine the surface area estimates with some measure of school depth to obtain a volume density for each school. Hampton et al. (1979) have performed such an exercise on pilchard schools off the southwest coast of Africa. There are no acoustic studies of capelin schools in shallow water in the Newfoundland region. The logistics of linking an acoustic density calculation of a school with its colour intensity is not feasible at the moment but would be an important step in enhancing the accuracy of these values.

Despite the preliminary nature of the findings which are based on three annual estimates, it is encouraging to note that the three indices describe the same trend. With a few more years of data one will be more confident in relying on surface area as an index of relative abundance.

Aerial surveys of capelin schools in the inshore area can describe short term changes in capelin distribution which cannot be detected by research vessels. These changes may correspond to fluctuations observed from landings by fixed gear fishermen. The aerial survey index of total school surface and possibly that of mean school size is independent of the fishery and may be more reliable since the entire survey can be performed in less than five hours and can be repeated several times. As an index of relative abundance, the same attributes of rapid survey time, repeatability, and independence from a commercial fishery apply. The index of total school surface area chosen for comparison with two indices currently in use followed similar trends even though the time period was only three years. While it is still too early to judge its utility in assessing relative abundance trends, the results to date are encouraging.

Acknowledgements

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Table 1. Summary of aerial surveys conducted from 1982-84.

	1982	1983	1984
Survey aircraft:	Piper Aztec	Aero-Commander 500B	Cessna 310
Camera Type:	RC 10	RC 10	RC 10
Lens (mm):	152	152	152
Filter type:	clear, anti-vignetting	clear, anti-vignetting	clear, anti-vignetting
Film type:	Aerocolour Negative 2445	Aerocolour Negative 2445	Aerocolour Negative 2445
Radar altimeter:	No	Yes	Yes
Survey period:	June 18-July 5	June 19-July 9	June 17-July 7
Altitude for photography (m):	152-610	457	457

Table 2a. Schooling data for the outside part of Trinity Bay from the Horse Chops to Gooseberry Cove, 1982-84.

Date	No. of schools	Total surface area (m^2)	Mean School size (m^2) ± SD
June 19, 1982	7	2963	423 ± 502
June 26, 1982	0		
July 3, 1982	1	522	522
June 23, 1983	7	11330	1619 ± 1315
June 24, 1983	10	13671	1367 ± 1260
June 25, 1983	7	11662	1666 ± 2151
June 29, 1983	8	2288	286 ± 228
June 30, 1983	13	18470	1420 ± 1613
July 1, 1983	3	6417	2139 ± 2176
June 18, 1984	9	3236	360 ± 423
June 19, 1984	8	3962	495 ± 703
June 25, 1984	22	30467	1385 ± 1959
June 26, 1984	38	37219	979 ± 1718
June 29, 1984	9	2790	310 ± 223
July 3, 1984	48	43412	904 ± 3010
July 6, 1984	34	16015	471 ± 485

Table 2b. Schooling data for the outside part of Trinity Bay from Gooseberry Cove to Hopeall, 1982-84.

Date	No. of schools	Total surface area (m^2)	Mean School size (m^2) ± SD
June 19, 1982	31	12724	411 ± 712
June 26, 1982	29	35607	1228 ± 2755
June 29, 1982	11	62397	5672 ± 8378
July 2, 1982	8	31365	3921 ± 9281
July 3, 1982	2	1920	960 ± 17
June 23, 1983	11	69583	6326 ± 6299
June 24, 1983	26	39004	1500 ± 1880
June 25, 1983	30	174487	5816 ± 12759
June 29, 1983	35	152557	4359 ± 11139
June 30, 1983	46	199373	4334 ± 6927
July 1, 1983	25	189497	7580 ± 19791
June 19, 1984	9	14341	1593 ± 2035
June 23, 1984	9	8314	924 ± 888
June 25, 1984	89	31526	354 ± 517
June 26, 1984	96	40510	422 ± 679
June 29, 1984	47	12053	256 ± 314
July 3, 1984	57	23827	418 ± 814
July 7, 1984	77	43245	562 ± 1124

Table 2c. Schooling data for the outside of Conception Bay from Caplin Cove to Harbour Grace Islands, 1982-84.

Date	No. of schools	Total surface area (m^2)	Mean School size (m^2) ± SD
June 29, 1982	10	6577	658 ± 366
July 2, 1982	2	1357	679 ± 554
June 23, 1983	34	51838	1374 ± 2266
June 24, 1983	16	10658	666 ± 823
June 25, 1983	4	4408	349 ± 184[a]
July 1, 1983	5	5413	1083 ± 1884
June 18, 1984	1	391	391
June 19, 1984	4	1283	321 ± 28
June 25, 1984	51	64002	1294 ± 2874
June 26, 1984	67	65956	697 ± 1091
June 30, 1984	21	22320	818 ± 1509
July 3, 1984	4	1786	446 ± 599

[a] excludes capelin in traps

Table 2d. Schooling data for the inside of Conception Bay from Harbour Grace Islands to Portugal Cove, 1982-84.

Date	No. of schools	Total surface area (m^2)	Mean School size (m^2) ± SD
June 26, 1982 AM	34	19408	571 ± 907
June 26, 1982 PM	20	36513	1826 ± 1914
June 27, 1982	49	151051	3083 ± 5963
June 29, 1982	27	30275	1121 ± 1707
July 4, 1982	3	13042	4347 ± 4951
July 5, 1982	7	5127	732 ± 582
June 23, 1983	52	97595	1787 ± 2754[a]
June 24, 1983	44	62273	1415 ± 2514
June 25, 1983	29	79961	2677 ± 3725[a]
June 30, 1983	7	8091	1156 ± 1181
July 1, 1983	1	2009	2009
June 18, 1984	0		
June 23, 1984	10	17689	1769 ± 2354
June 25, 1984	68	63891	899 ± 1812[a]
June 26, 1984	33	23603	703 ± 1708[a]
June 30, 1984	29	16852	508 ± 467[a]
July 3, 1984	18	9040	329 ± 254[a]
July 5, 1984	0		

[a] excludes capelin in traps

Table 3. Comparison of three indices for estimating relative trends in spawning biomass. The C/day index was based on capelin trap data from a logbook survey (Nakashima and Harnum 1985), the mature biomass index originated from NAFO Scientific Council Reports (Anon. 1982, 1983), and the school surface area index came from this study.

Year	C/day	Mature biomass (+)	School surface area (m^2)
1982	3.7	>346,000	222,988
1983	4.6	658,000	367,276
1984	3.5	384,000	216,504

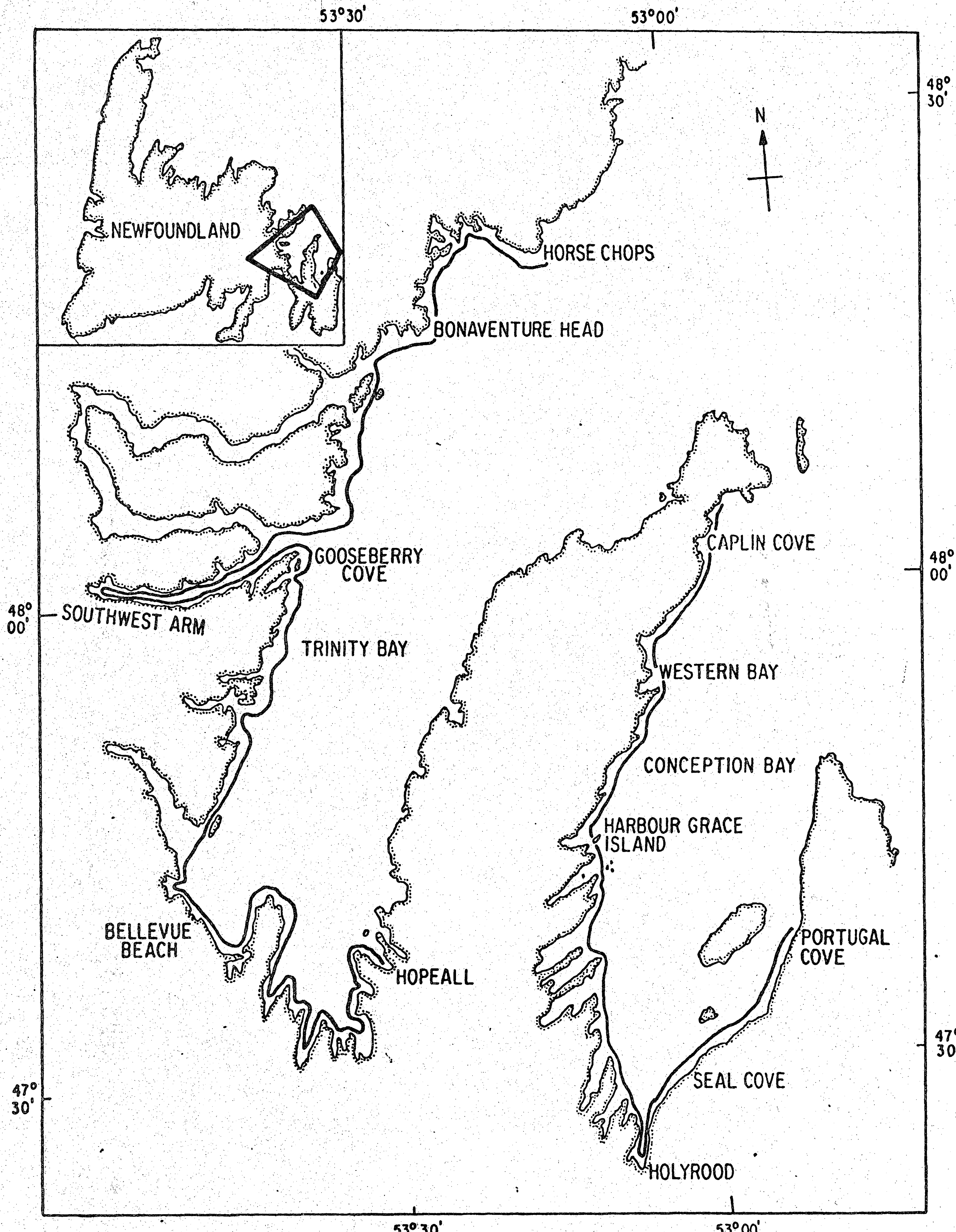

Fig. 1. Aerial survey track in Division 3L.

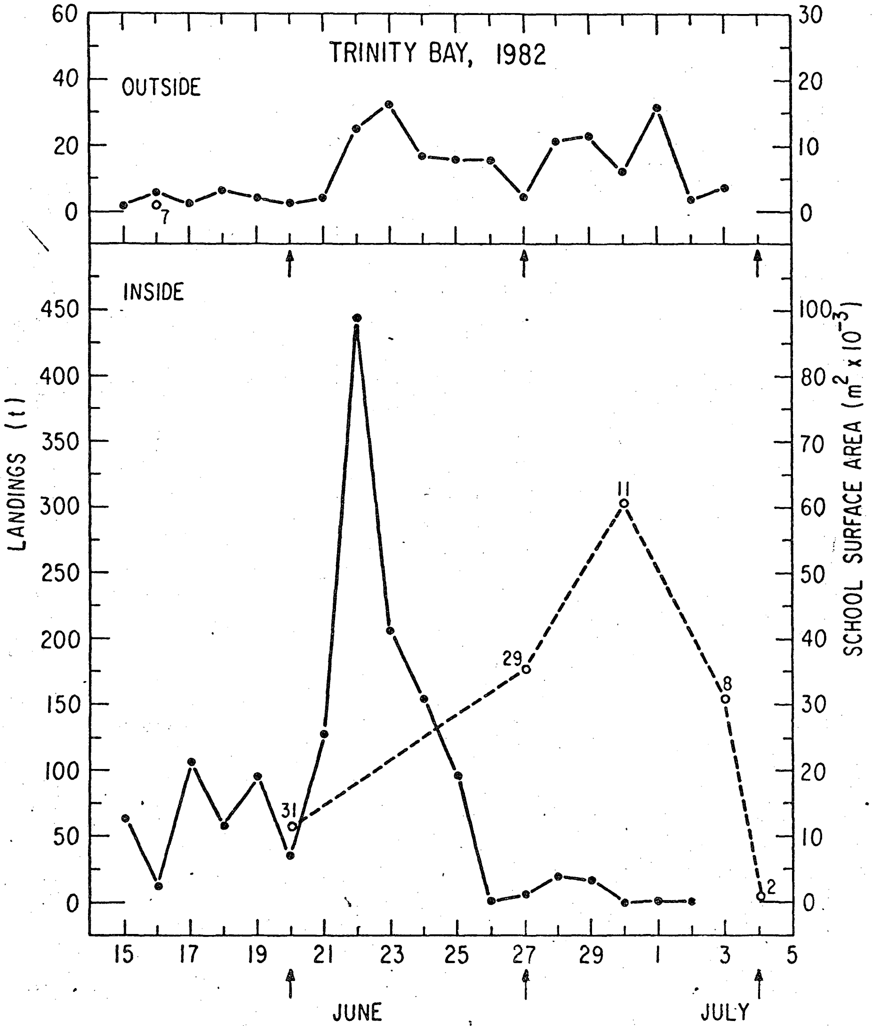

Fig. 2a. Comparison of fixed gear capelin landings (●—●) and school surface area (o---o) trends in 1982 for the outside and inside transects in Trinity Bay. Numbers near the open circles indicate the number of capelin schools observed. An arrow on the x-axis denotes a Sunday.

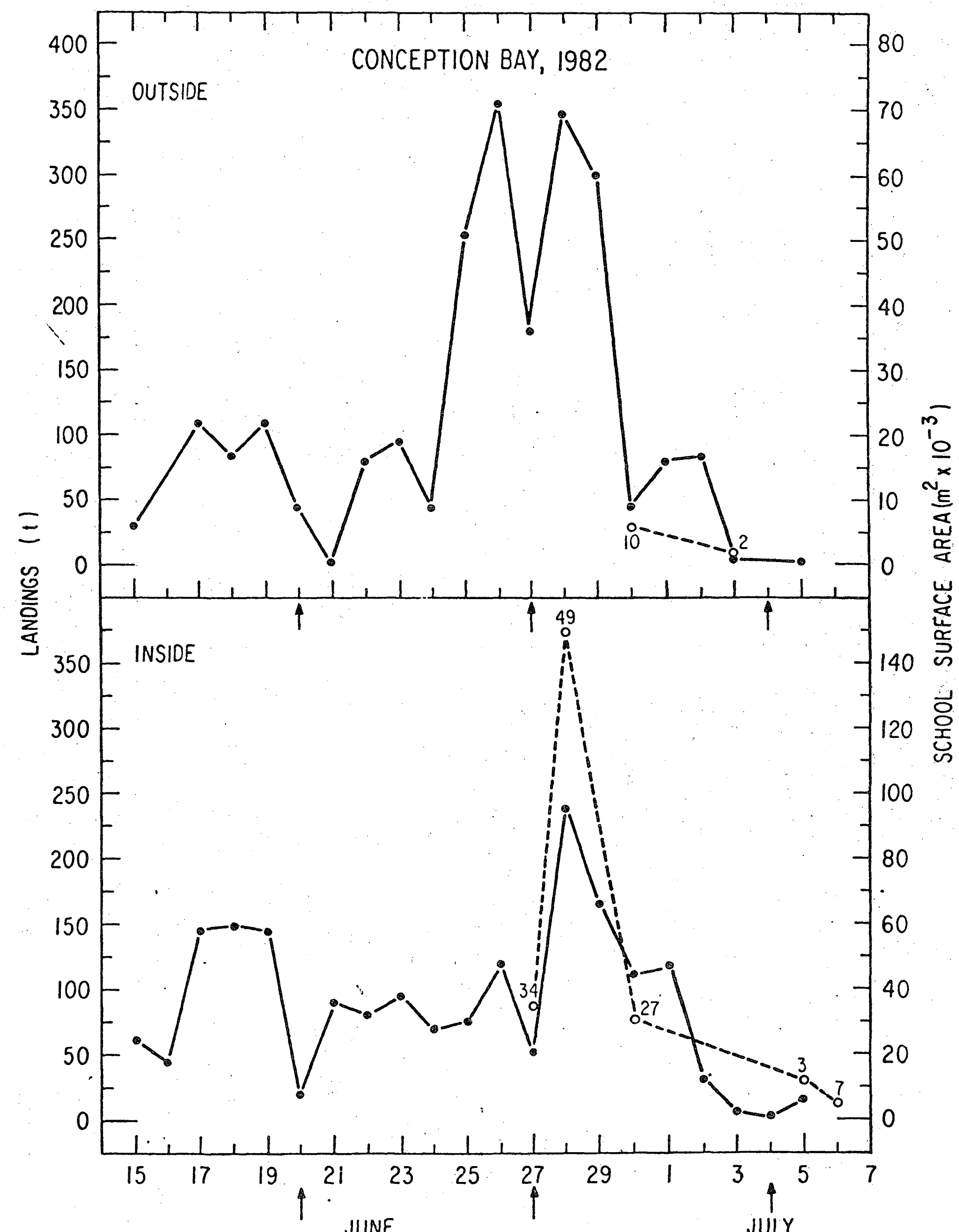

Fig. 2b. Comparison of fixed gear capelin landings (●—●) and school surface area (o---o) trends in 1982 for the outside and inside transects in Conception Bay. Numbers near the open circles indicate the number of capelin schools observed. An arrow on the x-axis denotes a Sunday.

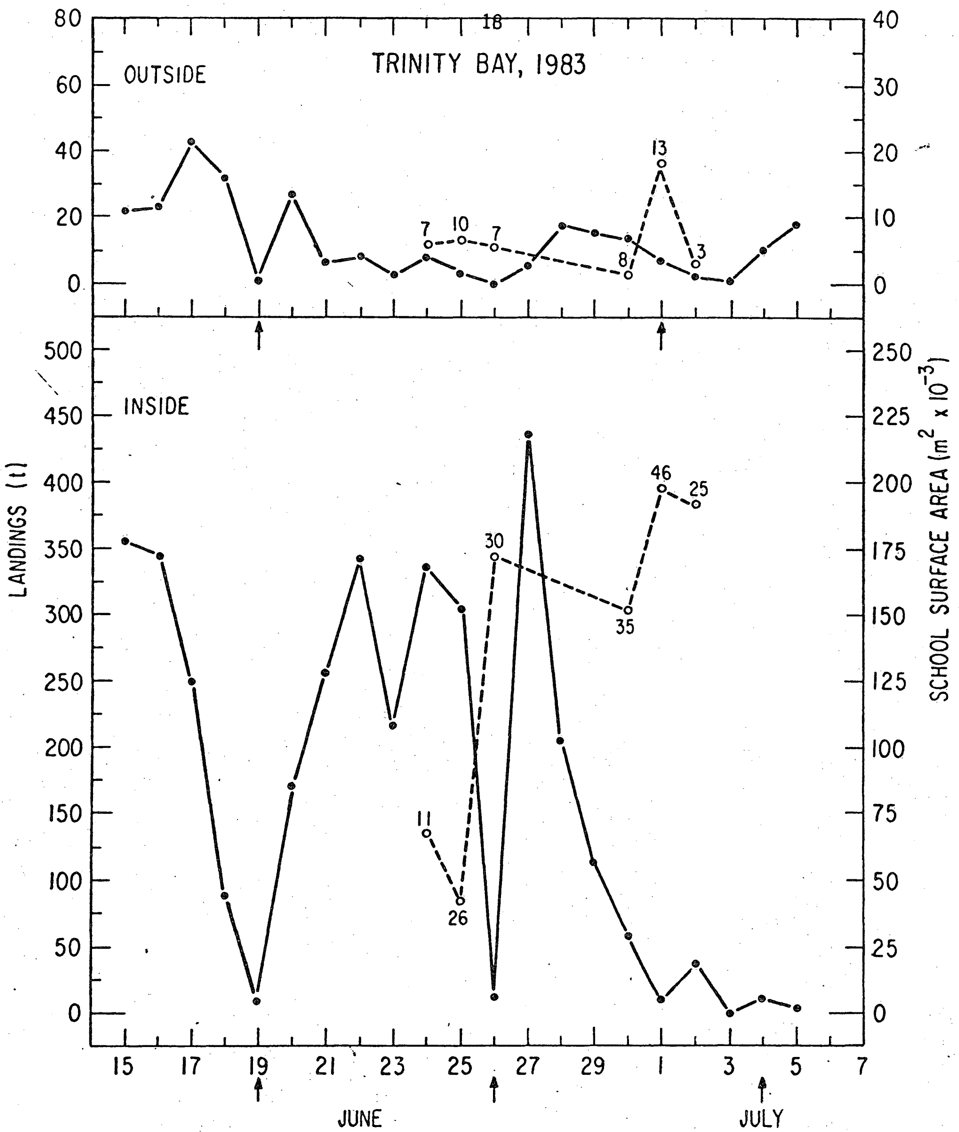

Fig. 2c. Comparison of fixed gear capelin landings (●—●) and school surface area (o---o) trends in 1983 for the outside and inside transects in Trinity Bay. Numbers near the open circles indicate the number of capelin schools observed. An arrow on the x-axis denotes a Sunday.

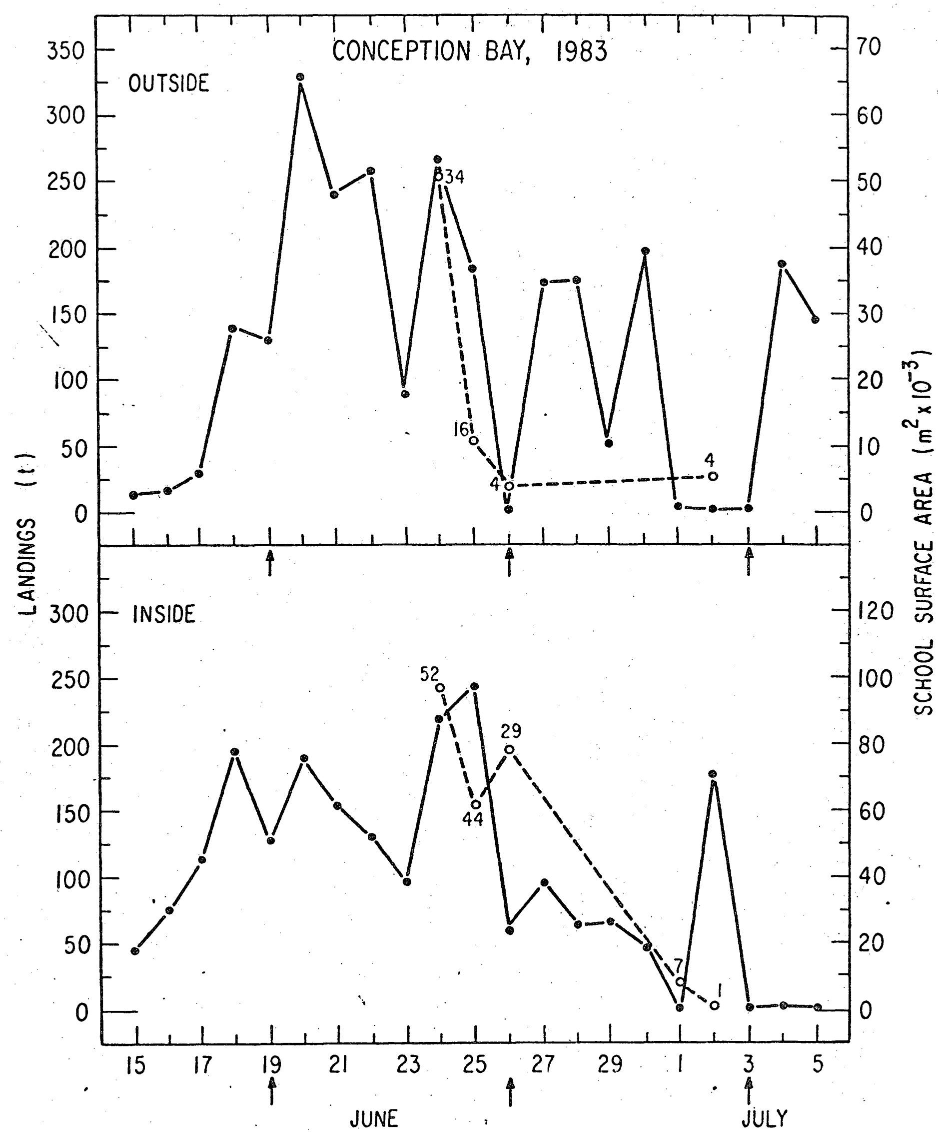

Fig. 2d. Comparison of fixed gear capelin landings (●—●) and school surface area (o---o) trends in 1983 for the outside and inside transects in Conception Bay. Numbers near the open circles indicate the number of capelin schools observed. An arrow on the x-axis denotes a Sunday.

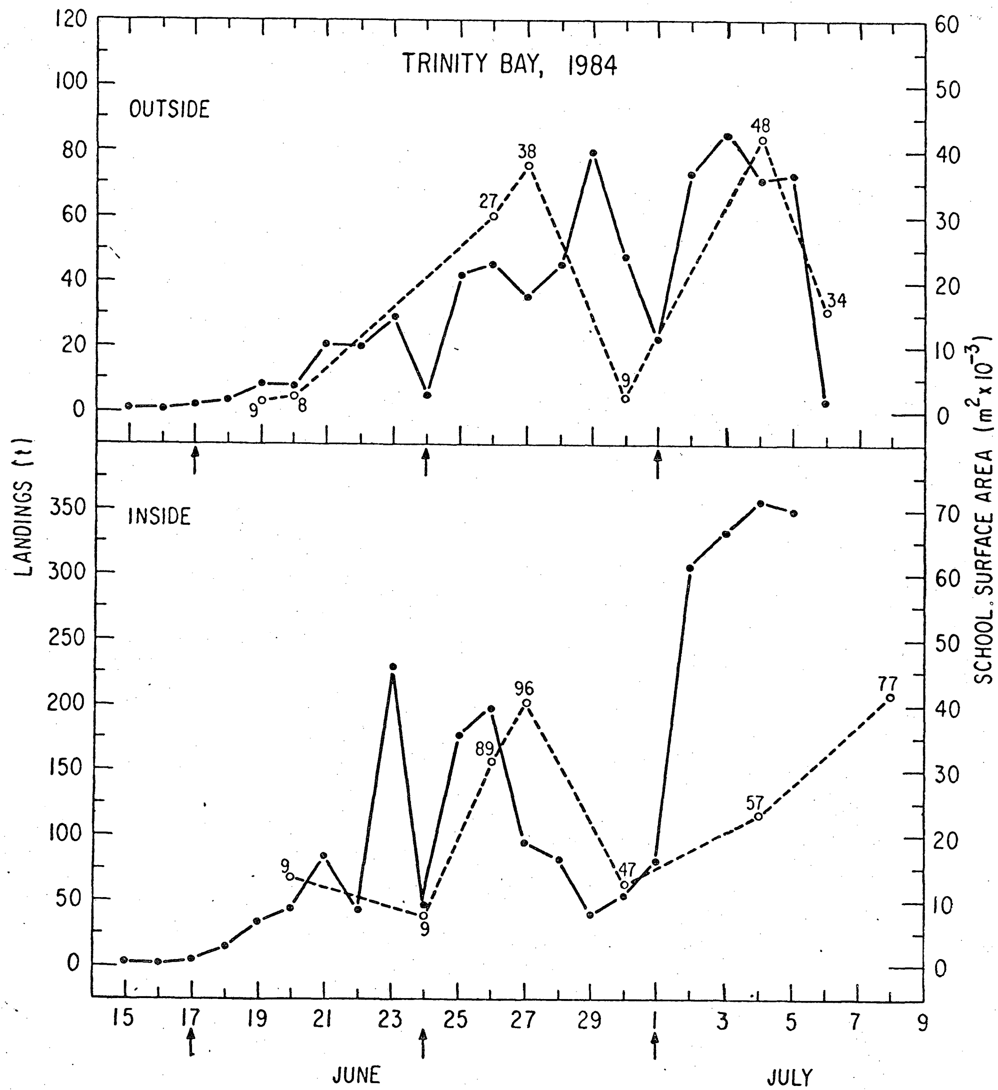

Fig. 2e. Comparison of fixed gear capelin landings (●—●) and school surface area (o---o) trends in 1984 for the outside and inside transects in Trinity Bay. Numbers near the open circles indicate the number of capelin schools observed. An arrow on the x-axis denotes a Sunday.

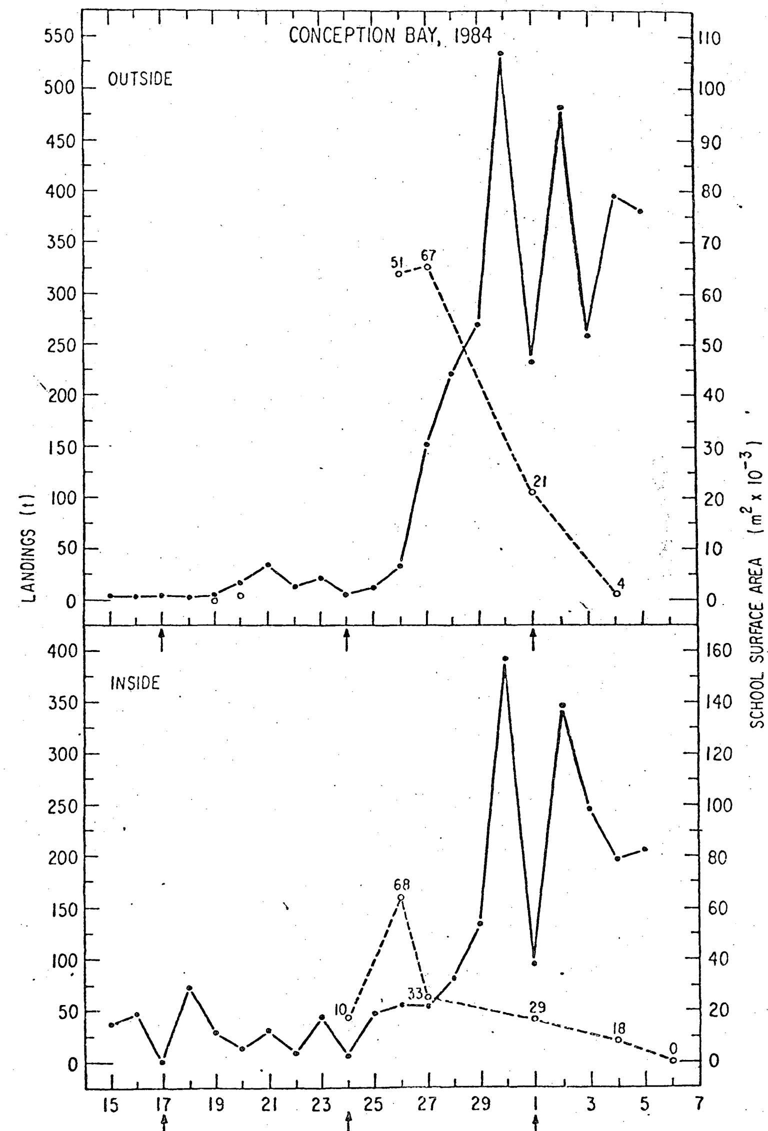

Fig. 2f. Comparison of fixed gear capelin landings (●—●) and school surface area (o---o) trends in 1984 for the outside and inside transects in Conception Bay. Numbers near the open circles indicate the number of capelin schools observed. An arrow on the x-axis denotes a Sunday.