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Results of Aerial Surveys of Capelin (*Mallotus villosus*) Schools Using the Compact Airborne Spectrographic Imager (CASI)

by

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Abstract

Aerial surveys were conducted over Trinity Bay and Conception Bay using a digital imaging spectrometer (CASI) in 1990 and 1991. Coverage was good in 1990 except for one transect. The 1991 survey underestimated the abundance and extent of the spawning biomass because the survey ended on July 17 which was almost one week before peak spawning occurred in Conception Bay. The school surface area index showed a decline between 1989 and 1990 which contrasted with the trap catch rate index which increased at the same time. The aerial survey series was significantly correlated with trends in the trap catch rate and NAFO projections of mature capelin biomass from 1982 to 1990. A revised aerial survey index using only the three transects most frequently covered will be the basis of future surveys.

Introduction

Aerial photographic surveys of capelin (Mallotus villosus) schools have been conducted since 1982 (Nakashima 1990). In 1989 we developed the application of an imaging spectrometer, the Compact Airborne Spectrographic Imager (CASI), to use in place of the photographic method of recording, measuring, and counting capelin schools (Nakashima et al. 1989, Borstad et al. 1990). All flights in 1990 and 1991 except for one flight on June 24, 1990 were conducted with the CASI. Comparisons of school area measurements showed a significant correlation between the photographic and digital techniques (Borstad et al. 1990). Differences between the two usually indicated that the photographic method underestimated the number and area of schools. For example, schools were more easily observed after classification and enhancement of images, especially those in low light or with some glare on the water.

The manuscript describes briefly the method using the CASI and processing with image analysis techniques, presents the 1990 and 1991 aerial survey results, and compares the school surface area index to other more traditional indices of relative abundance.

Material and Methods

Instrument Description

The CASI (Fig. 1) is an imaging spectrometer which uses a two dimensional (612 x 288) charge couple device (CCD) and a diffraction grating to collect image and spectral data. The CASI operates in the range of 423-946 nm. A 512 pixel width spatial image is formed in "pushbroom" fashion by reading out the cross track information as the aircraft moves forward. The remaining elements are used to obtain dark and electronic offset reference values. Spectral data are collected across 288 elements in the along track dimension of the array. The spectral resolution of each element is 1.8 nm and the spatial resolution of each element is 1.2 rad. Integration times are a function of ambient light levels, aircraft speed, and band selections.

In spatial or imaging mode the CASI operates like other pushbroom imagers except that band widths, positions and number are programmable during the flight. High spatial resolution imagery is collected in several spectral bands which can be programmed as narrow as 1.8 nm or wider. The spectral bands used in 1990 and 1991 were:

Year	Band widths				
	1	2	3	4	5
1990	470-522	523-550	555-595	659-692	700-719
1991	450-520	525-600	640-690	701-724	

The band width selections were based on prior work with the Fluorescence Line Imager (Borstad et al. 1985) and analysis of CASI data collected from Pacific herring (Clupea pallasi) schools (Borstad et al. 1992) and capelin schools in 1989 (Nakashima et al. 1989, Borstad et al. 1990).

CASI image data were then transferred to a PC-based image processor for classification and analysis. An algorithm, tested in 1989 to estimate school areas from the digital survey data (Borstad et al. 1990), was used to analyze the 1990 and 1991 data.

Survey Transects

Particulars of the aerial surveys including aircraft type, camera and film used, survey time, and altitudes flown are listed in Table 1. CASI surveys were flown at 1200 m to obtain a swath width comparable to aerial photographs taken at 457 m. Since 1982 the survey has covered four transects as often as possible during the spawning season. The four transects were the outside of Trinity Bay from the Horse Chops to Gooseberry Cove, the inside of Trinity Bay from Gooseberry Cove to Hopeall, the outside of Conception Bay from Caplin Cove to Harbour Grace Islands, and the inside of Conception Bay from Harbour Grace Islands to Portugal Cove (Fig. 2).

School Detection

Similar to the photographic survey (Nakashima 1990), we rely on experienced spotters to detect and direct the aircraft over capelin schools. Flight tapes were viewed following each flight or shortly thereafter to examine the quality of the imagery.

Analysis

For each transect flown, the mean and median surface areas of capelin schools, the total number of schools, and the total surface area of all schools observed were estimated.

The school surface area index for each year was estimated by summing the highest total school surface area observed on each of the four transects. I assumed that the peak in school surface area was indicative of inshore abundance for each transect for that year (Nakashima 1985). The trend in the index derived from 1982 to 1991 was compared to trends in catch rates from capelin traps and purse seines (Nakashima and Harnum 1992) and to projections of mature biomass derived from acoustic surveys (Anon. 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989). Mature biomass projections were unavailable for 1991 (Anon. 1990).

Results and Discussion

The 1990 survey used the aerial photographic method on June 24 and the CASI on the remaining flights (Table 1). In 1990 twelve of 20 days (June 17-23, 25, 28, and July 1, 2, 5) were lost due to poor weather conditions. The outside transect of Conception Bay (Table 2c) and the inside transect of Trinity Bay (Table 2b) were covered three times, the inside transect of Conception Bay was covered four times (Table 2d), and the outside transect of Trinity Bay was covered once (Table 2a). The observations on the afternoon of June 26 and the morning of June 27 over the outside transect of Conception Bay were combined. The observed peak in total surface area of schools was observed on June 26-27 in Conception Bay (Tables 2c, d) and on June 29 in Trinity Bay (Table 2b).

In 1991, the entire aerial survey was conducted with the CASI. Very few schools were digitally recorded due to the late arrival of capelin schools inshore. Eleven days (June 21, 22 and July 3, 4, 6-9, 12, 13, 15) were lost due to poor weather conditions. The survey was suspended between June 26 and July 2, however no capelin were present in the area. The survey was extended later into July than in previous years (Table 1), however, the CASI portion of the survey ended on July 17 a few days before capelin schools were fished in

Trinity Bay and Conception Bay (Nakashima and Harnum 1992) and one week before spawning took place (Nakashima and Slaney 1992). Visual observations of schools were conducted until July 20 indicating that more schools were arriving in the survey area. The inside transect of Trinity Bay was covered five times (Table 2d), the outside of Conception Bay three times (Table 2c), and the inside of Conception Bay four times (Table 2d). The outside of Trinity Bay was not surveyed in 1991. Only 19 schools were observed in Conception Bay for a total school surface area estimate of 14,827 m^2. The highest total area of schools observed on the inside of Trinity Bay was 170,681 mi^2 on July 5 (Table 2b).

I compared the school surface area index for all four transects to the commercial catch rate series from the trap and purse seine fisheries and the mature biomass projections from previous NAFO assessments of this stock for 1982-90. The purse seine catch rate series is not significantly correlated with the trap catch rate or school surface area ($p > .05$) but is significantly correlated with the NAFO projections ($p = .0243$) (Table 4). The trap catch rate index is significantly correlated with the aerial survey index ($p = .0138$) and the NAFO projections ($p = .0017$) (Table 4). The aerial survey index and NAFO projections are significantly correlated ($p = .0412$) with each other. In 1990 the school surface area total indicated a decline from 1989 whereas the trap catch series and NAFO projections increased between 1989 and 1990 (Table 3). There was no NAFO projection of mature biomass for 1991 (Anon. 1990) and the aerial survey in 1991 did not overlap with the peak spawning period.

A second school surface area index was calculated using only transects from the inside of Trinity Bay and both transects in Conception Bay (Table 2b, c, d). The coverage of the outside transect of Trinity Bay has been poor in recent years (Table 2a). In 1990 we surveyed this transect once and did not survey it at all in 1991. The 1982 coverage was also inadequate compared to the other three transects. This transect is the furthest from the airport which may account for the infrequent coverage. Consequently I derived a revised series based on those transects which have been surveyed adequately (in my view) in all years (Table 3). The aerial survey indices based on three and four transects from 1982 to 1991 were highly correlated ($r = .9926$, $p = .0001$, Fig. 4). Further, comparison of the aerial survey index using three transects with the trap catch rate index and the NAFO projections showed minor statistical improvements (Table 4). Because the two aerial survey indices are comparable future surveys will ignore the outside transect of Trinity Bay in favour of increasing the frequency of flights over the remaining three transects.

Acknowledgments

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Table 1. Summary of aerial surveys conducted from 1982 to 1991.

Year	Aircraft	Camera	Lens (mm)	Filter	Film	Radar altimeter	Survey period	Altitude (m)	Survey flight time (hrs)
1982	Piper Aztec	RC 10	152	Anti-vignetting	Aerocolour Neg. 2445	No	Jun 18-Jul 5	152-160	
1983	Aero-Commander	Wild RC 10	152	Anti-vignetting	Aerocolour Neg. 2445	Yes	Jun 19-Jul 9	457	21.8
1984	Cessna 310	Wild RC 10	152	Anti-vignetting	Aerocolour Neg. 2445	Yes	Jun 17-Jul 7	457	38.5
1985	Aero-Commander 500 B	Wild RC 10	152	Anti-vignetting	Aerocolour Neg. 2445	Yes	Jun 18-Jul 3	290-610	28.6
1986	Aero-Commander 500 B	Wild RC 10	152	Anti-vignetting	Aerocolour Neg. 2445	Yes	Jun 19-Jul 5	381-579	13.4
1987	Piper Aztec	Zeiss RMK	153	Anti-vignetting	Aerocolour Neg. 2445	Yes	Jun 16-Jul 3	457	37.0
1988	Piper Navajo Piper Aztec	Zeiss RMK	153	Anti-vignetting	Aerocolour Neg. 2445	Yes	Jun 15-Jul 5	305-488	33.0
1989	Piper Navajo	Zeiss RMK	153	Anti-vignetting	Aerocolour Neg. 2445	Yes	Jun 16-27 Jun 30-Jul 4	434-732	26.0
1990	Piper Aztec	Zeiss RMK CASI	153	Anti-vignetting	Aerocolour Neg. 2445	Yes	Jun 17-Jul 6	570-1260	27.0
1991	Piper Navajo	CASI				Yes	Jun 21-25 Jul 3-17	1200	27.3

Table 2a. Schooling data for the outside part of Trinity Bay from Horse Chops to Gooseberry Cove, 1982-90.

Date	No. of schools	Total surface area (m^2)	School size (m^2) Mean ± SD	Median
June 19, 1982	7	2963	423 ± 502	125
June 26, 1982	0	0		
July 3, 1982	1	522	522	522
June 23, 1983	7	11330	1619 ± 1315	1283
June 24, 1983	10	13671	1367 ± 1260	1088
June 25, 1983	7	11662	1666 ± 2151	725
June 29, 1983	8	2288	286 ± 228	195
June 30, 1983	13	18470	1420 ± 1613	1116
July 1, 1983	3	6417	2139 ± 2176	1172
June 18, 1984	9	3236	360 ± 423	223
June 19, 1984	8	3962	495 ± 703	279
June 25, 1984	22	30467	1385 ± 1959	502
June 26, 1984	38	37219	979 ± 1718	167
June 29, 1984	9	2790	310 ± 223	279
July 3, 1984	48	43412	904 ± 3010	223
July 6, 1984	34	16015	471 ± 485	167
June 21, 1985	0	0		
June 25, 1985	0	0		
June 29, 1985	18	15536	863 ± 983	316
July 1, 1985	32	48808	1525 ± 1622	893
July 2, 1985	24	49216	2051 ± 2965	949
July 3, 1985	9	2498	278 ± 183	270
June 18, 1987	59	41348	701 ± 985	391
June 22, 1987	81	45421	561 ± 780	279
June 28, 1987	15	5189	346 ± 384	223
July 3, 1987	9	12220	1358 ± 3042	279
June 19, 1988	41	45812	1117 ± 2569	279
July 5, 1988	13	10714	824 ± 617	502
June 17, 1989	78	97325	1248 ± 2664	433
June 30, 1989	4	1334	333 ± 307	203
July 3, 1989	0			
June 25, 1990	0			
June 27, 1990	26	31908	1210 ± 1266[a]	709

[a] calculation excludes capelin in traps

Table 2b. Schooling data for the inside part of Trinity Bay from Gooseberry Cove to Hopeall, 1982-91.

Date	No. of schools	Total surface area (m^2)	School size (m^2) Mean ± SD	Median
June 19, 1982	31	12724	411 ± 712	149
June 26, 1982	29	35607	1228 ± 2755	299
June 29, 1982	11	62397	5672 ± 8378	592
July 2, 1982	8	31365	3921 ± 9281	705
July 3, 1982	2	1920	960 ± 17	960
June 23, 1983	11	69583	6326 ± 6299	4241
June 24, 1983	26	39004	1500 ± 1880	753
June 25, 1983	30	174487	5816 ± 12759	781
June 29, 1983	35	152557	4359 ± 11139	781
June 30, 1983	46	199373	4334 ± 6927	558
July 1, 1983	25	189497	7580 ± 19791	2288
June 19, 1984	13	15624	1202 ± 1770	335
June 23, 1984	9	8314	924 ± 888	502
June 25, 1984	96	31526	328 ± 505	117
June 26, 1984	96	40510	422 ± 679	223
June 29, 1984	47	12053	256 ± 314	167
July 3, 1984	57	23827	418 ± 814	167
July 7, 1984	77	43245	562 ± 1124	223
June 21, 1985	13	7041	542 ± 706	270
June 25, 1985	35	22459	642 ± 1144	211
June 26, 1985	30	16540	551 ± 721	214
July 1, 1985	125	60245	482 ± 963	181
July 2, 1985	130	195659	1503 ± 6046[a]	179
June 28, 1986	59	95898	1625 ± 4502	340
June 17, 1987	45	167567	3724 ± 17727	223
June 19, 1987	91	399026	4385 ± 31197	167
June 27-28, 1987	37	59315	1603 ± 5612	446
July 3, 1987	5	1786	357 ± 322	279
June 16, 1988	27	18749	694 ± 902	391
June 19, 1988	50	104179	2084 ± 4546	502
June 22, 1988	67	112863	1685 ± 5749	391
June 25, 1988	20	87103	4338 ± 15287[a]	474
July 5, 1988	23	32252	1402 ± 3199	223
June 17, 1989	60	84349	1389 ± 5040[a]	191
July 3, 1989	0			
June 24, 1990	4	69498	17375 ± 11184	21483
June 27, 1990	30	58174	1831 ± 3717	701
June 29, 1990	38	141122	3714 ± 5486	1503
June 23, 1991	0			
June 24, 1991	0			
July 5, 1991	139	170681	1228 ± 1827	535
July 14, 1991	54	64598	1196 ± 1894	567
July 16, 1991	33	93680	2839 ± 5562	800

a calculation excludes capelin in traps

Table 2c. Schooling data for the outside of Conception Bay from Caplin Cove to Harbour Grace Islands, 1982-91.

Date	No. of schools	Total surface area (m^2)	School size (m^2) Mean ± SD	Median
June 29, 1982	10	6577	658 ± 366	642
July 2, 1982	2	1357	679 ± 554	679
June 23, 1983	34	51838	1374 ± 2266[a]	530
June 24, 1983	16	10658	666 ± 823	447
June 25, 1983	4	4408	349 ± 184	279
July 1, 1983	5	5413	1083 ± 1884	112
June 18, 1984	1	391	391	
June 19, 1984	0	0		
June 25, 1984	49	63779	1294 ± 2874	391
June 26, 1984	67	65956	697 ± 1091[a]	279
June 30, 1984	21	22320	818 ± 1509[a]	223
July 3, 1984	4	1786	446 ± 599	195
June 20, 1985	0	0		
June 24, 1985	0	0		
June 27, 1985	30	8840	268 ± 378[a]	120
June 28, 1985	125	50837	368 ± 800[a]	132
June 29, 1985	22	19253	875 ± 1169	291
July 1, 1985	28	28036	991 ± 1616[a]	264
July 2, 1985	66	69166	914 ± 2064[a]	223
June 19, 1986	88	132455	1462 ± 2853[a]	279
June 16, 1987	139	184307	1322 ± 2924[a]	391
June 19, 1987	143	112660	766 ± 1516[a]	279
June 27, 1987	21	12164	539 ± 559[a]	391
June 30, 1987	37	29462	790 ± 1481[a]	279
June 20, 1988	54	36993	679 ± 1099[a]	223
June 22, 1988	64	18916	230 ± 324[a]	112
June 25, 1988	116	87534	676 ± 1331[a]	279
July 4, 1988	51	39785	578 ± 805[a]	279
June 16, 1989	180	266878	1483 ± 5512	335
June 18, 1989	162	197372	1132 ± 3607[a]	335
July 1, 1989	8	6140	730 ± 1359[a]	198
June 24, 1990	89	85437	863 ± 1483[a]	396
June 26-27, 1990	42	88759	1937 ± 3671[a]	670
June 30, 1990	38	26013	686 ± 771[a]	368
June 23, 1991	0			
June 24, 1991	0			
July 14, 1991	11	6374	579 ± 2789	520

a calculation excludes capelin in traps

Table 2d. Schooling data for the inside of Conception Bay from Harbour Grace Islands to Portugal Cove, 1982-91

Date	No. of schools	Total surface area (m^2)	School size (m^2) Mean ± SD	Median
June 26, 1982 AM	33	19408	571 ± 907[a]	135
June 26, 1982 PM	20	36513	1826 ± 1914	2089
June 27, 1982	48	151214	3134 ± 6015[a]	527
June 29, 1982	27	30275	1121 ± 1707	418
July 4, 1982	3	13042	4347 ± 4951	1409
July 5, 1982	7	5127	732 ± 582	592
June 23, 1983	53	97595	1787 ± 2754[a]	558
June 24, 1983	30	56860	1819 ± 2965[a]	558
June 25, 1983	29	79961	2677 ± 3725[a]	781
June 30, 1983	7	8091	1156 ± 1181	558
July 1, 1983	1	2009	2009	
June 18, 1984	0	0		
June 23, 1984	8	17689	2085 ± 2556[a]	949
June 25, 1984	70	63891	879 ± 1789[a]	223
June 26, 1984	33	23603	703 ± 1708[a]	223
June 30, 1984	29	16852	508 ± 467[a]	335
July 3, 1984	18	9040	329 ± 254[a]	223
July 5, 1984	0	0		
June 20, 1985	0	0		
June 24, 1985	2	1600	800 ± 834	800
June 26, 1985	17	10124	596 ± 1145	314
June 27, 1985	76	16552	214 ± 426[a]	78
June 28, 1985	120	33858	274 ± 938[a]	67
July 1, 1985	16	43228	2702 ± 5140	308
July 2, 1985	17	13436	676 ± 1872[a]	191
June 19, 1986	39	31574	786 ± 1105[a]	357
June 20, 1986	4	3515	698 ± 769[a]	363
June 22, 1986	86	30930	343 ± 616[a]	131
July 2, 1986	10	5019	502 ± 600	358
June 17, 1987	196	53066	263 ± 350[a]	167
June 19, 1987	365	205846	556 ± 1482[a]	167
June 21, 1987	179	74128	393 ± 699[a]	167
June 27, 1987	138	94747	681 ± 2389[a]	167
June 28, 1987	63	68969	1036 ± 2402[a]	167
June 30, 1987	41	51336	1226 ± 2892[a]	391
July 3, 1987	47	34863	742 ± 1400	279
June 19, 1988	77	25780	335 ± 599	223
June 20, 1988	31	7742	240 ± 256[a]	167
June 24-25, 1988	289	201642	682 ± 1091[a]	391
July 4, 1988	24	32141	1295 ± 4242a	251
June 16, 1989	186	187311	991 ± 2032[a]	319
June 18, 1989	113	88283	686 ± 1422[a]	279
June 30, 1989	0			
July 1, 1989	22	13905	587 ± 512[a]	396
July 4, 1989	24	10707	446 ± 651	279
June 26, 1990	112	128743	1092 ± 2960[a]	360
June 29, 1990	32	88310	2591 ± 4544[a]	742
June 30, 1990	96	102615	1069 ± 1993[a]	489
July 3, 1990				
June 25, 1991	0			
July 8, 1991	Few schools observed - no CASI data			
July 11, 1991				
July 17, 1991	8	8453	1057 ± 531	875

a calculation excludes capelin in traps

Table 3. Comparison of three indices for estimating trends in relative spawning biomass. The catch/day index was based on capelin trap and purse seine data from logbook surveys (Nakashima and Harnum 1992), the mature biomass index from NAFO Scientific Council Reports (Anon. 1982-89), and the school surface area index for 4 and 3 transects.

Year	Catch (t)/day		Mature biomass (t)	School surface area (m^2)	
	Purse seine	Trap		4 transects	3 transects
1982	16.4	3.1	≥346,000	223,150	220,188
1983	18.8	3.4	648,000	367,280	348,806
1984	14.3	2.9	384,000	216,500	173,092
1985	16.4	4.6	596,000	357,270	308,053
1986	19.0	4.6	1,300,000	283,150	259,927
1987	18.1	8.8	2,830,000	762,953	717,532
1988	20.7	6.2	900,000	447,851	402,039
1989	24.3	6.7	3,345,000	635,863	538,538
1990	21.4	8.6	3,500,000	390,532	358,624
1991	16.2	7.3		185,508	185,508

Table 4. Pearson product moment correlation coefficients for two catch rate indices (purse seine, trap), two aerial survey series (3 transects, 4 transects), and NAFO projections of mature biomass from 1982 to 1990. The upper right triangle presents the correlation coefficients and the lower left triangle are probabilities.

	Purse seine	Trap	Aerial (3)	Aerial (4)	NAFO
Purse seine	*	.6064	.5119	.5488	.7343
Trap	.0834	*	.7878	.7827	.8815
Aerial (3)	.1589	.0117	*	.9923	.6908
Aerial (4)	.1260	.0126	.0001	*	.6864
NAFO	.0243	.0017	.0393	.0412	*

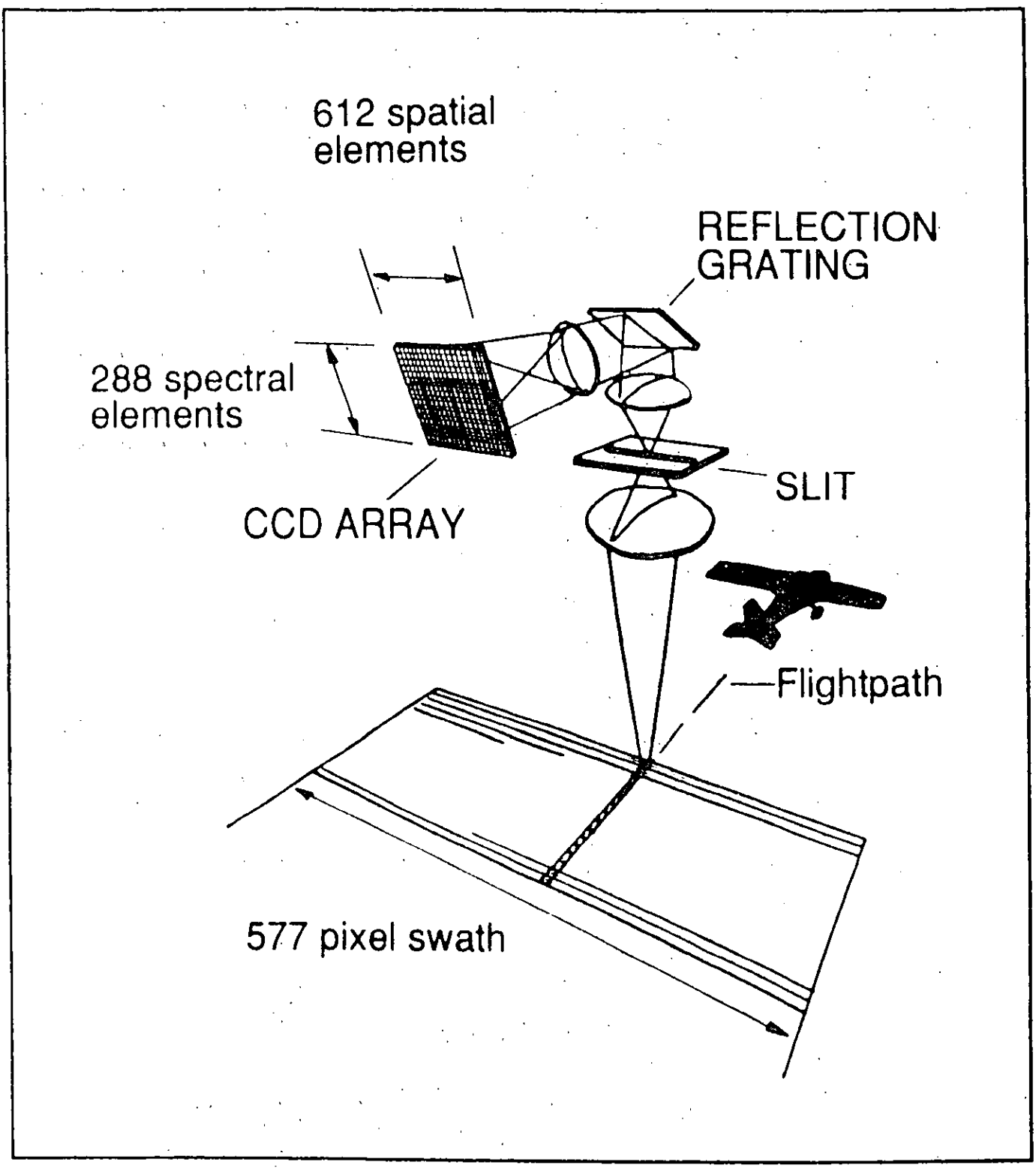

Fig. 1. Schematic of Compact Airborne Spectrographic Imager (CASI) from Borstad et al. (1990).

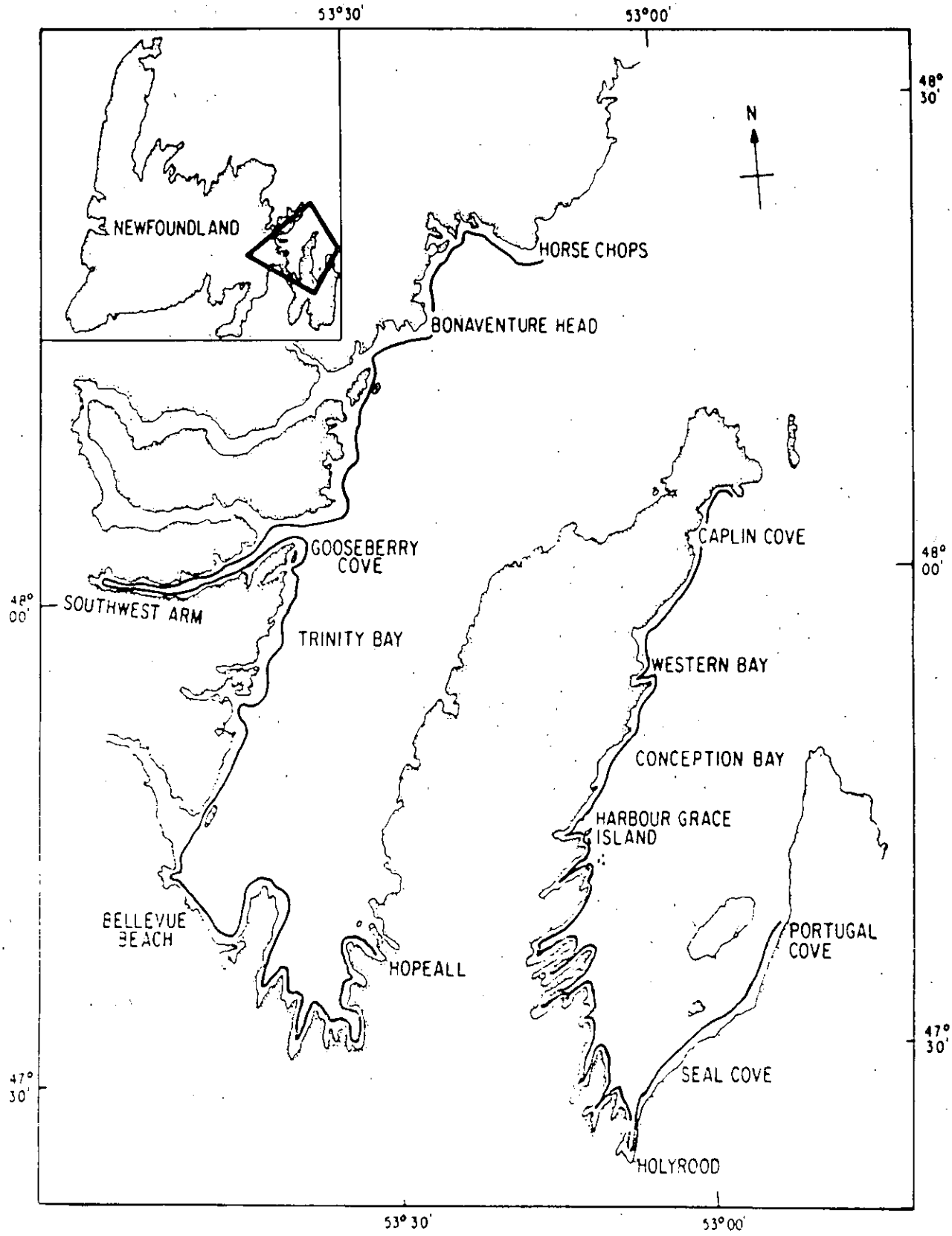

Fig. 2. Aerial survey transect for Trinity Bay and Conception Bay.

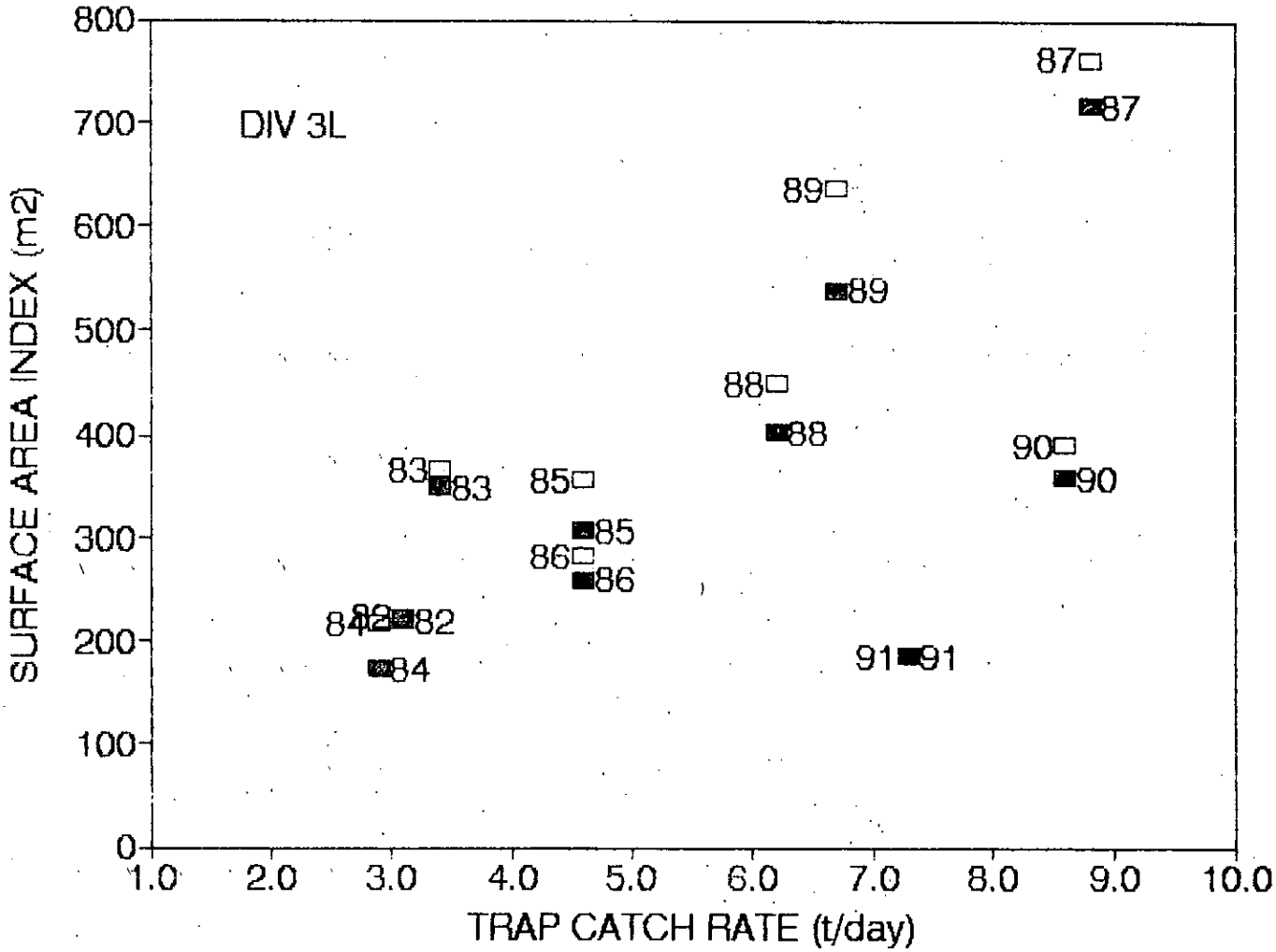

Fig. 3. Comparison of trap catch rate series and school surface area indices for 3 transects (▩) and 4 transects (□) in Div. 3L from 1982 to 1991.