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Capelin (*Mallotus villosus*) Egg Deposition on Fifteen Spawning Beaches in Conception Bay, Newfoundland in 1987-91

by

Brian S. Nakashima and Barry W. Slaney

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

ABSTRACT

From 1987 to 1991 egg deposition was estimated from the mid-tide zone of 15 capelin spawning beaches in Conception Bay. The surveys were timed to occur after peak spawning and before significant hatching and release of larvae from the sediments had occurred. The stages of development of eggs and concentrations of pre-emergent larvae in the sediments were determined. Spawning was delayed by up to 30 days in 1991 compared to 1987-90. Egg concentrations were varible among beaches within the same year and between years. The highest geometric mean concentration was in 1988 and the lowest in 1989.

INTRODUCTION

Capelin (Mallotus villosus) spawn intertidally on gravel beaches during June and July in coastal areas of the Northwest Atlantic. Eggs remain adhesive for as long as 2 hours after exposure to water (Fridgeirsson 1976), and attach to the surrounding beach substrates. The fertilized eggs incubate and develop in the beach sediments at depths of up to 20 cm (Taggart and Leggett 1987).

Capelin beaches are known to exhibit annual differences in the abundance of spawn. Fishermen have often reported that the abundance of capelin eggs observed along spawning beaches in Newfoundland is highly variable. Velikanov (1984) observed that egg concentrations on capelin beaches in the Sakhalin area were an order of magnitude higher in 1978 than in 1979. Taggart and Nakashima (1987) reported a range of $9x10^8$ to $8x10^{10}$ eggs among 16 beaches on the western perimeter of Conception Bay in 1983.

To provide a relative index of egg deposition we sampled 15 beaches along the perimeter of Conception Bay, Newfoundland, from 1987 to 1991.

MATERIALS AND METHODS

Sampling Sites

We selected 15 known capelin spawning beaches around Conception Bay (Fig. 1). Thirteen beaches are accessible by land and two (Caplin Cove and Kingston) by sea. Each year beach sampling commenced immediately following the occurrence of significant numbers of spawning capelin schools along the coastline of Conception Bay. Peak spawning was determined from aerial surveys (Nakashima 1992) and from periodic checks of a few beaches for evidence of egg deposition.

Samples were collected in the mid-tide (MT) zone during low tide to maximize the sampling of several beaches in a short period of time. The MT zone is defined as the area of the intertidal zone which lies between the low and high tide water marks. The low-tide zone is covered by seawater except at low tide conditions which would restrict sampling to one daylight period of less than two hours. The high-tide zone is exposed during most of the tidal cycle and eggs are subjected to faster development and higher mortality than the low- and mid-tide zones (Frank and Leggett 1981). Capelin tend to spawn more on the falling tide than the rising tide and mass spawning usually occurs at intermediate tidal levels (Templeman 1948). Consequently eggs are more likely

to be deposited in the mid-tide areas. Given the number of personnel and location of sites it was not feasible to sample all three tidal zones of each beach within the short time following peak spawning. Consequently we chose to sample only the MT zone assuming that the results would represent a minimum estimate of the number of eggs deposited there after peak spawning.

The area of the MT zone on each beach was calculated using length and width measurements estimated when samples were collected. The number of samples collected at each beach depended on a qualitative inspection of the egg distribution in the MT zone that consisted of visually examining the concentration of eggs along the entire length of the MT zone. Two qualitative and relative indices were employed: HC (high concentration) and LC (low concentration). When egg distribution was judged to be relatively heterogeneous the MT zone was stratified into HC and LC areas (each measured) and up to two sediment core samples were collected within each stratum. Beaches judged to have a relatively uniform egg distribution were sampled at two different locations randomly chosen in the MT zone.

A steel sediment corer (6.5 cm internal diameter) was used to collect each sediment core sample. At each sampling location the corer was manually "drilled" into the beach sediments to the greatest depth possible (limited by the strength of the operator or subsurface grains larger than 6.5 cm) and the depth was measured with a calibrated plunger inside the corer. Each core sample was fixed with a 4% formalin and seawater solution buffered with sodium borate to protect the eggs from deterioration. Egg concentration and development rate were assumed to be vertically homogeneous within the beach sediments (Frank and Leggett 1981).

Eggs and Pre-emergent Larvae

Adhesive capelin eggs were separated from beach sediments by rinsing each sample with fresh water over a 250 µm-mesh screen followed by submersion in a 2% (by weight) KOH solution for a period of 24 to 36 hr. Separated eggs were subsequently washed from the sediments, decanted, and collected on a 250 µm-mesh screen. If any adhesive eggs remained the sediments were submersed for an additional 6 hr in the KOH solution and washed again.

Egg abundance was estimated by subsampling the separated eggs with a ten-chamber whirling vessel (Pitt 1965). The entire sample was sequentially fractioned until the number of eggs per chamber was reduced to ~2500. Eggs from two randomly selected chambers were counted and averaged (Nakashima 1987). Average egg concentration (eggs cm^{-2}) for each beach was estimated using sediment-core egg concentration weighted by beach stratum area and core depth.

We examined variation in developmental stage among samples to ensure that our concentration estimates were not unduly biased by variations in egg development among beaches that might lead to a significant 'loss' of eggs through differential hatching. A minimum of 50 eggs from each core sample were placed in Stockard's solution (Bonnet 1939) and the eggs were classified as dead (opaque or showing arrested development), in early development (stages I-IV) as described by Fridgeirsson (1976) and generally associated with the first 6 days of development, or eyed (eyed embryo).

Pre-emergent (hatched) larvae were enumerated from each core sample collected. For large numbers of larvae (>500) the sample was subdivided and estimates were made using the Huntsman Marine Laboratory beaker technique (Van Guelpen et al. 1982). When numbers of larvae were low, all larvae were counted. The average larval concentration per beach was estimated using the sediment-core larval concentration weighted by stratum area and core depth.

To compare the egg and larval concentrations between years the estimates were standardized to a mid-tide area common for each beach. In most years except 1991 the mid-tide area where eggs were observed was equal to or less than the standard area. In 1991 the mid-tide area was larger for nine of fifteen beaches compared to previous years because the width of the mid-tide zone was wider. This may have been due to the differences in tidal conditions between late June-early July for 1987 to 1990 and late July-early August in 1991.

RESULTS

Sampling Time

Sampling times were variable between 1987 and 1991 (Table 1). The earliest sampling perod was 1987. In 1988 the beaches were surveyed about five days

later than in 1987. Collections in 1989 were two days later and 1990 was seven days later than in 1987. From 1987 to 1990 timing of the survey varied within seven days, however, the 1991 survey was 30 days later than in 1987.

Sampling times assume that all beaches are sampled after peak spawning and before significant hatching and larval release have occurred. Examination of the egg samples cleared in Stockard's solution showed that the proportion of dead eggs (at the time of sampling) varied among beaches but the annual means were similar (Table 1). The proportion of eggs in early and eyed developmental stages was quite variable among beaches in a given year. For example in 1987 eggs in early development ranged from 0% to 76% and eggs in eyed development from 4% to 76% (Table 1).

If the proportion of eggs in eyed development is indicative of eggs close to hatching then the 1988 survey was sampled closest to peak spawning and 1989 the furthest from peak spawning (Table 1). Estimates of concentrations of pre-emergent larval capelin indicated that in most instances beaches were sampled before significant hatching and release of larvae had occurred (Table 2). In 1989 every beach had some pre-emergent larvae which suggests that sampling may have been later relative to the peak spawning period compared to other years. The presence of pre-emergent larvae in the core samples may also indicate that spawning of small numbers of fish may have occurred prior to peak spawning. Based on the development stage of eggs in the MT zone and the low concentrations of pre-emergent larvae we concluded that our beach specific estimates of egg concentration were not biased by egg losses incurred through deferential hatching except possibly in 1989.

Beaches and Egg Deposition

There was a high degree of variation in egg deposition among the 15 beaches we sampled. The standard MT area varied from 231 m^2 for Holyrood to 13363 m^2 for Topsail. Egg concentration among the beaches varied over several orders of magnitude. For example egg concentrations in 1990 encompassed three orders of magnitude from as few as 45 eggs cm^{-2} at Burkes Cove to as many as 8978 eggs cm^{-2} at Western Bay (Table 2). In comparison, the total egg deposition among beaches ranged over four orders of magnitude from 7.0×10^{8} at Burkes Cove to 2.7×10^{11} at Western Bay (Table 2).

Egg abundance and concentrations differed among beaches within a given year. In general beaches on the western side of Conception Bay from Spout Cove to Caplin Cove (Fig. 1) had consistently higher abundances and concentrations than those in the bottom and eastern side of Conception Bay from Burkes Cove to St. Phillips (Table 2).

DISCUSSION

Total abundance of eggs, the mean concentration of eggs, and the geometric mean concentration of eggs varied between 1987 and 1991. The total abundance and mean concentration were highest in 1988 followed by 1990, 1991, 1987, and 1989. The geometric mean egg concentration was also highest in 1988 and was twice the estimates for 1987, 1991, and 1990 and three times the 1989 estimate. Annual egg deposition appeared to be unrelated to spawning biomass levels. For example 1988 had the highest concentration of eggs in the MT zone when the projected spawning biomass was lower than any other year from 1987 to 1991 (Nakashima 1992), however, there are only five years with which to make inferences.

This analysis assumes that eggs retained in the MT zone can be used as an index of egg deposition for Conception Bay provided the same beaches are always sampled, beaches are surveyed following peak spawning, and that a single spawning peak represents the most abundant portion of the spawning population. Spawning may occur several times and over several days on a beach (unpublished data, Winters and Nakashima), consequently our estimates do not represent the total egg deposition of the entire spawning biomass. Also we do not take into account eggs in the high-tide or low-tide areas due to the logistics of sampling. Finally spawning can occur in subtidal areas such as observed in 1991.

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REFERENCES

Bonnet, D. D. 1939. Mortality of the cod egg in relation to temperature. Biol. Bull. 76: 428-441.

Frank, K. T., and W. C. Leggett. 1981. Prediction of egg development and mortality rates in capelin (Mallotus villosus) from meteorological, hydrographic, and biological factors. Can. J. Fish. Aquat. Sci. 38: 1327-1338.

Fridgeirsson, E. 1976. Observations on spawning behaviour and embryonic development of the Icelandic capelin. Rit Fiskideildar 5: 1-24.

Nakashima, B. S. 1987. Regional and temporal variations in fecundity of capelin in Newfoundland waters. Trans. Am. Fish. Soc. 116: 864-873.

1992. Results of aerial surveys of capelin (Mallotus villosus) schools using the Compact Airborne Spectrographic Imager (CASI). NAFO SCR Doc. 92/5, Ser. No. N2038. (in press)

Pitt, T. K. 1965. Modification of the whirling vessel for fecundity studies. J. Fish. Res. Board Can. 22: 247-251.

Taggart, C. T., and W. C. Leggett. 1987. Short-term mortality in post-emergent larval capelin Mallotus villosus. I. Analysis of multiple in situ estimates. Mar. Ecol. Prog. Ser. 41: 205-217.

Taggart, C. T., and B. S. Nakashima. 1987. The density of capelin (Mallotus villosus Muller) eggs on spawning beaches in Conception Bay, Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. No. 1580. 19 p.

Templeman, W. 1948. The life history of the capelin (Mallotus villosus O.F. Muller) in Newfoundland waters. Nfld. Dept. Nat. Resources, Res. Bull. 17: 1-151.

Van Guelphen, L., D. F. Markle, and D. J. Duggan. 1982. An evaluation of accuracy, precision, and speed of several zooplankton subsampling techniques. J. Cons. int. Explor. Mer 40: 266-236.

Velikanov, A. Y. 1984. Ecology of reproduction of the far- eastern capelin, Mallotus villosus socialis (Osmeridae), along the coasts of Sakhalin. J. Ichthyology 24: 43-48.

Table 1. Collection dates, number of samples, and developmental stages of capelin eggs for 15 beaches in Conception Bay, Newfoundland, 1987-91.

Beach	Collection date	No. of samples	Developmental stages (%)		
			Early	Eyed	Dead
1987					
Bryants Cove	Jun 23	3	60.9	10.6	28.5
Bristols Hope	Jun 24	3	46.0	25.6	28.4
Bears Cove	Jun 24	4	40.3	33.1	26.7
Caplin Cove	Jun 25	2	75.5	3.6	21.0
Jobs Cove	Jun 25	2	53.1	32.2	14.9
Ochre Pit Cove	Jun 26	3	76.3	11.3	12.4
Western Bay	Jun 26	5	42.2	26.7	31.1
Kingston	Jun 27	4	38.1	43.5	18.5
Spout Cove	Jun 28	3	21.4	34.2	44.4
Coleys Point	Jun 28	4	11.6	58.7	29.8
Chapel Cove	Jun 29	3	8.0	56.8	35.3
Burkes Cove	Jun 29	3	26.4	59.3	14.3
Holyrood	Jun 30	3	0	76.0	24.0
Topsail	Jun 30	4	51.4	30.1	18.5
St. Phillips	Jun 30	2	39.0	38.4	22.8
Mean			39.3	36.0	24.7

Table 1. Continued.

Beach	Collection date	No. of samples	Developmental stages (%) Early	Eyed	Dead
1988					
Western Bay	Jun 28	5	92.9	0.6	6.4
Ochre Pit Cove	Jun 29	3	84.9	3.2	12.0
Spout Cove	Jun 29	5	85.0	5.3	9.6
Bears Cove	Jun 30	3	55.9	1.6	42.6
Bryants Cove	Jun 30	4	48.5	7.7	43.7
St. Phillips	Jun 30	2	60.4	22.7	17.2
Topsail	Jun 30	4	55.3	8.7	36.1
Chapel Cove	Jul 1	3	81.8	4.9	13.2
Holyrood	Jul 1	2	22.4	22.6	55.1
Burkes Cove	Jul 2	3	95.5	1.4	3.1
Caplin Cove	Jul 2	4	74.3	4.3	21.4
Jobs Cove	Jul 2	3	70.2	7.9	21.8
Bristols Hope	Jul 3	3	21.5	52.0	26.6
Coleys Point	Jul 3	6	75.7	10.8	13.4
Kingston	Jul 4	5	76.4	14.3	9.3
Mean			66.7	11.2	22.1
1989					
St. Phillips	Jun 26	4	55.1	17.0	30.5
Holyrood	Jun 26	3	0	62.9	37.1
Topsail	Jun 27	6	0.3	67.6	32.2
Chapel Cove	Jun 27	3	4.9	56.0	39.0
Bears Cove	Jun 28	4	28.1	36.0	35.9
Bryants Cove	Jun 28	3	51.0	35.9	13.1
Bristols Hope	Jun 28	3	50.2	33.3	16.6
Burkes Cove	Jun 29	2	5.9	85.7	8.5
Coleys Point	Jun 29	6	2.7	82.1	15.3
Spout Cove	Jun 30	5	55.5	30.6	14.0
Western Bay	Jun 30	6	52.0	27.5	20.6
Jobs Cove	Jul 1	4	61.9	13.6	29.5
Kingston	Jul 1	5	52.4	27.6	20.1
Ochre Pit Cove	Jul 1	3	13.3	63.1	22.3
Caplin Cove	Jul 2	4	55.8	13.9	30.4
Mean			32.6	43.5	24.3
1990					
Bears Cove	Jul 1	4	89.1	0.2	10.7
Holyrood	Jul 1	3	0	31.2	68.8
St. Phillips	Jul 1	2	69.7	0	30.3
Topsail	Jul 1	6	73.9	10.8	15.3
Bristols Hope	Jul 2	3	83.4	5.5	11.1
Chapel Cove	Jul 2	3	53.3	22.8	23.9
Ochre Pit Cove	Jul 2	3	85.8	0.6	13.6
Bryants Cove	Jul 3	3	75.7	16.3	8.0
Burkes Cove	Jul 4	4	0	75.0	25.0
Coleys Point	Jul 5	6	15.7	56.0	28.3
Jobs Cove	Jul 5	3	24.1	57.1	18.8
Spout Cove	Jul 5	7	59.6	21.1	19.3
Caplin Cove	Jul 6	3	34.5	32.3	33.2
Kingston	Jul 7	5	48.8	33.6	17.6
Western Bay	Jul 8	5	34.5	37.4	28.1
Mean			49.9	26.7	23.5

Table 1. Continued.

Beach	Collection date	No. of samples	Developmental stages (%)		
			Early	Eyed	Dead
1991					
Chapel Cove	Jul 23	2	65.0	12.0	22.0
Bears Cove	Jul 27	4	78.5	0	21.5
Bristols Hope	Jul 27	3	85.4	0	14.6
Bryants Cove	Jul 27	4	73.1	7.0	19.9
Kingston	Jul 28	6	74.7	8.3	17.0
Ochre Pit Cove	Jul 28	3	66.8	8.4	24.8
St. Phillips	Jul 29	5	18.9	50.0	31.1
Topsail	Jul 29	6	33.0	33.4	33.6
Burkes Cove	Jul 30	5	55.0	20.6	24.4
Holyrood	Jul 30	3	8.7	36.6	54.2
Spout Cove	Jul 31	5	29.4	39.0	31.6
Western Bay	Jul 31	6	32.6	29.4	38.0
Caplin Cove	Aug 1	3	32.3	37.5	30.2
Jobs Cove	Aug 1	3	71.6	21.0	7.4
Coleys Point	Aug 2	4	18.2	61.9	19.9
Mean			49.5	24.3	26.0

Table 2. Total abundance of capelin eggs (no. eggs x 10^{-10}), egg concentration (no. eggs/cm²), pre-emergent larval concentration (no. larvae/cm²), and mid-tide area (m²) for 15 beaches in Conception Bay, 1987-91.

Year	Caplin Cove	Jobs Cove	Ochre Pit Cove	Western Bay	Kingston	Spout Cove	Bristols Hope	Bears Cove	Bryants Cove	Coleys Point	Burkes Cove	Chapel Cove	Holyrood	Topsail	St. Phillips		
Abundance																**Total**	
1987	8.50	3.02	2.49	8.57	22.10	4.29	2.52	3.28	6.40	3.18	0.30	2.07	0.52	0.91	0.26	68.41	
1988	6.73	3.16	5.33	13.45	6.73	9.47	5.11	16.73	5.06	12.90	7.23	5.39	0.45	27.90	1.03	126.67	
1989	4.18	2.81	0.91	6.99	13.44	6.55	1.90	0.27	1.40	1.53	0.55	1.10	0.35	3.08	1.11	46.17	
1990	7.45	2.58	5.27	26.94	21.19	11.83	4.63	4.29	5.77	14.96	0.07	1.02	0.04	2.06	0.17	108.27	
1991	1.25	4.56	1.49	18.45	20.88	5.46	3.65	4.04	5.57	0.74	3.29	1.75	1.17	0.70	0.44	73.44	
Egg Concentration																**Mean**	**G Mean**
1987	4453	3265	1973	2640	4084	1902	1563	1269	4661	699	192	1863	2396	361	385	2114	1503
1988	3524	3229	4225	4144	898	4198	3169	6474	2931	2836	4053	4588	2089	2625	1522	3367	3066
1989	2188	2863	718	2153	2484	2536	1178	106	1016	337	350	987	1594	230	1646	1359	960
1990	3905	2634	4172	8300	3915	5243	2873	1661	4205	3288	45	914	203	154	258	2785	1403
1991	653	4653	1177	5684	3857	2422	2265	1564	4057	163	2112	1493	5378	66	650	2413	1470
Pre-emergent Larval Concentration																**Mean**	
1987	0	0	0	0	0	38	0	0	0	0	0	0	0	97	8	10	
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
1989	6	1	16	30	9	11	6	14	5	8	4	30	24	23	27	14	
1990	21	34	0	23	10	86	0	0	3	11	38	7	3	1	0	16	
1991	1	88	0	6	19	39	0	0	0	1	6		0	0	0	11	
MT	1998	1042	1479	3246	7498	2583	1612	3468	1726	5005	1785	1175	231	13363	675		

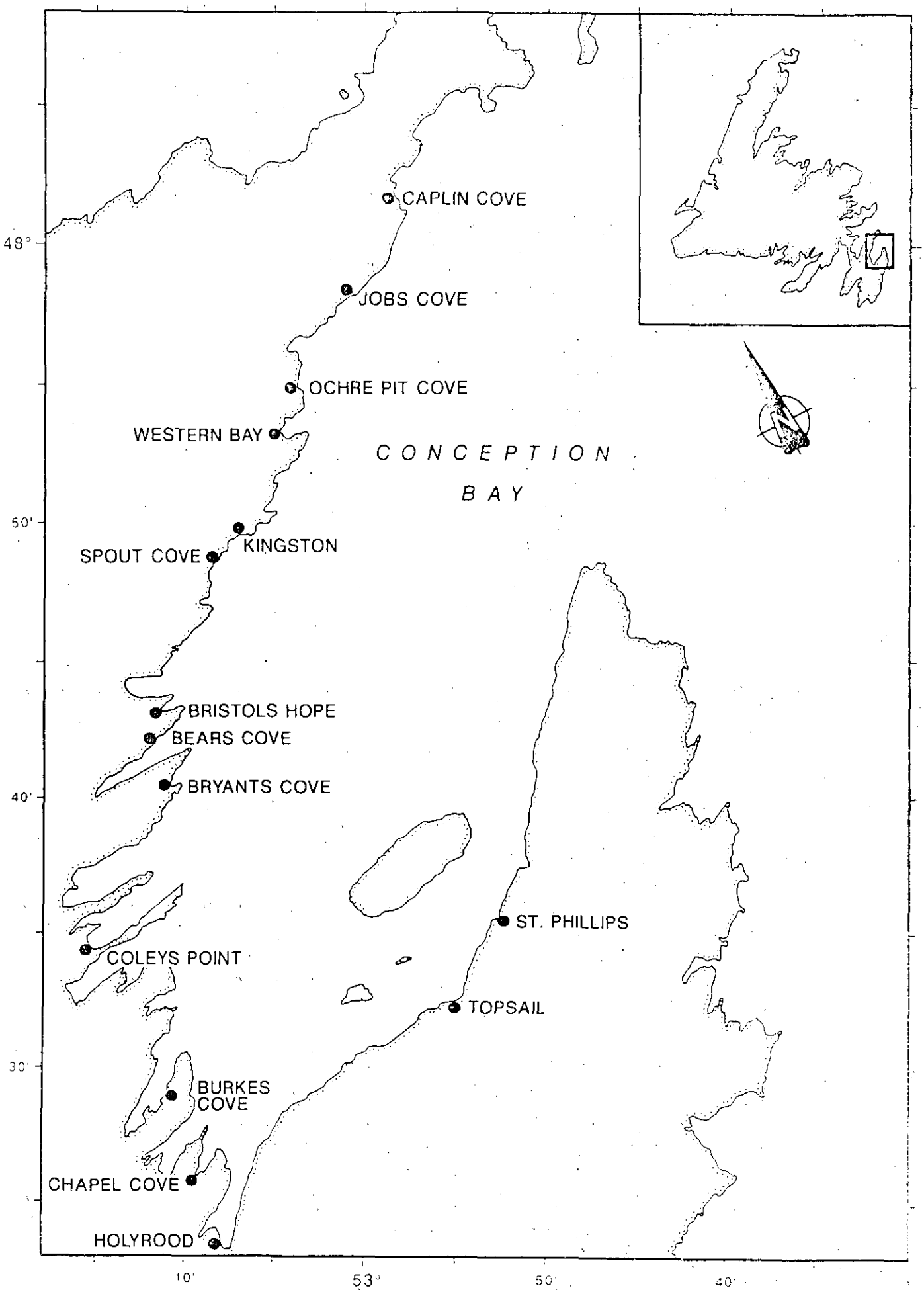

Fig. 1. Capelin spawning beaches in Conception Bay.