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An Evaluation of Techniques Designed to Assess Lobster Fishing Effort in Eastern Canadian Waters

by

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Abstract

Little information is available on either the pattern of distribution of lobster fishing effort or lobster buoy density in eastern Canadian waters. Logbook records for individual lobster fishermen were deemed too costly; consequently, workers have recently developed three techniques to attain these types of data. Two of the techniques involve remote sensing from airplanes; one employs color photographic techniques (ACP), the other visual scanning by observers (AVS). The other technique involves individual fishermen interviews (IFI). Each technique was employed and the costs in both monies and manpower are presented here. The ACP technique was the most costly; monetary and manpower costs were \$109.10 Canadian km^{-2} and 5.8 km^2 per survey hour. These values for the AVS and IFI techniques respectively were \$10.40 km^{-2} and 7.0 km per survey hour and \$2.68 km^{-2} and 11.23 km per survey hour. The merits and drawbacks of each technique are discussed.

SPECIAL SESSION ON BIOLOGICAL SURVEYS

Introduction

The American lobster, Homarus americanus Wynne Edwards, is consistently the single most economically important species in the eastern Canadian fishery (Pringle et al. 1983). Regulations were first implemented in 1873 (DeWolf 1974) which makes it one of the longest, continuously managed Canadian fisheries.

Independent assessments of lobster abundance over the thousands of miles of coastline in the Scotia-Fundy Region are difficult to produce for this resource. Finfish biologists tend to use catch per unit of effort (CPUE) as a measure of stock density (Cushing 1981). The CPUE data are derived from logbook data, required under law, to be recorded by vessel captains.

However, a logbook system was deemed impractical for inshore fisheries (Anthony and Caddy 1980; Conan and Maynard 1983). Consequently, little is yet known about spatial or temporal CPUE values or, for that matter, the spatial distribution of regional lobster fishing effort. Techniques to directly assess the latter were recently developed (Pringle and Duggan 1983; Conan and Maynard 1984). As well, an indirect assessment technique involving interviews of fishermen was developed (Pringle and Duggan 1984). Here we compare and contrast these techniques and assess the costs and efficiencies of each.

Methods and Equipment

Lobster trap buoy distribution by aerial color photography (ACP)

The distribution of lobster fishing effort in a portion of Lobster Fishing District (LFD) 6B (Fig. 1) was required for an environmental impact assessment. The technique developed by Pringle and Duggan (1983) was employed. Aerial photographs (scale 1:6000) were taken in July from an altitude of 915 m using a Zeiss RMK 15/23 survey camera with a 15.0 cm lens and Kodak #2448 color positive film. Photo interpretation and map production were completed by personnel of Maritime Resource Management Services (MRMS), Amherst, N.S., Canada using a digitizer and a geobased information system. The maps showed buoy locations plotted in relation to bathymetry and shoreline (Fig. 2A). Maps were overlaid with a 2.25 h grid, and buoy density in each section was identified by X and Y coordinates. Density contours (Fig. 2B) were then plotted from this matrix using DISPLA[1].

Lobster trap buoy distribution by aerial visual scanning (AVS)

The lobster season in LFD 4A (Fig. 1) extends from late November to May 31. Effort can extend from near shore to mid shore. The technique of visually counting lobster trap buoys (see Conan and Maynard 1983) was employed to assess fall and spring patterns of fishing effort. Based on pre-flight information (altitudes from 610 m to 2,440 m), areas of 5,667 km^2 and 11,204 km^2 (Fig. 1) were chosen and outlined on navigation charts. Baselines were established, running approximately parallel to the coast and coincidentally along the longest side of each area. Flight lines spaced at 5.5 km were plotted parallel to the baselines.

[1]DISPLA - Integrated Software System and Plotting Language. Integrated Software Systems Corp., 4186 Sorrento-Valley Blvd, San Diego, California 92121.

The survey aircraft was a high-wing, twin-engine, Norman Britten Islander. The observation crew included a Department of Fisheries & Oceans senior technician, a computer operator, and two observers. Lines were flown at 213 m altitude at an air speed of 185 km hr^{-1}. Ground speed varied with wind speed and direction. Buoy count and location were assessed according to the techniques of Conan and Maynard (1983). Data were transferred to a mainline computer, and buoy counts with location were plotted on a Tektronix 4663 plotter.

Determination of fishing effort by individual fishermen interviews (IFI)

Data for this study were obtained from a program described by Pringle and Duggan (1984). Fishermen, in direct personal interviews, responded to questions concerning gear, fishing area, and fishing effort. We define fishing effort per fishing district as the total number of trap hauls per square kilometer of fishing ground per season. CPUE will be the catch per trap haul; yield will be the reported annual landings (AL) adjusted for private sales, per LFD (from Statistics Division, DFO, Scotia-Fundy Region) divided by the area (square kilometer) of the fishing grounds.

Catch/unit fishing effort determinations

Fishing effort information was acquired via interviews of fishermen (Pringle and Duggan 1984). The number of licensed fishermen per district was acquired from Fisheries Operations Branch, DFO, Scotia-Fundy Region. We did not correct for an estimated 5% "back pocket" licenses. Mean number of both days and traps fished per license per district per season were estimated by Pringle and Duggan (1984). Annual district fishing effort (f) and CPUE (c/f which is catch per trap haul) was determined as follows:

$$f = \frac{NF \cdot Tr \cdot DF}{A} \qquad \text{where}$$

NF = number of licensed fishermen per district;

Tr = the sum of the mean number of traps employed for "A" and "B" licensed fishermen per LFD;

DF = mean number of days fished per licensed fishermen; and

A = area of (km^2) LFD fishing grounds (see below)

$$c/f = \frac{C}{TrH} \qquad \text{where}$$

C = LFD annual landing; and

TrH = total trap hauls LFD^{-1}

Fishing area determinations

The seaward boundary of district fishing grounds was estimated from responses of interviewees to questions of maximum depth and distance fished offshore. District mean maximum depth was contoured on a navigational chart. The shoreward fishing limit was always the upper-sub-tidal fringe. Unsuitable lobster bottom, i.e. large areas of sand and mud, heads of bays, and estuaries, etc., were eliminated using the survey of Moore and Miller (1983). The perimeter of the lobster grounds was traced on a digitizer (HP9874) with a computer interface (HP9825) equipped with software which converted enclosed area to square millimeters. Yield (Y) or catch per square kilometer per LFD was then calculated as follows:

$$Y = \frac{C}{A}$$

Results

Aerial color photography

The area surveyed with ACP was 427.2 km^2 (Table 1). The total man hours expended and monetary expenses were 74 h and $46,600 (Canadian) respectively. These costs per unit area of study were 5.8 km^2 per man hour and $109.1 km^{-2} (Table 2). Detailed maps giving the location of each buoy were difficult to interpret directly (Fig. 2A). By contouring these data we were able to identify small areas <1 km^2 with buoy densities exceeding 6, 2.25 ha^{-1} as well as define the outer limits of fishing effort (Fig. 2b).

Aerial visual scanning

The total area surveyed with AVS was 3,001 km^2 (Table 3). The total man hours expended and monetary expenses were 430 h and $31,000 respectively (Table 3). The man hours expended and costs per unit area of the study site were 7.0 km^2 and $10.4 km^{-2} respectively (Table 2). Two map types were generated: one giving buoy densities per transect (flight line) (Fig. 3A); the other, following integration of these densities, yields buoy density contours (Fig. 3B). The methodology defined the outer limits of fishing effort and the overall pattern of effort distribution.

Individual fisherman interviews

Fishermen along ~3,000 km of coastline were sampled; they set gear on ~3,655 km^2 of lobster grounds (Table 4). The total man hours expended and monetary expenses from the study were 325.5 h and $9,800 respectively

(Table 4). The total man hours expended and the cost per unit area of the study site were 11.2 km^2 per man hour and \$2.68 km^{-2} respectively (Table 2). This technique yields mean buoy densities per square kilometer only for each LFD (Fig. 4); exact buoy locations cannot be determined. A more accurate distribution of lobster fishing effort could be determined if individual interviewee fishing ports were recorded by the interviewer.

Discussion

The three techniques recently developed (see Pringle and Duggan 1983; 1984; Conan and Maynard 1984) to assess lobster fishing effort distribution in eastern Canadian waters differ markedly in the following characteristics: ease of procedure and technical sophistication, manpower and monetary costs, and final data format. Unfortunately the spatial and temporal settings varied between techniques and estimates of variance are available from one technique only. Consequently, precision estimates, based on coefficients of variation, could not be made. Nevertheless, the data are sufficient to give an approximation of both the cost effectiveness and potential uses of each technique.

The ACP technique involves an airplane, modified to accept sophisticated photographic equipment. Generally, this equipment is not part of a government-run fishery agency. Consequently, as in our case, the survey would normally be contracted out to a private firm which may be a burden on the budget of the fishery agency. For example, the monetary costs of ACP were higher (Table 2) by factors of 40.7 and 10.5 over IFI and AVS techniques respectively. (It is recognized that were the overall economics considered the private firm may indeed be more cost effective. We attempted to determine hidden government costs and add them to the AVS and IFI techniques but were unable to attain the appropriate figures.) As well, the ACP manpower input per square kilometer (Table 2) was higher by factors of 1.2 and 1.9 over that of AVS and IFI respectively.

The AVS technique requires an aircraft as well, but special features are not required. The observers need not be specialists and with a brief training session can perform the task including use of an unsophisticated on-board computer. Thus, this technique can be carried out by personnel from a typical fishery assessment agency. Airplane rental and manpower are the major expenses.

The IFI technique does not require equipment. Of prime importance, however, are interviewers who understand fishermen, who can meet them on a one-to-one basis, and gain their confidence. This technique is much less expensive in both monies and manpower than either the ACP or AVS techniques (Table 2). However, the data on distribution of fishing effort are not spatially specific; and buoy number is only a mean value per area studied.

During the studies described above, error estimates were not made. However, Pringle and Duggan (1983) noted an 11.3% error for buoy density during ACP technique development. The error would be less for determining overall spatial patterns in lobster fishing effort distribution. The IFI technique estimated a potential of 35,815 traps in the area where ACP found 17,105. However, latent effort (See Pringle and Duggan 1984), severe storm damage, and possible use of trap strings reduced the estimated projected trap number of IFI to between 19,250 and 23,638 traps. This along with the 11.3% error of the ACP technique would bring the 17,105 trap bouy count into close agreement with IFI data. Conan and Maynard (1983), when developing the AVS technique, found that direction of flight had little influence on port/starboard buoy density ratios. However, this ratio varied significantly between flights. They were not able to provide an estimate of influence on precision of factors such as hour of day, position of sun, etc. Our experience would suggest that ACP would yield more accurate assessments of buoy density than AVS. Both techniques, however, provide an excellent assessment of overall patterns of lobster fishing effort distribution.

There is little doubt the ACP is by far the most costly in both monies and manpower, of the techniques assessed. The estimates of buoy distribution, however, are the most detailed and likely the most accurate. As well, if money is of little concern and manpower is in short supply then a private contractor can, with little contractee interaction, carry out the study. We opted for this technique in Cape Breton because detailed data were required for an environmental impact assessment and manpower was being used elsewhere. ACP information was used in conjunction with bottom typing and bathymetry to correlate adult lobster distribution with habitat type.

Presently, there is considerable interest in the "oceanic" Nova Scotia (LFD 4B, 5A, 5B, 6A, 6B, and 7A) lobster fishery. The fishery was recently near collapse (Pringle et al. 1983) and a number of hypotheses have been developed, which range from recruitment overharvesting (Robinson 1979), through community structural change (Breen and Mann 1976), to ocean climate (Harding et al. 1983). Knowledge of fishing effort distribution and yields, in what might be a single system, is important. This was the area in which the IFI study was conducted; it cost ~$10,000 (Canadian) and 325.5 man hours were expended (Table 2). Greater detail on lobster trap distribution could be obtained from either ACP or AVS at projected respective costs of $38,000 and $398,000 and 522.1 and 630.2 man hours (Table 2). We will likely opt for a combination of the above techniques for future studies in this system.

Acknowledgements

We thank the following for their contributions to this or associated studies: D. Maynard and G. Conan for demonstrating the AVS technique; personnel of Maritime Resource Management Service Inc. for their positive interaction with the ACP technique; the numerous fishermen for their cooperation in the IFI study; and M. Guy and G. Jeffrey for technical assistance.

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Table 1. Estimated cost of determining lobster fishing effort distribution in portions of LFD's 4A and 6B using aerial color photography (the work was performed by MRMS under contract).

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Study site	Area surveyed (km^2)	Labour costs (h)			Expenses ($000)		
		Non-flight	Flight	Total	Non-flight	Flight	Total
SWNS	97.2	18	7[a]	25	6.8	7.0	13.8
Cape Breton	330.0	31	18[b]	49	14.8	18.0	32.8
Total	427.2	49	25	74	21.6	25.0	46.6

[a]Includes 3 h ferry time from home airbase to study site.
[b]Includes 3 h ferry time from home airbase to study site plus 7 h of incomplete missions.

Table 2. The cost effectiveness of each of three techniques used to assess lobster effort distribution.

(1)	(2)	(3)	(4)	(5)
	Cost effectiveness			
Technique	Monies ($ km^{-2})	Manpower (km^2 h^{-1})	Projected cost ($000) to assess the IFI study area (3,655 km^2)	Projected manpower (h) costs to assess the IFI study area (3,655 km^2)
Aerial visual survey	10.4[a]	7.0[b]	38.0[g]	522.1[h]
Aerial color photography	109.1[c]	5.8[d]	398.8[g]	630.2[h]
Individual fisherman interview	2.68[e]	11.23[f]	9.8[g]	325.5[h]

[a]From Table 3: Total column (10) ÷ total column (2).
[b]From Table 3: Total column (2) ÷ total column (9).
[c]From Table 1: Total column (8) ÷ total column (2).
[d]From Table 1: Total column (2) ÷ total column (5).
[e]From Table 4: Column (7) ÷ column (10).
[f]From Table 4: Column (10) ÷ column (8).
[g]Column (2) x 3,655.
[h]3,655 ÷ Column (3).

Table 3. Estimated cost of determining lobster buoy distribution off southwestern Nova Scotia using the computer-assisted aerial visual technique (AVS).

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
		Flight costs			Non-flight costs			Total costs	
Study period	Area studied (km²)	Actual observation (h)	Non-observation (h)	Monies ($000)	Manpower (h)	Manpower ($000)	Incidental ($000)	Manpower (h)	Monies ($000)
Fall (1983)	987	13.5[a]	12.2[b]	8.6[c]	214.3	3.6[d]	1.8[e]	240.0[f]	14.0[g]
Spring (1984)	2,014	23.7[a]	17.1[b]	13.4[c]	149.2	2.9[d]	0.8[e]	190.0[f]	17.1[g]
Total	3,001	37.2	29.3	22.0	363.5	6.5	2.6	430.0	31.1

[a]Actual observation time plus refueling time.
[b]Includes pre-flight survey plus "ferry" time (to and from operation base).
[c]Invoice from private flying firm.
[d]Columns (3) + (4) + (6) x $15.00 Canadian.
[e]Includes data processing and travel costs.
[f]Columns (3) + (4) + (6).
[g]Columns (5) + (7) + (8).

Table 4. Estimated costs associated with the individual fisherman interview technique (IFI) (winter of 1982/83).

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Actual interview costs		Non-interview costs			Total costs			
No. of interviews	No. man hours (h)	Monies ($000)	No. man hours (h)	Monies ($000)	Incidental costs ($000)	($000)	Manpower (h)	Estimated length of coastline (km)	Estimated area fishing grounds (km²)
225	112.5	1.7[a]	213[b]	3.2[c]	4.9[d]	9.8[e]	325.5[f]	3,000[g]	3,655[h]

[a]Column (2) x $15.00 (Canadian).
[b]Costs include technical aspects including coastal area determinations.
[c]Column (4) x $15.00 (Canadian).
[d]Costs include vehicle mileage, meals, accommodation, phone, mail and EDP.
[e]Total of columns (3) + (5) + (6).
[f]Total of columns (2) + (4).
[g]Source: Moore and Miller (1983) plus Moore (pers. comm.).
[h]Source: Pringle and Duggan (in preparation).

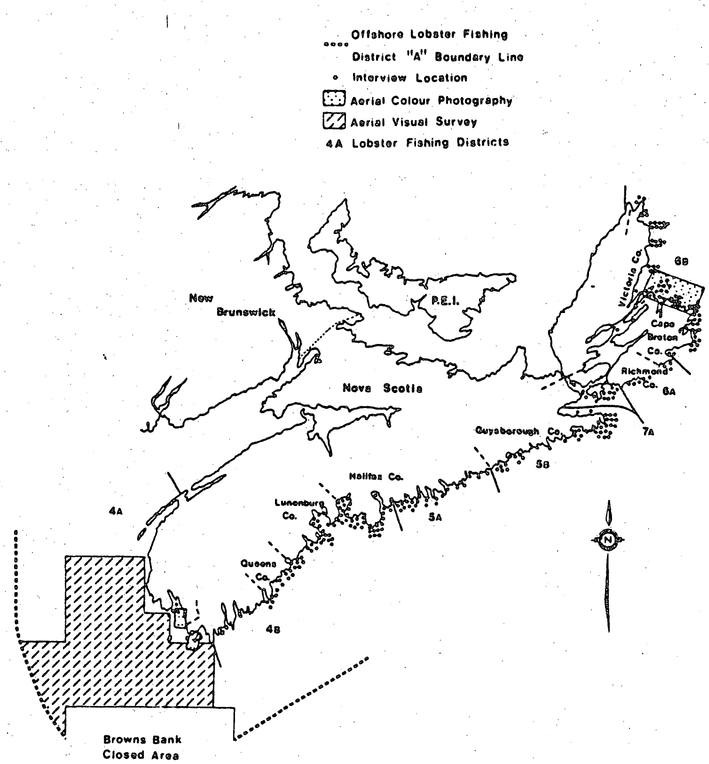

Figure 1. Lobster fishing districts of Atlantic Nova Scotia and the location of study areas for three methods of lobster fishing effort assessments. Scale identical to Figure 4 (1:1,000,000).

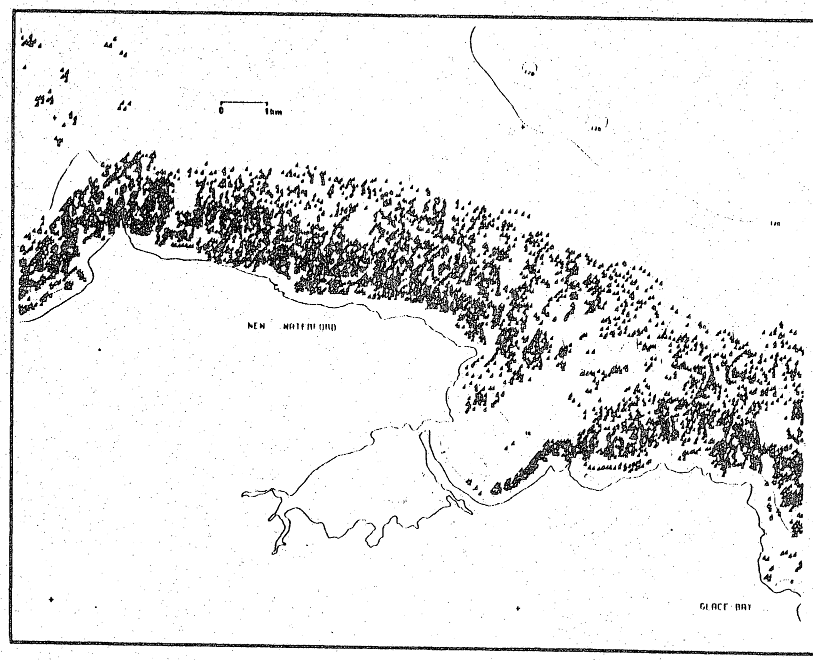

Figure 2A. Point plots of lobster trap buoy locations from a sampled area (ACP) of southwestern Nova Scotia.

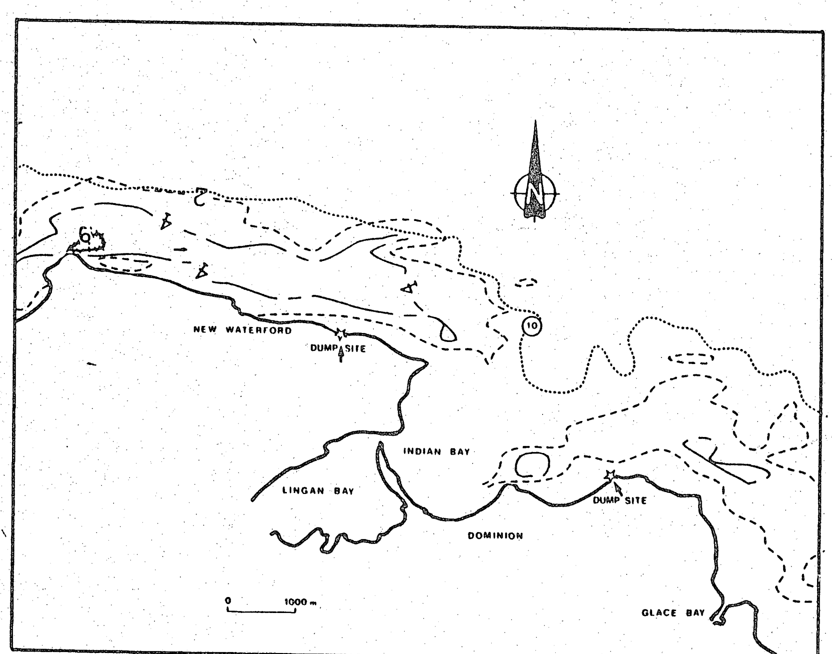

Figure 2B. Final contouring plot of lobster trap buoy densities using ACP in the Point Aconi to Glace Bay area of Cape Breton. Density units are 2.25 ha^{-1}; increments of 2.

Grid Number Two - May 11,15, 1984

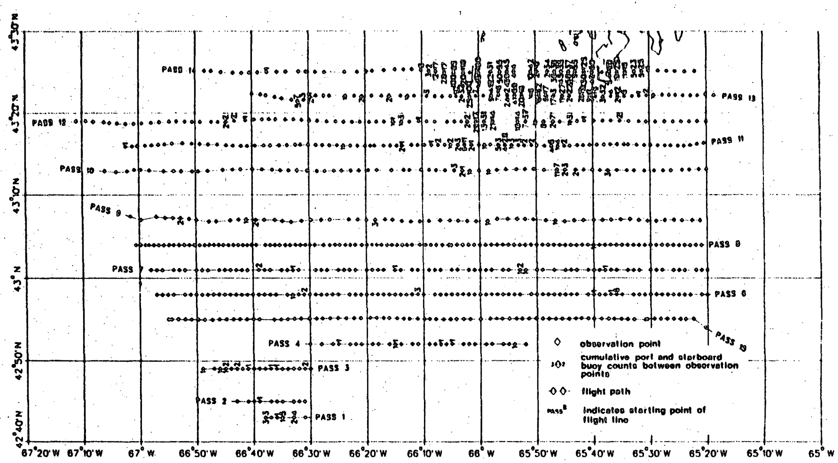

Figure 3A. Flight lines south of Cape Sable Island, Shelburne Co., N.S., with port and starboard lobster trap buoy counts at each observation point using aerial visual scanning (AVS).

Grid Number Two - May 11,15, 1984

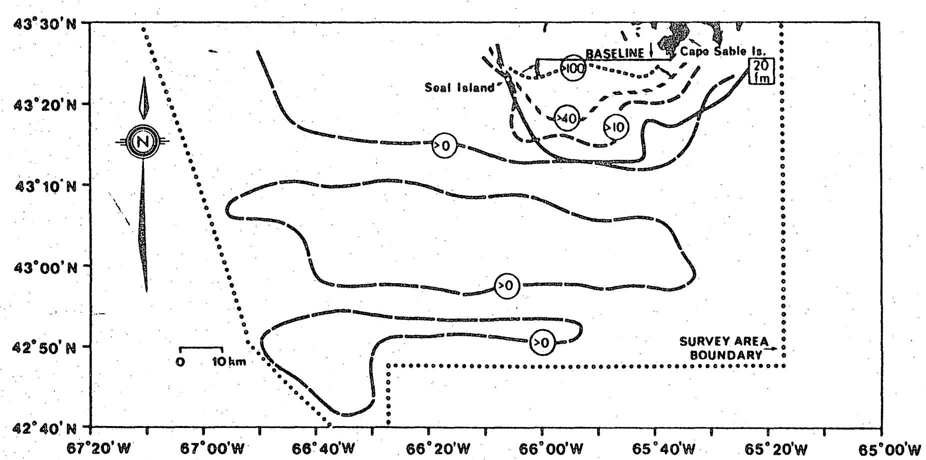

Figure 3B. Density of lobster trap buoys per square kilometer derived from aerial visual scanning (AVS) in May 1984, south of Cape Sable Island, Shelburne Co., N.S.

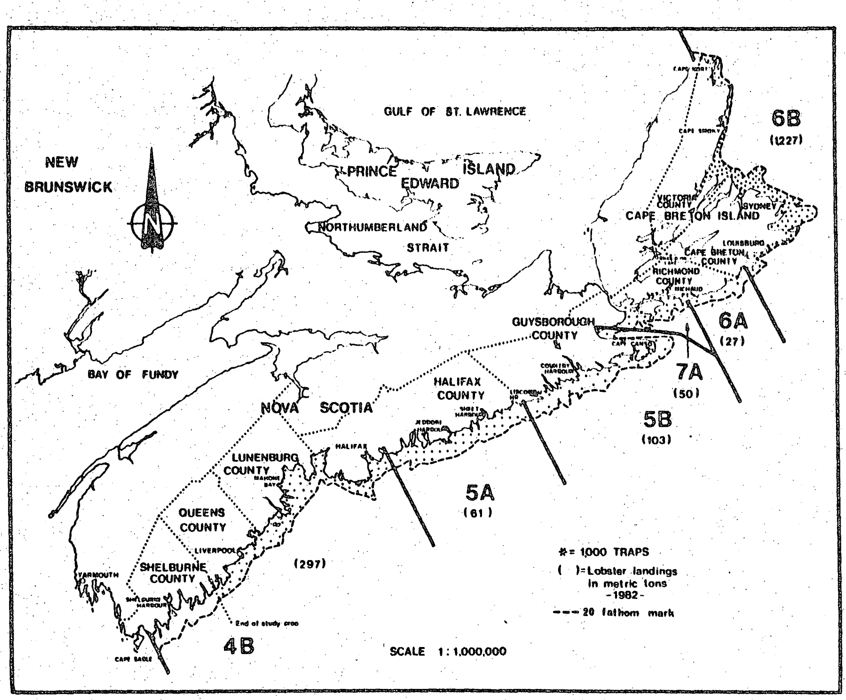

Figure 4. Distribution of lobster fishing effort from individual fisherman interview (IFI) data for Atlantic Lobster Fishing Districts 4B-7A and 1982 lobster landings by district.