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Estimates of Lobster Fishing Effort by Aerial Surveys

by

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SPECIAL SESSION ON BIOLOGICAL SURVEYS

Summary

Aerial surveys of lobster trap buoys spatial distribution are used in the Southern Gulf of St. Lawrence for monitoring seasonal and year to year changes in location of fishing effort. The main difficulty is to calibrate the efficiency of the observers counting the buoys. The relative contours of fishing effort isopleths are consistent over successive surveys, but it is difficult to convert the counts into actual density estimates. We attempted to calibrate our estimates by simulating a distribution of fishing effort by spreading a known number of buoys over a small bay and then studying their spatial distribution and estimating their density and number by aerial survey. We used a photographic survey and a survey using observers. The first technique is very efficient but very costly. The second is cheap and fast but requires delicate calibration. Automatic contour plotting techniques such as kriging may provide an efficient approach for processing the data once the efficiency of the observer is calibrated.

Résumé

Des reconnaissances aeriennes de la distribution spatial des bouées de casiers à homards sont utilisées dans le sud du Golfe du Saint Laurent pour suivre les variations saisonnières et annuelles de la localisation de l'effort de pêche. La difficulté majeure consiste à calibrer l'efficacité des observateurs qui comptent les bouées. Les contours relatifs des isoplethes d'effort de pêche sont

semblables d'une reconnaissance aerienne à la suivante, mail il est difficile de convertir les comptages en estimations de densité effectives. Nous avons tenté de calibrer nos estimations en simulant une distribution d'effort de pêche. A cette fin nous avons distribué un nombre connu de bouées à l'intérieur d'une baie et nous avons effectué des survols aeriens pour étudier leur dispersion spatiale et évaluer leur densité et leur nombre par reconnaissances aeriennes. Nous avons utilisé la technique des photographies aeriennes et celle des observateurs embarqués. La première technique est très efficace mais très coûteuse. La deuxième est peu coûteuse et rapide mais elle requière de opérations de calibration délicates. Les techniques de tracé automatique de contours telles que le kriging peuvent fournir une méthodologie efficace pour traiter les données une fois que l'efficacité des observateurs a été calibrée.

INTRODUCTION

The traditional method of assessing fishing effort and its spacial distribution is to collect information recorded by the fishermen in logbooks. The investment of resources required for such a project and the accuracy of the results warrent further investigation into alternate methods of data collection. One method that has been employed on the Atlantic coast lobster fisheries is aerial survey (Conan and Maynard 1983, 1984, and Pringle and Duggan 1983, Sharp and Duggan, 1985).

In determining the spacial distribution and intensity of the lobster fishing effort over the fishing grounds, either aerial photography or aircraft observer buoy ocunts have been used. Aerial photography as a means of estimating population counts over a large surface area is precise and accurate, but costly. One alternative method is to conduct an aerial survey which will be cost efficient and yet may provide sufficiently precise estimates, is to use on-board observers counting buoys.

This document will assess the accuracy of observer aerial surveys by comparing the results of an aerial survey with those of an aerial photo taken over a given test area. Hereon, we will also consider data processing techniques which will enhance the accuracy of the estimates by aerial surveys.

Materials and Methods

In an area of Malpeque Bay, Prince Edward Island 385 multicolored, 42 cm long X 18 cm diameter styrofoam buoys were positioned to represent a lobster fishing area (Fig. 1). The color patterns and physical dimensions of the buoys were similar to those used in the southern Gulf of St. Lawrence lobster fishery. An aerial survey consisting of twelve flights was conducted over the test area. The pattern of the flights being designed to reduce variations caused by observers and direction flown, by using replicate lines in a North-South, East-West direction, (Fig. 2).

The aircraft used for the survey was a wing over, twin engine Brittian Norman Islander, with a pilot and scientific crew of a navigator, computer operator, and two observers (port, starboard). An on-board Loran C unit provided instantaneous locations for the buoys counted by the observers. The computer operator entered the locations, corresponding buoy counts, and time of observation on the on-board HP85 which recorded the data on magnetic tape. In situations where the Loran C could not provide accurate locations, the navigator recorded the start and stop point of the flight from landmarks. With the aircraft speed and times of observations recorded on magnetic tape, calculations can then be made to pinpoint the location of the buoy counts.

The flights over the test area were at an altitude of 700 feet with a speed of approximately 200 km per hour. The navigator directed the pilot on the proper course of the pre-arranged pattern and the computer operator would interrogate the port and starboard observers and enter the buoy counts and position on the computer. The data on magnetic tape was then transferred to an HP9845 desktop computer and processed by custom programs written at CRBM/MBRC. The number of buoys per km^2 along each transect is calculated and plotted on a map of the test area, as a function of the distance viewed laterally by the observers (Fig. 3).

The distance viewed laterally by the observers was calculated from results obtained by flying over a reference area of known dimensions (air strip) and recording the outer and inner limit of lateral vision in relation to the reference distances and altitudes (Fig. 4). The outer lateral distance viewed was limited by each engine cowling. With the lateral distance viewed at known altitudes, a trigonometric calculation (tan x) deduced the blind spot and the lateral area on the water that could be ideally viewed from the aircraft at an altitude of 700 feet.

On the same day as the aerial survey, an aircraft from Maritime Resource Management Service of Amherst, Nova Scotia, color photographed the test area and processed the results into a map format (Fig. 5). This map was divided into km^2 areas and the number of buoys counted in each km^2. Contours showing concentration of lobster buoy per km^2 were drawn for both observers and aerial photo results using a method similar to that developed for the 1983 aerial survey (Conan and Maynard, 1984).

The surface areas of each individual countour of both isocontour maps were calculated using a surveyor algorithm without correction for an imperfect sphere, as used in the 1983 aerial survey (Conan and Maynard, 1984). The buoy counts per km^2 for the observer and photo data were processed by a second method called kriging (David 1977) the software was supplied by Geomin Computer Services of Vancouver, British Columbia.

Kriging is a two stage process in which at the first stage the user determines the spatial structure of the data. A "semi-variogram" is calculated, which is a graph constructed from the data using both the position and value information. It consists of a scatter of points on a graph of the average of the squares of the differences in value between sample pairs versus the distance between sample pairs. The variogram is used to define the type of continuity the data possess and to provide a model for interpolating the isocountour plot generated by the second stage.

A semi-variogram shape most common for our applications is shown in figure 6. The spatial structure of the data implies that

*Geomin Computer Services Corporation, 408 Kapilano 100, West Vancouver, BC, V7T 1A2. (604) 922-9367 provide kriging and contouring software for Hewlett Packard Computers series 200, 300 and 500 and 9845.

samples which are close in space are related in values. As the sample positions become more distant, the ½ of square root of averaged squares of the differences in values increases. However, at a certain distance ('A') the ½ square root of averaged squares of the differences in value reaches a constant level, and at this point the sample values have become independent from one another. A model is fitted tothe observed semi-variogram. The "search radius" variable which is passed on to the second stage for further interpolation should correspond to a number less than or equal to 'A'.

In the second stage of kriging, contouring, the data and model for the semi-variogram are supplied to the kriging routine. The output is a grid of interpolated values as well as a standard deviation map. This grid will not be dependent on the actual sample values but rather on the model used for the semi-variogram and the layout of the data points which are weighted as a function of their distance from the interpolated point and the characteristics of the variogram model. The kriging technique thus performs a smoothing of data which takes into account the uncertainties of the different values. This means that if we were to sample the same position twice we would almost certainly obtain different but related counts. kriging provides the optimum estimator which minimizes the sum of the estimate of errors.

The most simple approach to estimate the number of buoys from the observers data is to calculate the mean number of buoys observed per km^2 over the total flights with an appropriate lateral viewing distance and applying it to surface of the test area. This simple process with no contouring i.e. poststratification is what is frequently called "random sampling" in surveys of fish.

Results

The maximum distance that could be viewed laterally by each observer was found to be 860 m, this distance was used for computing the number of buoys per km^2.

The number of buoys read from the aerial photographs was 378, 98% of the buoys positioned on the test site. The contours of buoy concentration in the observer and aerial photographic data are drawn in Fig. 7 and Fig. 8 respectively. The surface area of each of the individual contours, mean density of buoys per contour and number of buoys per contour as calculated for the observer and aerial photo data are presented in Table 1.

The kriging software was used for processing the observer and photographic data and producing a variogram, a contour map of buoy concentrations and a three dimension contour, Fig. 9, 11, 13, and Fig. 10, 12, 14, respectively. The kriging software also provided estimates of the number of buoys by summing up the number of buoys within the interpolated fine mesh grid. Estimates were of 516 and 511 buoys for the observer and photographic surveys respectively.

Applying the mean number of 3.06 buoys per km^2 as obtained by calculations conducted with a lateral viewing distance of 860 m to the surface of the test area, 36.72 km^2 we estimate a total number of 112 buoys.

Discussion

When we compare the total number of buoys calculated from the surface areas of the contours for the observer data versus the number of buoys actually positioned in the test area we can estimate that the observers were only 26% efficient. One of the factors causing this discrepancy is due to the lateral viewing distance of 860 m used in the computations. The distance the observer is able to see buoys may be 860 m but we have to consider the loss of efficiency in counting buoys as a function of distance in a survey situation. In actual fact, the probability of detection decreases as the perpendicular distance from the transect line (flight path) increases (Burnham et al. 1980).

With loss of efficiency as a function of distance in mind we can develop a correction factor. The number of buoys calculated using the observer data with a lateral viewing distance of 860 m was 80. Therefore, using a knife edge approximation we may calculate the lateral distance at which the observers would be theoretically 100%efficient, given the actual number of 385 buoys.

$$\frac{860}{385} \times 80 = 179 \text{ m}$$

Fig. 15 shows how the knife edge approximation works for two different detection curves.

We changed the lateral distance viewed to 179 m and then analysed the observer data and drew the contours in Fig. 16. By recalculating the total number of buoys for the area we find 298, which represents 77% of the buoys positioned in the test area.

To draw conclusions from the kriging approach we must first analyze the variograms for the observer and photographic data. The semi-variogram of the observed data in Fig. 9, shows that buoy counts within a range of 0.25 or 0.50 nautical miles were correlated. But a "saturation" or "sill" is reached at a distance of 1.5 nautical miles, meaning that counts which are separated by distances exceeding this range become uncorrelated. A spherical model (David, 1977) was fitted to this variogram with the resulting equation:

$$\gamma = 39.696 + 43.234*[h - (h/3)\ 3]$$

where h is the distance between samples and γ is the semi variogram statistic. Fig. 11 shows the isocontour which has been calculated using the observer data. A three dimensional plot of these isocontours obtained by kriging is shown in Fig. 13.

The same technique was performed on the aerial photo data but the variogram (Fig. 10) showed us that the counts are correlated within a radius of up to 1.9 nautical miles and then become correlated again within the range of 2.5 to 4 nautical miles. This would indicate that the larger sample counts are clustered within a radius of less than two nautical miles, and that they are surrounded by constant counts (in this case 0) for distances up to 5 nautical miles. Referring to Fig. 5 we can see that the variogram reflects the buoy concentration pattern in the test area. Fig. 12 shows the resulting isocontour plot along with the three dimensional plot in Fig. 14.

The number of buoys for the photographic data as calculated by the kriging program is an over estimate. In the kriging technique it is assumed that the counts we supply are samples associated with a sampling error while we are dealing in this case with exact counts averaged over constant areas and attributed to point estimates in the center of the area. Kriging proceeds by interpolating and smoothing the data into a higher definition grid. Fine contours are drawn around the points in the fine grid. In the present case smoothing of the data was not required, a more simple linear interpolation would have been sufficient for drawing the contours because the counts were made with no error.

The number of buoys for the observer data is also an over estimate. Some adjustments to the variogram model used and survey constants will be required before this technique becomes fully efficient.

The approach of calculating the average buoy number and applying it to the surface area gives an under estimate. Using the same method and a lateral viewing distance of 179 m, we calculate 13.79 buoys per km^2 and a total of 506 buoys. This approach appears to be inadequate, in the presence of highly aggregated data with a spatial structure.

The kriging drawn contours for the observer and photo data, Fig. 11 and Fig. 12 bear a resemblance to the contours drawn in Fig. 7 and Fig. 8. The kriging drawn and ordinary contours drawn for the observer data both have the characteristic of flattened high buoy concentration peaks. This phenomenon can be related to the method of data acquisition. The relatively high speed of the aircraft means that it covers large distances very quickly, and since the computer operator only querried the observers approximatly every 30 seconds, it would mean that counts registered into the computer are smoothed and that high buoy concentration are averaged out during the aerial survey (Fig. 17). A single buoy count may actually cover an area of high buoy concentration followed by an area of no buoys at all.

It should also be mentioned that the surface of the test area was very small in comparison to an actual aerial survey of the fishery (compare Fig. 1 and Fig. 2). Technical errors or difficulties the observers may have encountered counting the buoys were considerably increased by the short observation time when the aircraft covered such a small area. Also the spatial pattern by which the buoys were placed on the test area did not fully represent an actual lobster fishing pattern.

In conclusion, aerial surveys using observers to count lobster trap buoys may become an efficient tool for estimating total fishing effort but calibration of data collection methods needs to be improved. A particularly important step will be to model and estimate the parameters of the detection function. Also, better insight needs to be gained in objective automatic techniques for contour drawning and density integration of the data. The logical and analytical approach of the kriging technique offers a promising potential to provide statistically precise and accurate estimates.

Acknowledgements

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Table 1. Surface areas and mean buoys per contour of buoy concentration for observer and photographic aerial survey data.

	OBSERVER VIEWED FLIGHT		AERIAL PHOTOGRAPH	
BOUYS PER KM^2 CONTOUR DEFINITION	AVERAGE NUMBER OF BUOYS PER CONTOUR	SURFACE AREA OF COUTOUR KM^2	AVERAGE NUMBER OF BUOYS PER CONTOUR	SURFACE AREA OF CONTOUR KM^2
1 - 10	2.46	12.67	3.38	7.96
11 - 20	11.37	2.80	15.83	4.94
21 - 30	24.00	0.34	21.00	1.71
31 - 50	35.00	0.24	40.00	0.69
50			90.00	1.09
TOTAL OF BOUYS FOR THE TEST AREA		79.56	266.71	

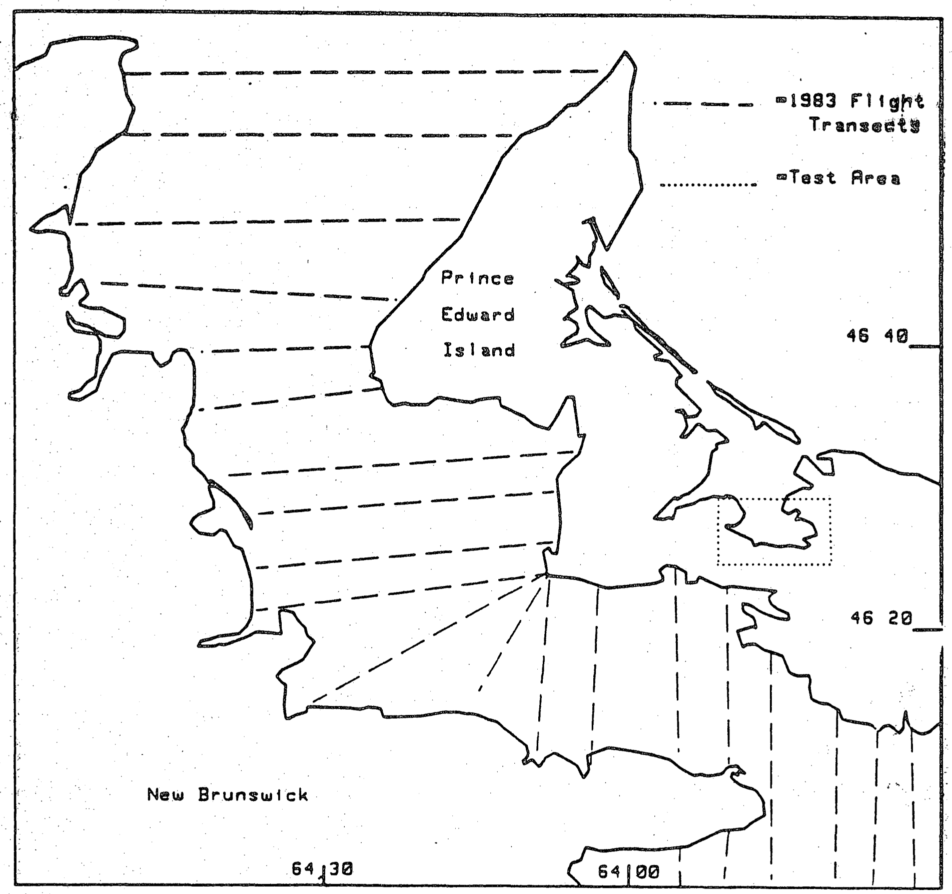


Fig. 1 Geographic location of aerial survey test area and 1983 northern Northumbeland Strait aerial survey flight transects.

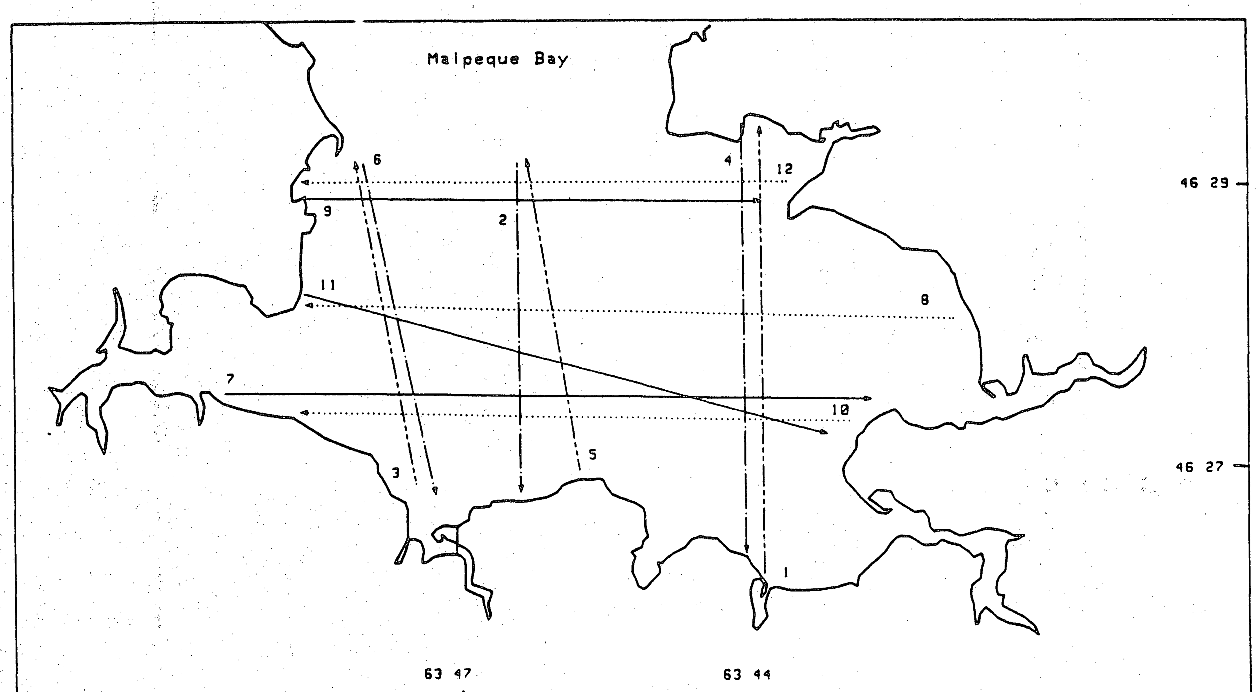


Fig. 2 Direction and sequence number of the test aerial survey flight transects.

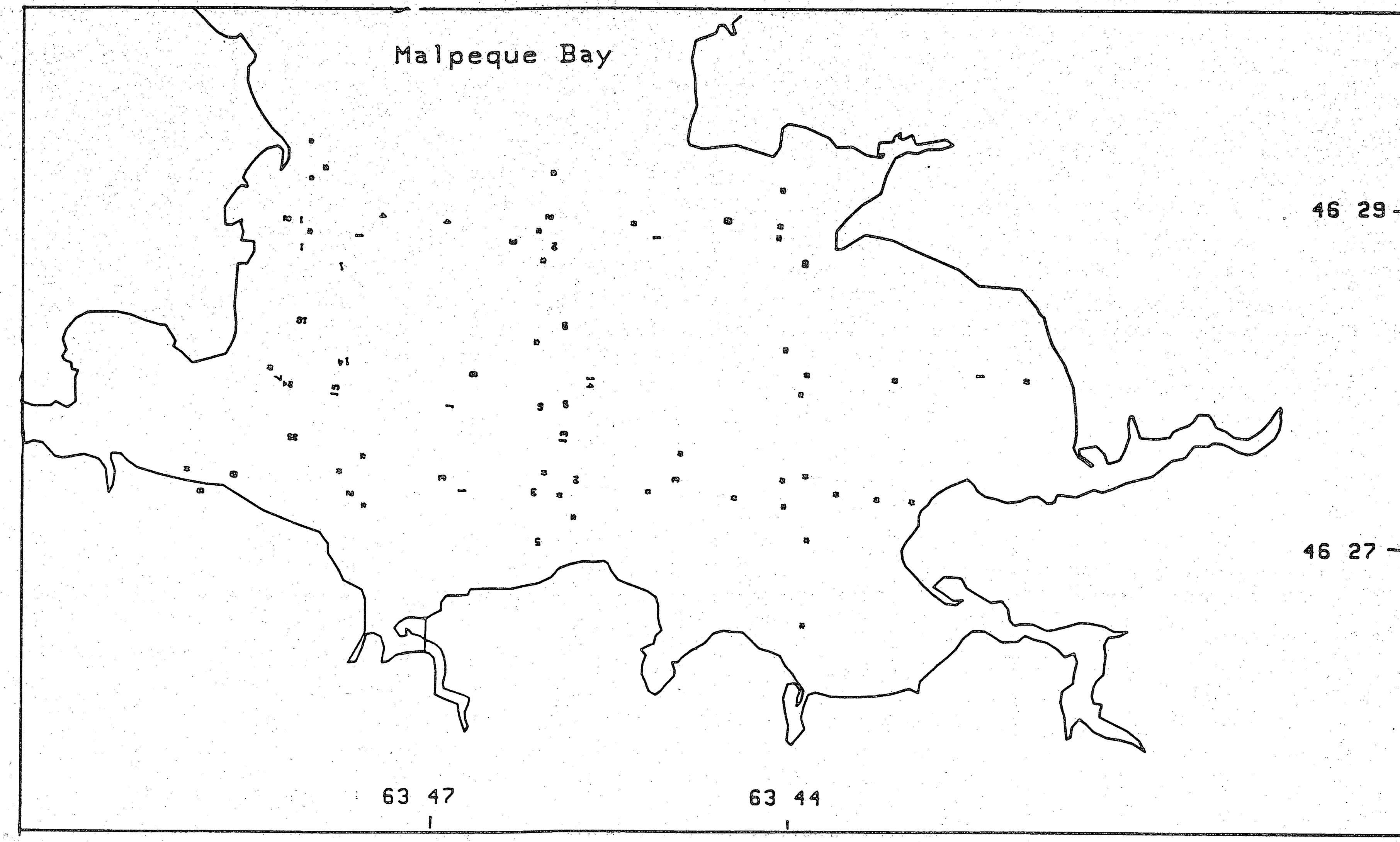
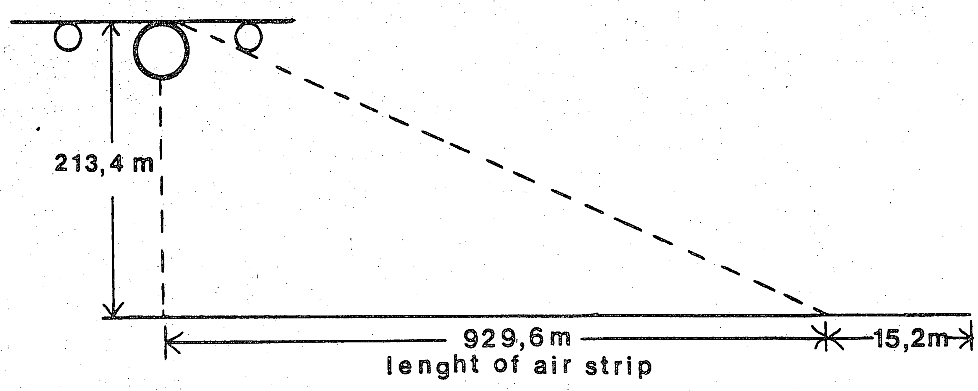
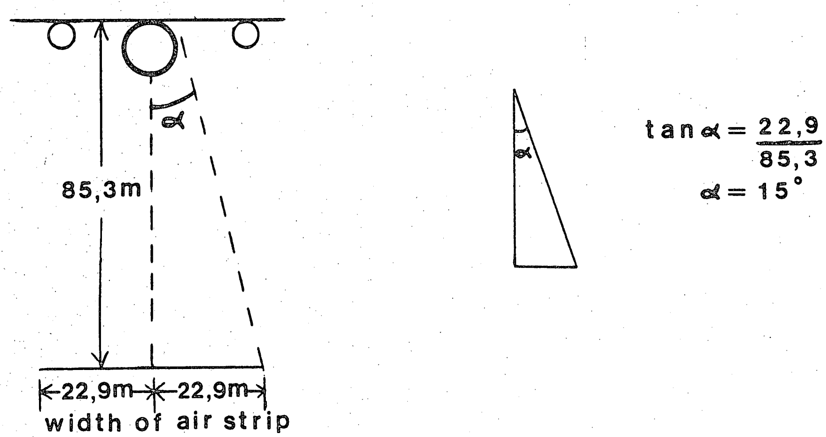


Fig. 3 Observers buoy count data converted to buoys per km^2 and plotted along the appropriate flight transect.

- Outer limit of view



- Inner limit of view



- Total lateral distance viewed

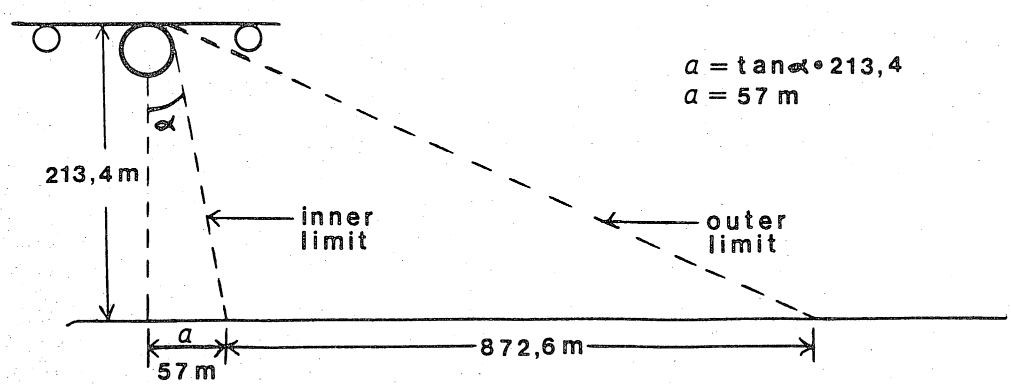


Fig. 4 Calculation of the distance viewed laterally by the observers.

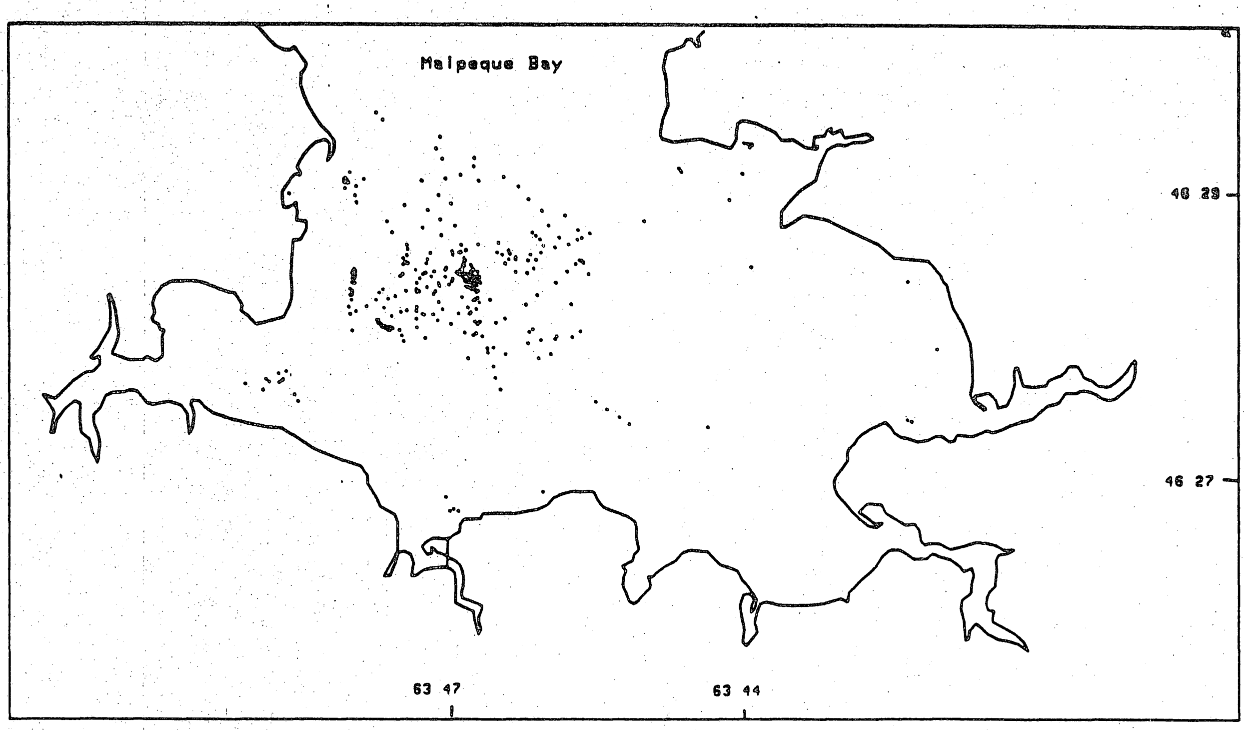


Fig. 5 Test area with the location of the 378 buoys interpreted from the aerial photo. (one dot one buoy)

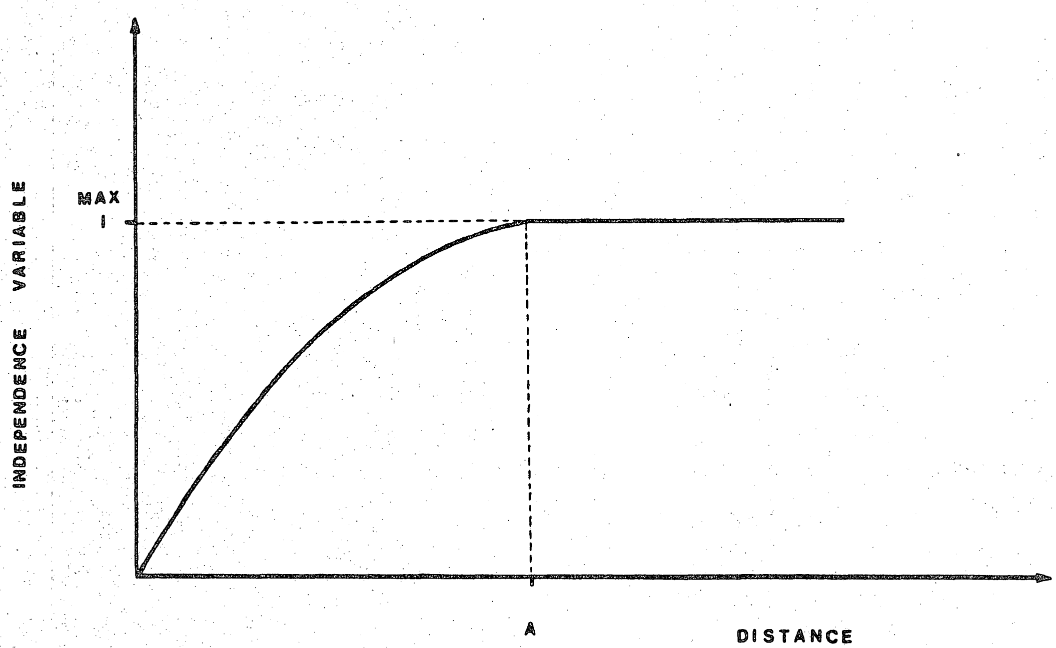


Fig. 6 A semi-variogram most common to kriging applications. Constructed by plotting the half square root of the mean squares of differences for values in sample pairs versus distance between sample pairs.

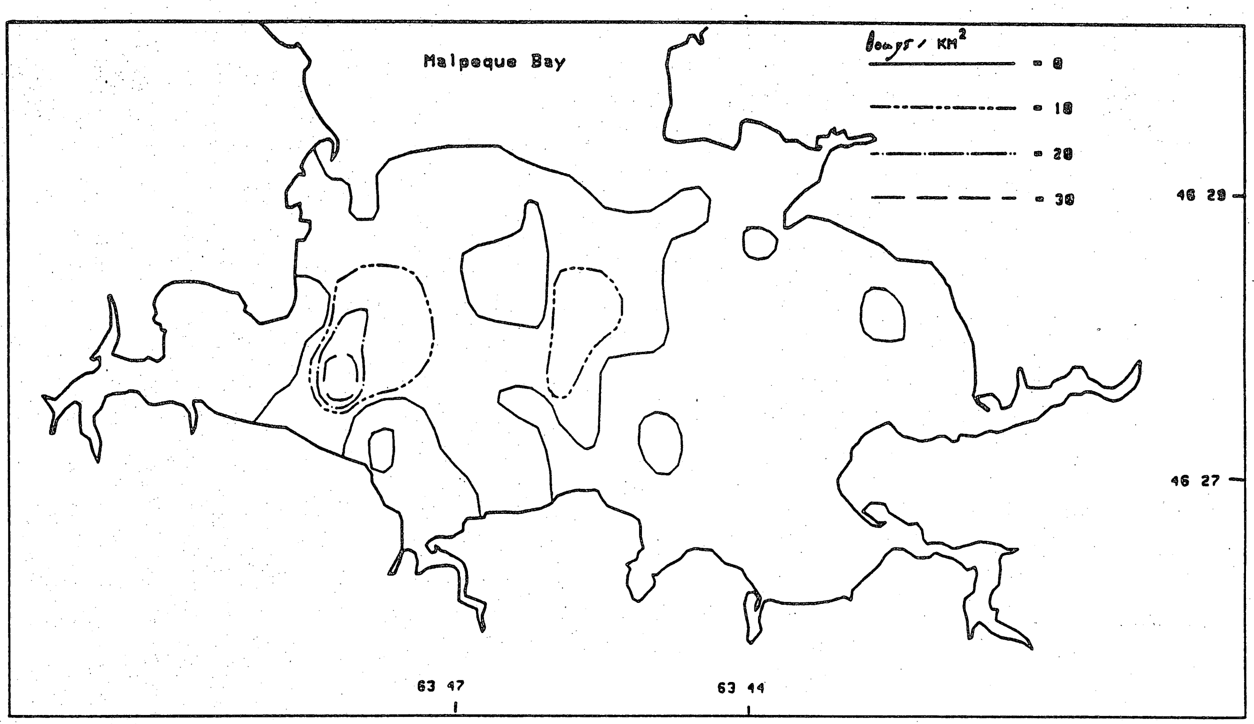


Fig. 7 Contours of buoy concentrations hand drawn from the observers buoy counts, assuming a lateral viewing distance of 860 m.

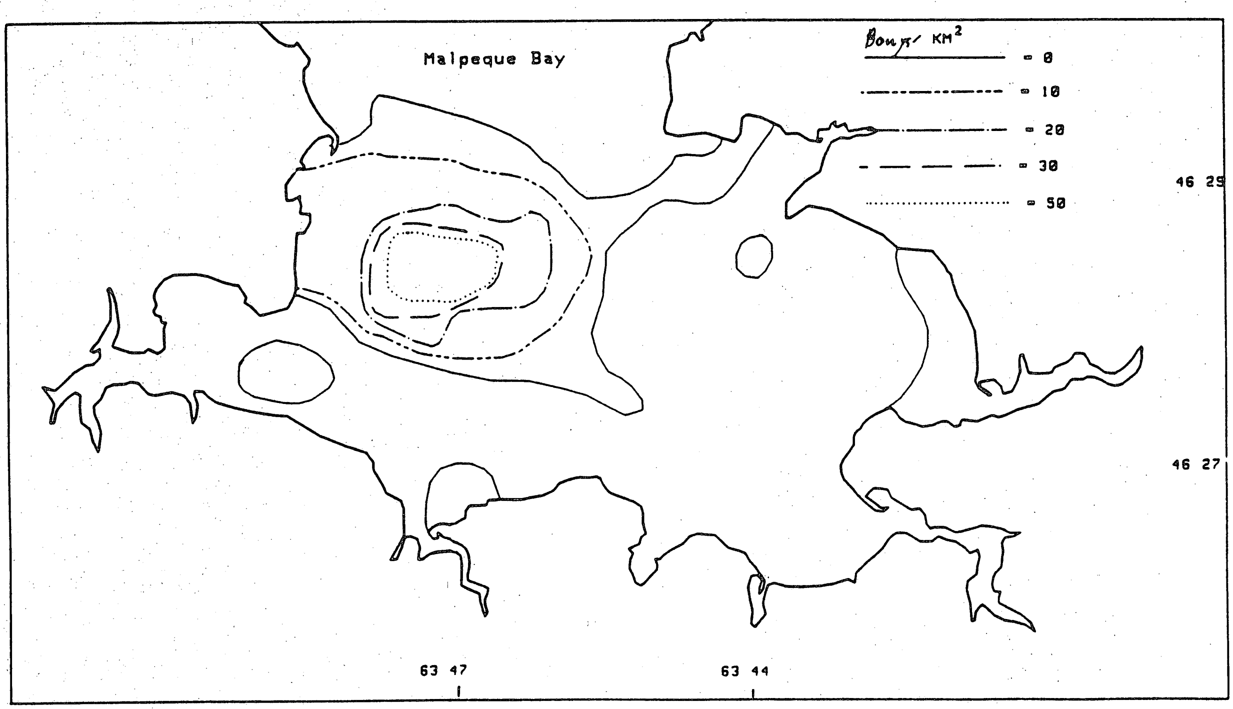


Fig. 8 Contours of buoy concentrations hand drawn from the aerial photo.

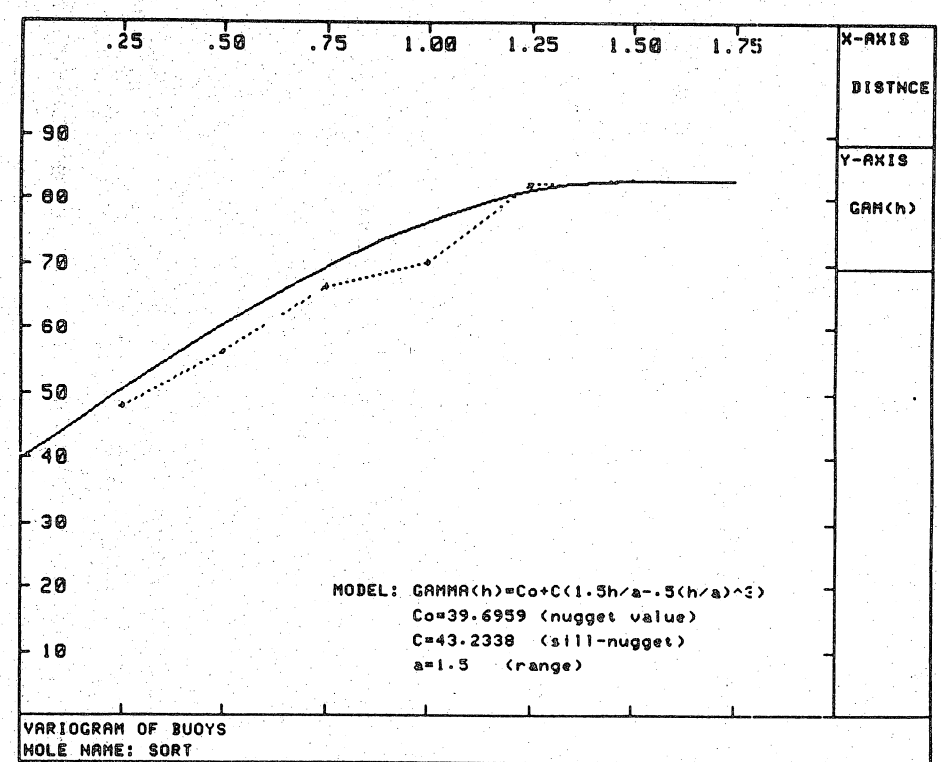


Fig. 9 Variogram modelling the observed spacial statistical dependency between pairs of sample points set apart by a distance h versus distance h - observer data.

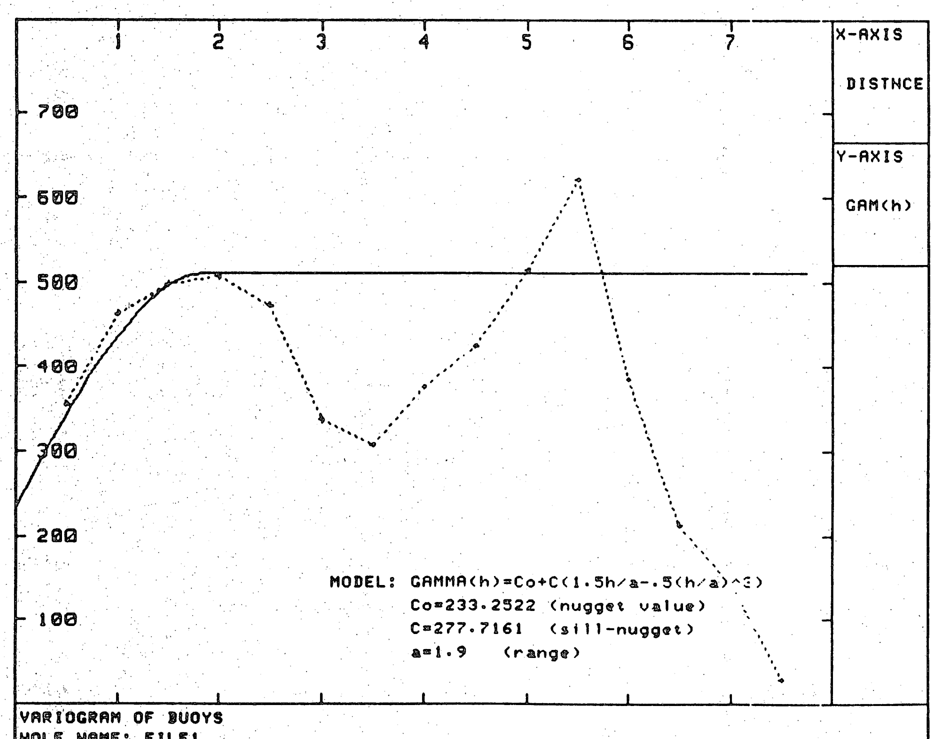


Fig. 10 Variogram modelling of the observed spacial statistical dependency between pairs of sample points set apart by a distance h versus distance h- photographic data.

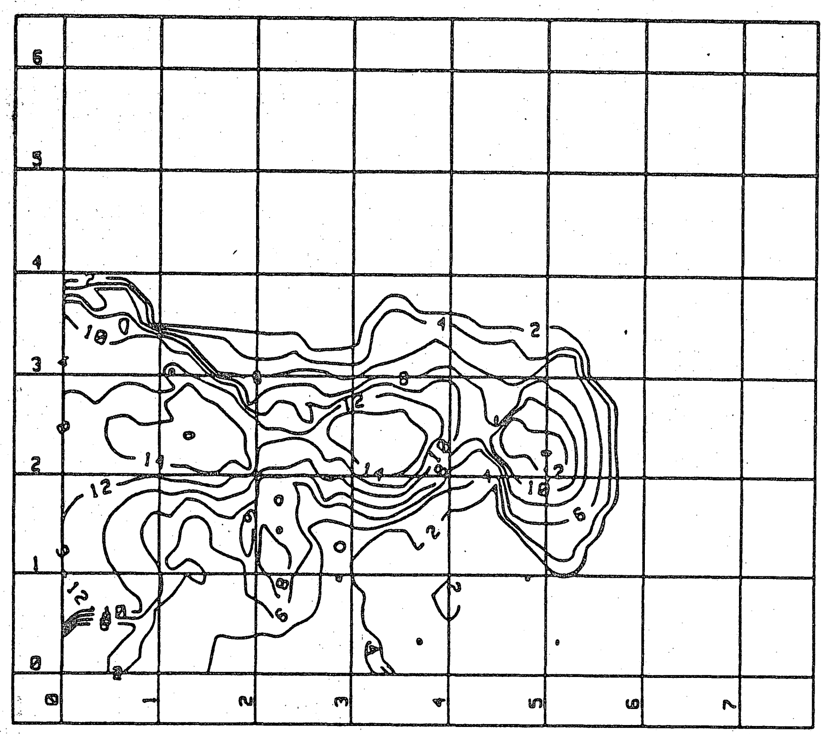


Fig. 11 Contours of buoy concentrations as calculated by the kriging program from the aerial survey observers data, assuming a lateral viewing distance of 860 m.

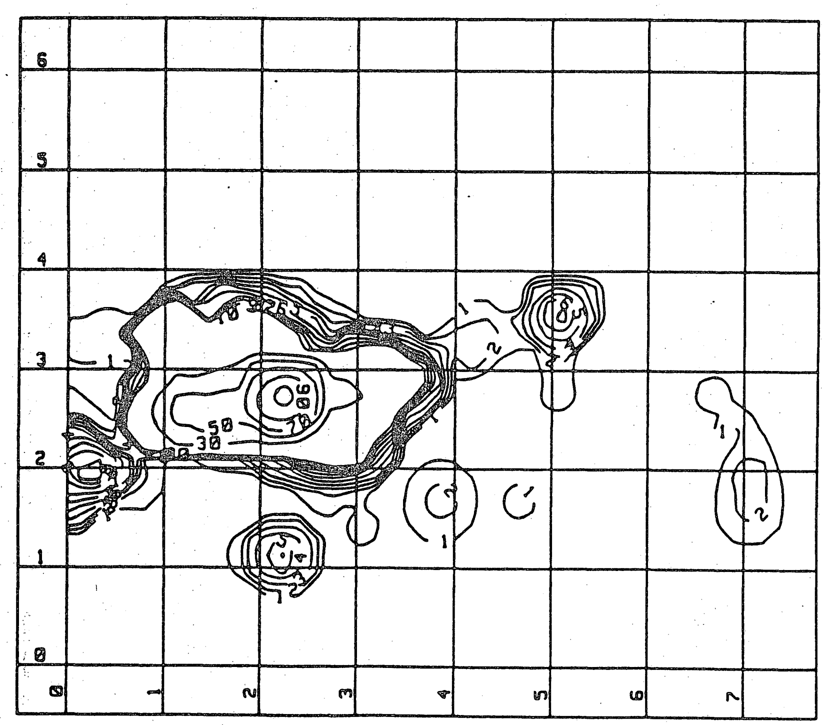


Fig. 12 Contours of buoy concentrations as calculated by the kriging program from the aerial photo data.

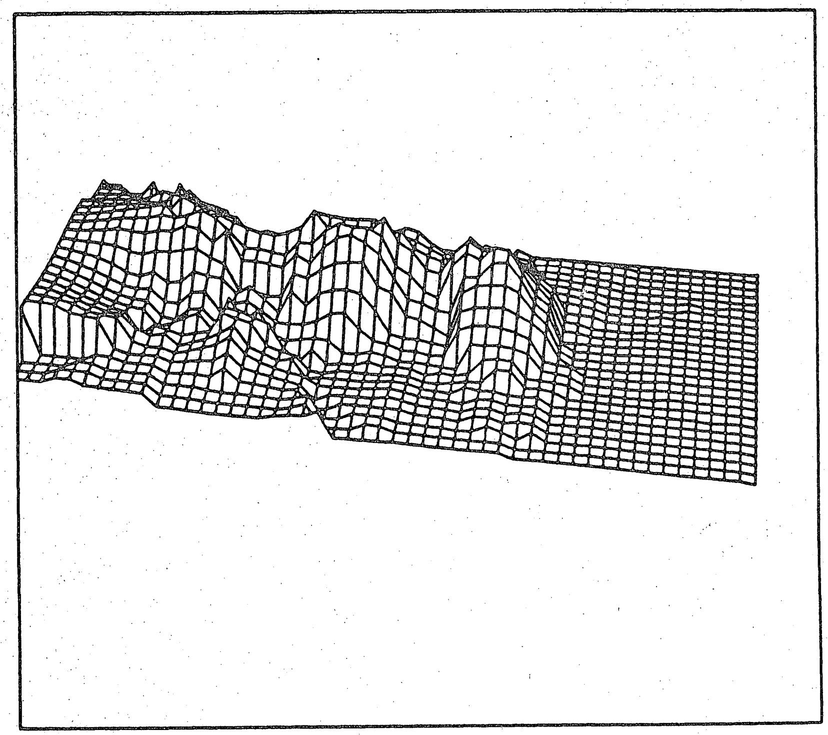


Fig. 13 A three-dimension representation of the contours of buoy concentrations as calculated by the kriging program from the aerial survey observers data, assuming a lateral viewing distance of 860 m.

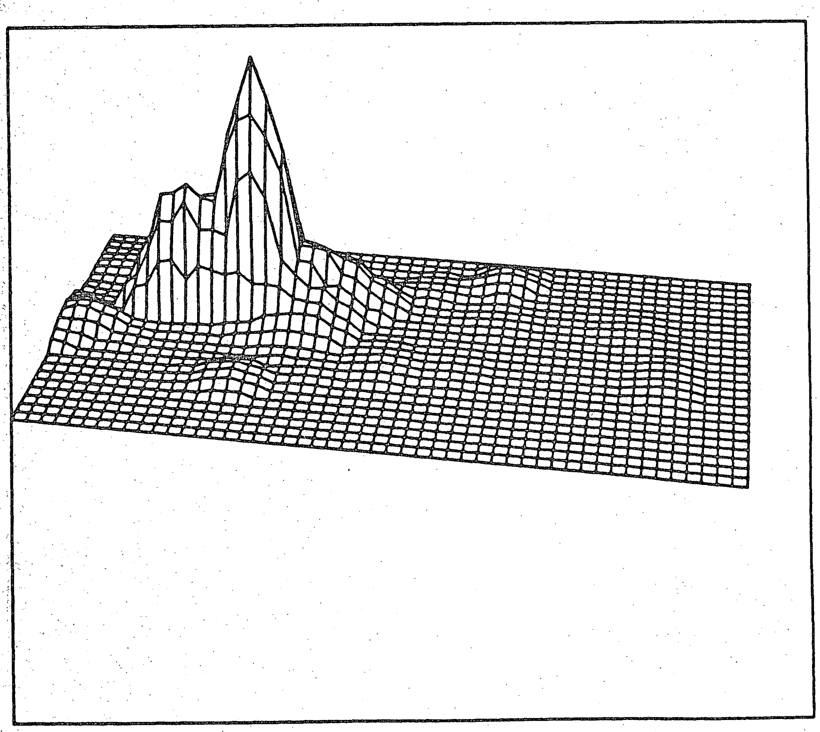


Fig. 14 A three-dimension representation of the contours of buoy concentrations as calculated by the kriging program from the aerial photo data.

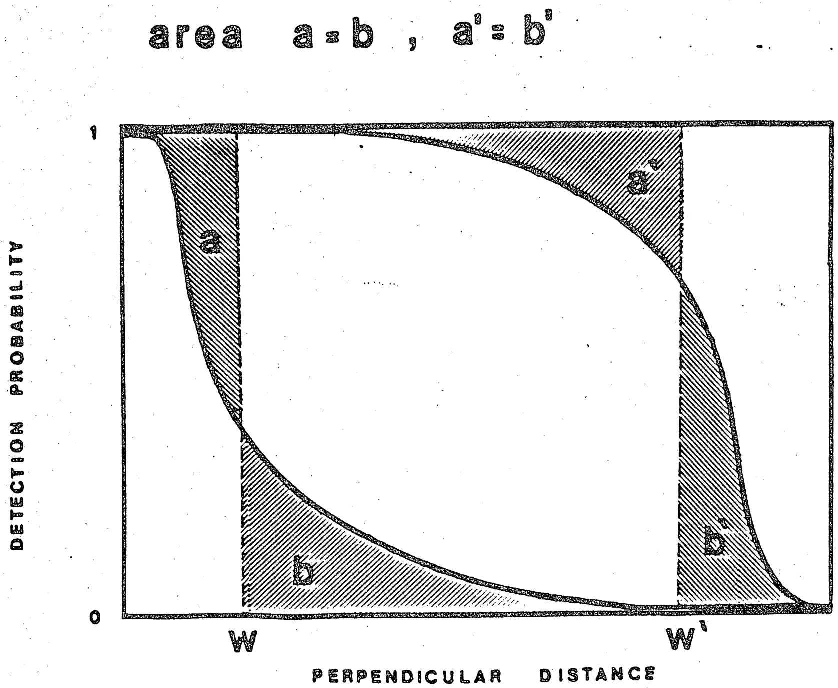


Fig. 15 Diagrammatic representation of two possible shapes of the detection curve (concave, convex). Buoy counts would only be made to the point of w on the curves, the truncation.

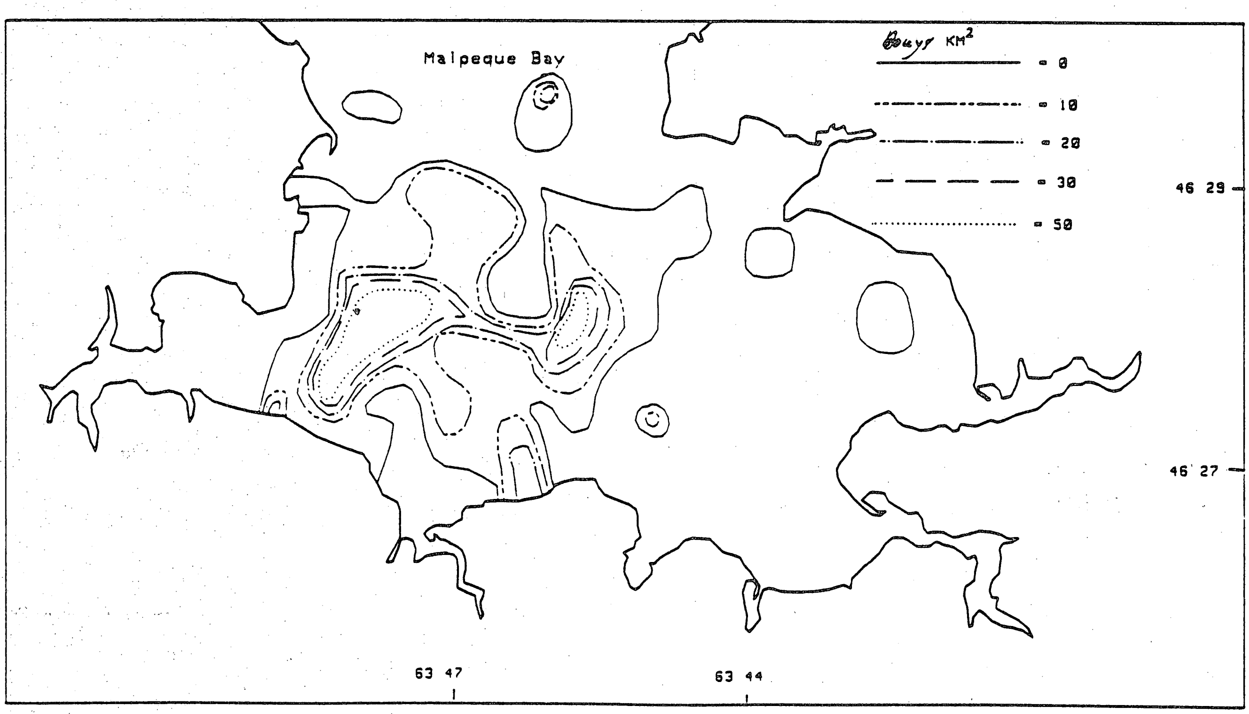


Fig. 16 Contours of buoy concentrations hand drawn from the observers buoy counts, assuming a lateral viewing distance of 179 m.

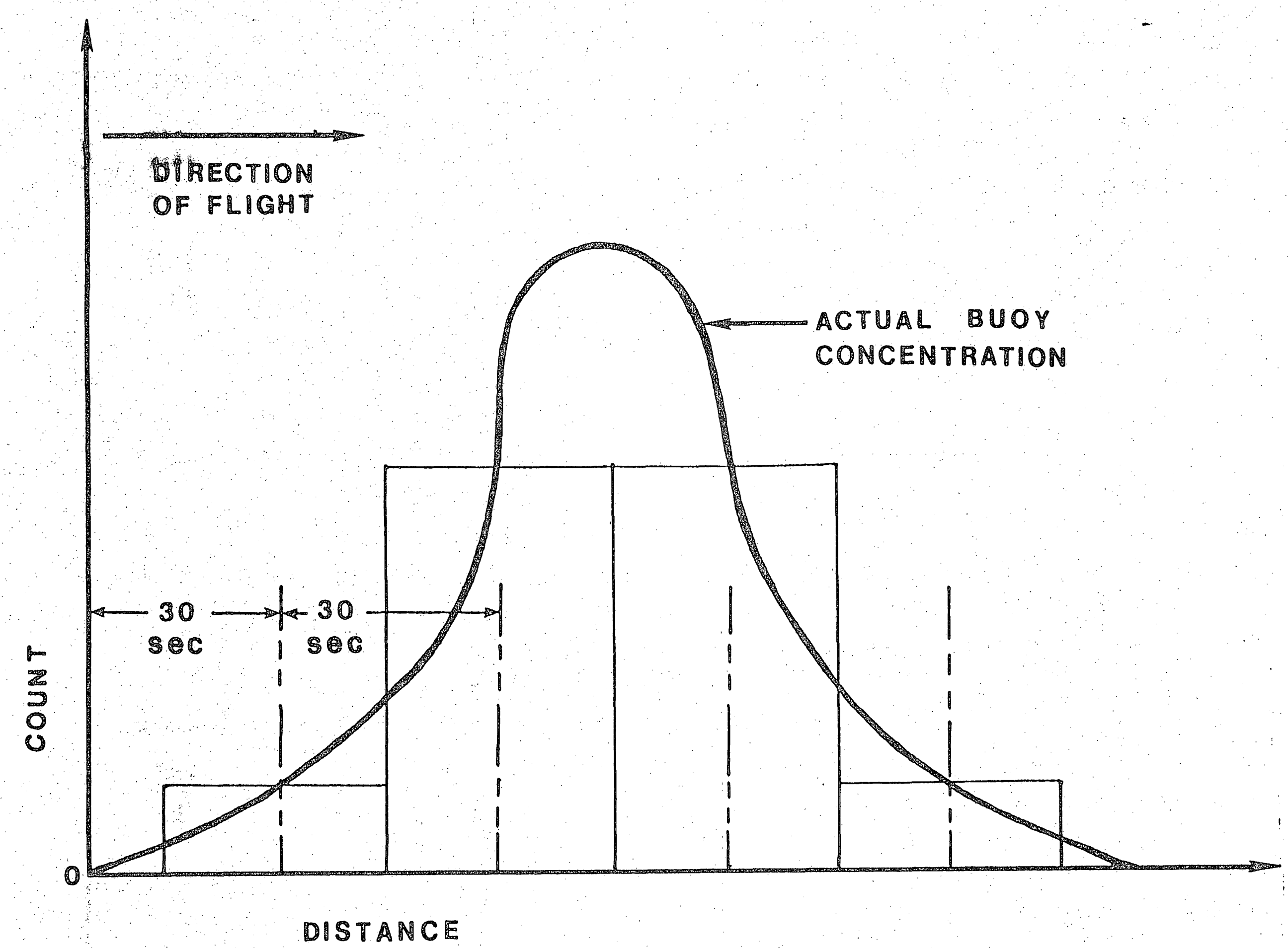


Fig. 17 Buoy counts made by observers over a flight transect as compared to actual buoy concentration.