NEW ZEALAND MARINE DEPARTMENT

FISHERIES TECHNICAL REPORT
No. 59

SURVEY OF FOVEAUX STRAIT OYSTER BEDS 1960 -1964

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NEW ZEALAND MARINE DEPARTMENT

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ERRATA

Changes in compilation during editing resulted in a number of errors appearing in this report. The most important of these are listed below.

Page 9: In paragraphs 5 and 6, "(see Figures 3-13)" should read "(see Figures 1-13)".

Figures 1 and 2 should read Figures 13 and 14.

Page 10:	Reference	to	"Figure	3"	should	read	"Figure 1"
	"	"	"	4	"	"	" 2
	"	"	"	5	"	"	" 3
Page 11:	"	"	"	6	"	"	" 4
	"	"	"	7	"	"	" 5
	"	"	"	8	"	"	" 6
	"	"	"	9	"	"	" 7

("Bird Island West Bed") should read ("Bluff Hill West Bed")

Page 12:	"	"	"	10	"	"	" 8
	"	"	"	11	"	"	" 9
	"	"	"	12	"	"	" 10
	"	"	"	13	"	"	" 11
Page 13:	"	"	"	14	"	"	" 12
	"	"	"	15	"	"	" 16
	"	"	"	16	"	"	" 17
	"	"	"	17	"	"	" 18

After the first paragraph on page 13, the following should be inserted:-

"Figures 13 and 14 show variation in oyster length frequencies from single survey dredge samples at different stations.

Figure 15 shows length frequencies for oyster samples dug from square yard quadrats at diving stations."

Page 14: Reference to "Figure 18" should read "Figure 19"

Page 18: " " " 19 " " " 20

Page 19: On the second line of the second paragraph "eastern" should be "western".

Page 23: The last line on this page should have "bit" amended to read "but".

Page 24: "Figure 20" on first line should be "Figure 15".

Page 28: "(see Appendix)" in the 4th paragraph should read "(see Appendix 6)".

Page 32: 2nd to last paragraph should contain (see also Cranfield 1968).

Page 39: Last paragraph "(Square E32 - Map 8)" should read "(Square T32 - Map 8)".

P.T.O.

Page 40: Last paragraph "Figure 4A" should read "2A" and "(Fig 5)" should read "(Fig 3)".

Page 44: "Figures 23-26" should read "Figures 23-27".

Page 46: Last paragraph. The word "that" should be inserted after the words, "It was reported".

Page 54: The 3rd and 4th sentences should be deleted and replaced by the following:-

"These cycles may not be related to dredging intensity and thus it may be feasible to vary the annual quotas according to natural fluctuations.

Dr D. Eggleston (pers. comm.) has also suggested that any quota should vary each season with the abundance of oysters and points out that a more satisfactory method of regulating the fishery may be to specify the number of dredging hours, rather than a sack quota."

Page 57: "Efficiency" on 2nd to last line should read "efficacy".

Page 58: "(Figure 16)" should read "(Figure 17)".

Page 63: D.H. Stead's report - "Observations on the Biology and Ecology of the Foveaux Strait Dredge Oyster (Ostrea lutaria Hutton)" should be dated 1971 and is Fisheries Technical Report No. 68.

Page 64: Reference to "Captain N. Hazzard and Mr P.G. Simpson" should read as "Captain N. Haszard and Mr P.J. Simpson".

FISHERIES TECHNICAL REPORT

SURVEY OF FOVEAUX STRAIT OYSTER BEDS 1960-1964

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WELLINGTON.

CONTENTS

SUMMARY

This report examines results of the 1960-1964 survey of dredge oyster (O. lutaria) populations in Foveaux Strait.

The main aim was to assess the maximum sustainable yield for the fishery. Distribution, densities, population structure, and quality of oysters were studied.

Studies of oyster biology and ecology, hydrology, and commercial dredge efficiency were also carried out and these are reported in another publication. (Stead 1966, 1971).

Methods include the use of grabs, dredges, underwater cameras, and diving.

The survey was carried out as follows:

A preliminary study to determine sampling techniques followed by:

Phase 1 - Exploratory survey using a sampling dredge

Phase 2 - Dredge calibration

Phase 3 - Studies of oyster density

Phase 4 - Commercial dredging.

Results showed that:

Oysters occurred over an area of some 300 square nautical miles in Foveaux Strait, though commercially fishable grounds occurred in an area of about 121 square nautical miles, mainly along the central regions of the Strait in depths of 9-21 fathoms.

Most oyster beds occurred on coarse sediments containing sand, gravel, pebbles and broken shell. Most populations contained a large proportion (over 40%) of takeable stock.

Where much dredging had occurred oysters were evenly distributed. More isolated beds, often with high oyster densities, occurred in lightly dredged or underworked areas.

Diving showed that dredging and tidal currents influenced oyster distribution.

Oyster quality was generally better on eastern areas.

Some areas, mainly in the eastern zone, had been depleted by overfishing before 1961. Dredging effort was not equally distributed on the commercial beds in proportion to the distribution of the resource.

The standing crop of takeable size oysters was assessed at about 1,000 million. The optimum yield was assessed at an average 125,550 sacks per year, equivalent to 15,689 hours at 8 sacks per hour.

Calculated area quotas and suggestions for management of the dredge fishery are included in the text.

Commercial farming of the dredge oyster is considered feasible.

INTRODUCTION

This report examines the results of 1960-1964 oyster surveys in Foveaux Strait.

(a) The Area and the Environment

Foveaux Strait, separating the South Island of New Zealand from Stewart Island, is about 16 nautical miles wide and has an average depth of 15 fathoms. Map 1 (N.Z. Chart 14) shows the area with depths and contours marked.

Foveaux Strait is strongly tidal (up to about 3 knots) and the Southland Current, a branch of the East Australia Current, flows through the Strait from the west. The area is exposed to frequent strong south-westerly gales which generate heavy seas. The bottom sediments consist of sand, gravel, pebbles, cobbles, broken shell and "corals", the proportions of each varying in different parts of the Strait. (Cullen 1967 and Map 2). Average salinity is normally over $35^{o}/oo$ except in areas close to river mouths in the north of the Strait and in some Stewart Island estuaries. Mean sea temperature ranges from about 9°C (48°F) in winter to 15.5°C (60°F) in summer.

(b) The Oyster

The species found in Foveaux Strait is *Ostrea lutaria* Hutton, the dredge or mud oyster (Hollis 1963). This species also occurs in other parts of New Zealand such as Otago and Wellington harbours, and Tasman and Golden Bays, but not in the quantities which occur widely in Foveaux Strait.

Ostrea lutaria incubates larvae to a late stage of development before release. On release most larvae have lost the velum and have an eyespot, twin shells, and a prehensile foot. After release the larvae remain close to the sea bed and soon attach to solid, clean objects such as other live oysters. Growth is fairly rapid; the oyster can reach legally takeable size in 2-3 years. Most breeding occurs in oysters more than three years old during November-February (Stead 1970).

(c) The Fishery

Oysters were first marketed in small quantities as early as 1830, and during the 1860's most came from Oyster Cove, Port Adventure, a shallow tidal estuary on the east coast of Stewart Island, and were taken, in the shell, to Dunedin by sailing vessels (Sorensen 1968). These estuarine beds were almost depleted by 1867, but in 1868 an oyster bed was discovered off Port William, Stewart Island, in depths of 12-15 fathoms, and was dredged by sailing cutters from Oban. Another bed was discovered off Halfmoon Bay in 1872 and, in the following years as boats ranged further afield, other productive oyster grounds were discovered and dredged.

The oyster industry transferred from Stewart Island to Bluff in the early 1900's, sail gave way to steam power, and boats and dredges increased in size. Oil power gradually replaced steam and the boats are now all diesel-powered, over 60 ft long, and tow two large dredges over the port side - (Plate 1). Regulations limit the maximum dredge width to 11 ft.

Dredges are emptied on to benches where takeable oysters are sorted and bagged and other material is discharged to sea through chutes. Annual catches steadily increased over the years, and before 1960 most dredging occurred on Areas A-E (Map 1). Figures 23 to 27 show the statistics of the fishery.

This oyster fishery is one of the few which is still based on the exploitation of an uncultivated, sub-littoral population. An account of the industry and its practices is included in the Report of the Fishing Industry Committee 1970.

(d) Pre-1960 Surveys

Surveys were carried out by R.E. Hunter (1906), M.W. Young (1926), and E.F. Watson (1945), to locate new oyster grounds, define known beds, and assess the commercial productivity of oyster grounds in Foveaux Strait (Sorensen 1968). Concern over possible depletion of stocks by over-fishing led to the 1960-1964 survey.

(e) Aims of the 1960-1964 Survey

The main aims were to assess the maximum sustainable yield and to obtain information on which to base a rational management policy for the oyster fishery. To do this, the distribution, density and population structure of oysters were examined. Studies on the biology and ecology of *O. lutaria*, other benthic fauna, dredge efficiency and other commercial aspects, were carried out concurrently with the resources assessment programme but these results are examined in other publications (Stead 1966, 1971).

THE SURVEY

Methods - General

Methods include the use of dredges, grabs, underwater cameras, and diving.

To assess oyster resources the survey was planned in stages as follows:

(a) Preliminary phase - Introduction and determination of sampling techniques.

(b) Phase 1 - Exploratory surveys using a standard sampling dredge on a regular grid pattern in the Strait.

(c) Phase 2 - Calibration of the sampling dredge against a commercial oyster dredge.

(d) Phase 3 - Studies of the density and distribution of oysters by diving and underwater photography.

(e) Phase 4 - Commercial dredging observation and studies of dredge efficiency.

The data from all phases were used to determine oyster bed distribution and their commercial significance.

Map Reference

The recording of catch statistics by areas (A-J) was established in February 1960. These areas are shown on Map 1 together with a nautical mile reference scale at the margins. The square mile grid used is shown on Map 8.

Boat Charters

Appendix 1 shows boats chartered, stations covered, and the study programme.

Rough seas in the Strait limited sea time to 259 days out of 417 available charter days. Together with time spent on commercial oyster dredgers during the season 280 days were spent at sea from May 1960 to May 1964.

Position Fixing

Station positions were fixed by radar and sextant on "Matai" and "Viti", and on other boats by compass cross-bearings, horizontal or vertical sextant angles, or by alignment of landmarks. Photographs, often using a telescopic lens, were taken of known landmarks at some stations to record positions. The echo sounder was frequently used with chart reference as an added check on positions.

Field Data

All field data were recorded on typed sheets. These are available for reference at Fisheries Division Laboratories at Wellington and Bluff.

PRELIMINARY PHASE

Methods

In May-June 1960, observations were made aboard "Viti", a vessel chartered by the New Zealand Oceanographic Institute, DSIR, to study benthic fauna, sediments and the hydrology of Foveaux Strait. Standard sampling occurred at 63 five-mile grid stations (B215-B278 O.I., DSIR) - see Map 2 (after Cullen 1967). Instruments used include 'Ironsand', cone and standard naturalist dredges, Dietz, Petersen and "orange-peel" grabs, plankton nets, core samplers, reversing bottle and thermometer, and bathythermograph.

During tests to determine the suitability of a grab as a standard oyster sampler, a large "orange-peel" grab was used in comparison trials with an oyster boat dredging in Area D2. The open grab covered about 4 square feet of seabed and dug to a depth of about one foot.

Results

Results of the standard 5 mile grid sampling are published in DSIR publications (Cullen 1962, 1967, Cullen and Gibb 1965).

The following table shows results of the grab/dredge comparison trials in 1960; Map 5 shows station positions.

GRAB/COMMERCIAL DREDGE COMPARISON RESULTS

Station	No. of Grabs	Mean No. of T.S. Oysters (Range)	No. T.S. Oysters in 2 Large Dredges 10 Min. Tow.	Ground Evaluation
1	5	2.2 (0-4)	2100 Mean for 3 hauls	Good
2	5	4 (0-9)	1533 Mean for 2 hauls	Average - Good
3	5	2 (0-1)	1750 Mean for 3 hauls	Good
4	5	4.2 (0-11)	840 Mean for 1 haul	Average
5	5	1.2 (0-3)	1550 Mean for 2 hauls	Average - Good

These results show no correlation between grab samples and commercial evaluation of the ground presumably because of the small size of the samples taken, but indicate the densities of takeable-sized oysters on commercially workable grounds. Grab sampling was time-consuming.

Conclusions from this preliminary phase were that:

(1) A grab was not suitable for use during the survey.

(2) The grab results indicated that the distribution of oysters was variable but generally sparse.

(3) The 5 mile grid sampling indicated that oysters were widely distributed in Foveaux Strait (Cullen 1962).

(4) Most oysters occurred on firm sediments composed of coarse sand, gravel, pebbles, whole and broken shell and "coral"/bryozoa fragments. None were taken on mud substrates in Stewart Island inlets - (see Map 2, Cullen 1962, 1967).

(5) A varied and abundant benthic fauna was recorded on most oyster grounds.

PHASE I - EXPLORATORY SURVEY

Aims

To obtain standarised quantitative data on oyster distribution, population structure, condition and mortalities over a wide area.

To sample the sediments and other benthic fauna at each station.

Sampling Dredge

A small dredge (shown in Plate 2) was used. It had a 3' x 1' rectangular mouth and a rigid $\frac{3}{4}$" steel mesh container, 3' x 3' x 1". An adjustable steel bar or bit protruded about $\frac{3}{4}$" below the runners on which the dredge was mounted, and a steel depressor plate was fitted to improve dredge performance at higher towing speeds.

Methods

Survey dredge samples were taken on a grid pattern at approximately one mile intervals (see Map 3). Preliminary trials had shown that five minutes was the most effective towing time for this dredge, and these five minute tows were used throughout the survey. All living and dead oysters were sorted from each dredge catch and the shell lengths (at right angles to the hinge), measured to the nearest half centimetre were recorded. A sample of oysters was retained for internal examination and condition studies. A small sediment sample was retained for further analysis, and other relevant data were recorded.

Results

(a) Distribution

Map 3 shows the number of live oysters and those of legally takeable size (6.4 cm shell length) , taken at each station. Oysters mainly occurred at stations along the central regions of the Strait between Green Island in the east to Black Rock Point, Stewart Island in the west, in depths ranging from 9 to 21 fathoms. Oyster abundance was uniform in Areas A, B and D where most commercial dredging had occurred. Survey dredge catches were frequently small on these grounds suggesting a dispersed population.

Some of the best catches were taken in Area G, which was virtually unexploited before 1961. The best catch was at Station 262 (Area G), where 589 (326 takeable size) oysters were taken. In Area G oyster beds were well defined and separated by oysterless areas and large catches were frequently taken among the patches of densely aggregated epifauna known locally as "mullock".

Outside the main oyster area in the middle of the Strait oysters occurred in isolated beds surrounded by extensive unpopulated areas. Many of the oyster beds were oriented in an east-west direction suggesting that their distribution is influenced by tidal currents.

Sediment composition varied: a large proportion of pebbles occurred on oyster beds in Areas A, B, C, D2, E2, and H whereas in Areas D1, E1, F, and G, sand and broken shell were the main components. Except for some isolated patches, oysters were rare on firm sand and on clean pebble/cobble sediments.

O. lutaria occurs frequently on rocks on the lower shore and on firm substrates in the shallow sub-littoral but are rare on soft bottoms in Stewart Island inlets such as Port Pegasus, Port Adventure, Lords River and Paterson Inlet.

(b) Population Structure

Figures 1 and 2 show that there is considerable variation in size composition in different areas even within the same statistical area. However, due to the large number of stations and the large amount of length frequency data obtained, it was possible to combine samples so as to obtain representative data for the whole Strait and for different statistical areas (see Figures 3-13).

Length frequency data from all stations are available for reference. As Figures 3-13 are for data collected throughout the survey growth of oysters during the period will have tended to smoothe any separation of year groups.

The majority of small oysters in Areas A, B and D were attached to large oysters. In most western areas many small oysters were separate. Many small oysters in Area C were also separate.

Figure 3A shows the length composition of oysters taken by the survey dredge from 123 stations throughout the Strait during 1960-62. This shows a skewed population with more than 50% of the oysters of takeable size and with a mode at 7 cm. At 7 cm oysters are about 3 years old (Stead 1971).

Figure 3B (length frequency of dead oysters (curved valves only measured)) shows fewer oysters under 6 cm long than in live oysters. The dredge retained very small oysters and this difference may be explained either by low mortalities in oysters under 6 cm (once they have passed the small spat stage when mortality is high) or by more rapid breakdown of small dead shells. Dead attached oysters were included in the counts.

Area A - ("East Bed")

Figure 4A shows that at Bed A 49% of stock are takeable with a large proportion of immature, growing, stock - (mode 4.5 cm). These small oysters were nearly all attached to large oysters. The samples were taken from a wide area in Area A but mainly on grounds which had been heavily exploited for many years. The large number of small oysters may indicate either that future recruitment will be good or conversely that the numbers of large oysters had been greatly reduced by dredging.

Figure 4B shows a small mode of dead shell at 4.5 cm and a large mode at 7.5 cm. Many dead oysters still retained the conchiolin and were articulated, indicating that recent mortality on the bed had been high.

Area B - ("Ruapuke Bed")

Figure 5A represents oysters from most parts of Area B in 1960-62 . 55% were takeable (mode 8 cm). Most small oysters (modal length 2 cm), were attached to large oysters, often in large aggregations. This area had also been heavily exploited for many years.

Figure 5B shows relatively few dead small oysters but many large dead oysters. Many of the dead oysters were articulated with intact conchiolin.

Area C - ("Bird Island Bed")

Figure 6A shows that on this bed 54% of the oysters were of takeable size and few were very small. Most were free-living and on loose pebble sediments. The dead oyster sample in Figure 6B is too small to be significant.

This area has been exploited intermittently over the years.

Area D1 - ("Bird Island West Bed")

Figure 7A shows four length modes and that 38% of the stock are of takeable size. Many oysters were aggregated in large clusters. These grounds had been dredged for many years and this may explain the reduced percentage of takeable oysters. Many articulated dead oysters were taken but old, white, single shells were also abundant.

Figure 7B shows a higher than average proportion of small dead oysters.

Area D2 - ("Bluff Hill East Bed")

Figure 8A shows that 57% of the stock are takeable with a mode at 2.5 cm of young oysters, most of which were attached to large oysters. Grounds in this area had been dredged for many years.

Figure 8B indicates low mortalities among young oysters. Many dead oyster shells were articulated.

Area E1 - ("North Island West Bed")

Figure 9A shows 65% of the population to be takeable - (modal length 7.5 cm). This area is noted for the generally smaller size of oysters; these productive grounds had been dredged for many years. Most oysters were free-living but attached oysters were numerous on certain patches.

Figure 9B again suggests low mortality of immature oysters although many old large white shells also occurred.

Area E2 - ("North Island East Bed")

Figure 10A shows the population to have 72% takeable stock (modal length 8.5 cm). Although some parts of this bed had been dredged for many years some new grounds were discovered and worked in 1961 and samples from these are included in the histogram.

Figure 10B again suggests low mortalities in younger stock. Many dead oysters were articulated and had intact conchiolin.

Area F - ("New River Heads Bed")

Figure 11A shows that on this bed 58% of the stock are takeable. There is a secondary mode at 5 cm. The histogram represents unworked or lightly-dredged oyster grounds. The incidence of oyster aggregation was low.

Figure 11B indicates the mortality of immature oysters is low.

Area G - ("Saddle Bed")

Figure 12A represents a very large sample from a wide area which was largely unexploited before 1961. The histogram shows a balanced population 57% of which was takeable. The curve is characteristic of those from many single station samples in Area G. Smaller size groups are well represented though the incidence of attachment was low compared with eastern areas.

Figure 12B shows a higher percentage of large dead oysters, the bulk of these consisting of old white shells, often thick and perforated by the borer Cliona sp.

Area H - ("Centre Island Bed")

Figure 13A shows a balanced population with all size groups well represented. Several stations were on previously unexploited grounds. Most small oysters were attached to larger oysters although many were single.

Most dead oysters were large, articulated, and had an intact conchiolin.

Grouping of Length Frequency Data

Figure 14 shows length frequency histograms of the oysters measured in each three-month period during the exploratory survey. 11,576 oysters are represented. Results are complicated due to the fact that sampling occurred in different Strait areas at different times of the year but the apparent migration of modes may represent growth (see also Stead 1971).

Oyster Quality

Methods

Recorded data for samples of oysters at each survey station included length, breadth, and depth of shell; also whole weight, shell weight, and flesh weight. General condition was also noted.

Results

Appendix 2 includes data on various parameters of some of the oysters sampled and measured during the survey.

Figure 15 shows oyster shell length plotted against shell width for samples from many Strait areas. Considerable variation exists, but the graph shows a linear trend. The trend line on the graph was fitted by eye. The shell length equivalent to the legal takeable size (6.7 cm - 2⅛" in 1961 is shown.

Figure 16 shows mean flesh weights plotted against shell width for a large sample from many Straits areas. The curve shows a sharper increase in mean flesh weight as the oysters reach maturity. In young oysters growth in length is rapid and is generally accompanied by little increase in width - when approaching takeable size, increase in length slows and the oyster becomes more cup-shaped - thus with only a small length increase, shell volume and meat size increase rapidly.

Adjustment of the takeable size from 2⅛" to 2¼" represents a difference of about one gram (16%) in mean flesh weight.

Figure 17 compares shell length/mean flesh weight data for oysters from the eastern Areas A-E and from western Areas F-H.

The two curves are similar but mean flesh weights are higher in Areas A-E but particularly in oysters smaller than 5 cm long. In general, the condition of oysters was better in the eastern areas than in western areas: western areas are deeper than eastern.

Figure 18 shows whole weight plotted against flesh weight for oysters from the Straits and from Port Adventure. The latter show a higher flesh to shell weight ratio than the former. The considerable variation in individual Strait samples is due to variation in shell thickness. Many Strait oysters, especially from deeper water western areas, had thickened shells; this may indicate considerable age. The trend lines in Figure 18 were fitted by eye.

A typical good specimen of O. lutaria is one from the shallow sub-littoral zone in Port Adventure. These oysters have thin, close-fitting shells and a more cupped lower shell than Straits oysters. Adductor muscle tone is good and the creamy-white flesh usually fills the shell cavity. These oysters are sweeter and less salty than Straits oysters.

A typical poor oyster is from "mullock" areas in 20 fms off Saddle Point and has a thick, misshapen, often elongated, and friable shell. The shell is sometimes slightly gaping, suggesting poor adductor muscle tone and the flesh translucent, with reduced glycogen reserves and the brown digestive gland visible.

During the Straits surveys a higher proportion of good quality oysters was recorded on eastern areas in depths under 15 fathoms than elsewhere. In this locality very few were infected by Cliona. (Stead 1971). Oysters with shells infected by Cliona had often poor quality flesh.

During 1960-61 oyster flesh condition was generally good in the Strait, except in some areas close to Saddle Point and in depths greater than 25 fathoms. "Condition" was judged by eye from the white appearance and "fatness" of the gonad tissue. Flesh condition was generally poor in 1962 and 1963 when many oysters were infected by a trematode parasite Bucephalus sp. (Howell 1965). Infected oysters contained the thread-like sporocyst of the parasite, had emaciated gonad tissue and were often translucent and sometimes yellowish in colour. A lower incidence of parasite infection was recorded in 1964 and oyster condition improved.

Oysters were generally in good condition in August and September just before spawning, but spent oysters were frequently seen in late September and October. Most had regained condition by late February to March.

Conclusions

The exploratory survey showed oysters to be widely distributed in variable densities over some 300 square nautical miles of the Strait. Commercially workable grounds (judged by comparison of survey dredge catches on exploited and unexploited grounds) were estimated to occur in an area of approximately 100 square nautical miles but within this area distribution was variable: commercially profitable oyster beds probably cover about 50 square miles.

Catch statistics, local information, and the survey results showed that before 1961, only about 30 square nautical miles of commercial grounds, mainly in Areas A-E had been exploited and some of these grounds were depleted. Good survey dredge catches were taken in many unexploited western areas. The oysters were comparable in size and flesh weight to those from frequently exploited grounds, but flesh quality was often poor among "mullock" in western areas. Shell condition was generally better on eastern areas. More spat and small oysters were seen on the heavily exploited eastern areas than on the western areas. During a parasite outbreak in 1962 many oysters died; this caused a sharp decline in dredging catch rates.

PHASE 2 - DREDGE CALIBRATION

The small dredge survey supplied data on oyster distribution and abundance in the Strait. In order to assess the commercial significance of the survey it was necessary to calibrate it by comparison trials with a large commercial dredge.

Methods

The standard commercial dredge is 11' wide, has a steel bar bit about 2½" x ½", and a flexible steel ring bag with cord meshes on top (Plate 1). This dredge and the survey dredge (Plate 2) were towed simultaneously. A buoy was used to mark the station. Map 4 shows the calibration stations. At stations 1-40 both dredges were towed, first for 5 minutes and then for 10 minutes. At stations 41-123, the two dredges were towed for 5 minutes three times. To reduce errors these comparison trials were conducted on all grades of oyster ground in different parts of the Strait, three different oyster boats were used, towing speed and length of warp were varied, and dredges were switched between forward and after towing positions. Depths were checked by echo sounder and weather and tidal conditions were recorded.

Results

Appendix 3 shows all dredge calibration results. The results from Stations 1-40 where both 5 and 10 minute tows were taken, are summarised in the following Table.

COMPARISON OF 5 AND 10 MINUTE TOWS WITH SURVEY AND COMMERCIAL DREDGES

Evaluation of Ground	Catch (number of takeable oysters)					
	Survey Dredge			Commercial Dredge		
	5 minute Mean (Range)	10 minute Mean (Range)	* Percentage	5 minute Mean (Range)	10 minute Mean (Range)	* Percentage
Good 10 stations (40 trials)	23 (3-61)	34 (7-10)	68	678 (451-1112)	1040 (718-1820)	65
Average 5 stations (20 trials)	30 (10-37)	28 (7-53)	107	284 (64-574)	447 (167-671)	64
Poor 20 stations (80 trials)	9 (0-29)	8 (0-46)	112	77 (4-208)	76 (4-160)	101
Mean	16	18	88	290	402	61

*"Percentage" is the calculated average percentage of the catch taken in the first 5 minutes of a 10 minute tow.

Some incomplete data for Stations 1-40 were not included, but at 10 stations classed as good 68% of the mean catch was taken in the first 5 minutes of a 10 minute dredge tow, and 65% in the commercial dredge for the first 5 minutes. On average and poor grounds the mean catch in the survey dredge was less in 10 minute than in 5 minute tows. With the commercial dredge on average grounds 64% of the catch was taken in the first 5 minutes of a 10 minute tow, but on poor grounds the catch for 5 and 10 minute tows was the same.

Results were complicated by varying dredge efficiency under different conditions and the presence of "mullock" at some stations.

It was necessary to calculate the number of takeable oysters in a 5 minute commercial dredge tow which, if prolonged to 10 minutes, would yield an acceptable catch.

The commercial catch rate for 1960-62 was 9.6 sacks per hour. At five 10 minute tows per hour this gives an average catch per tow of about one sack (700-800 oysters at that time). Over 60% of the catch is taken in the first 5 minutes of a 10 minute commercial dredge tow therefore, on good ground at least 500 oysters would be taken in the first 5 minutes. On average quality grounds yielding a minimum commercial catch (7 sacks/hr), at that time) a 5 minute commercial dredge tow should yield about 375 oysters. It was then necessary to evaluate how many oysters in the survey dredge after a 5 minute tow are equivalent to 375 in a large dredge in a 5 minute tow.

Appendix 3 shows the data obtained in full.

At Stations 41-123, both survey and commercial dredge were towed for 5 minutes.

The results from the heavily exploited eastern zone and the lightly exploited western zone are shown in Figure 19 with the trend lines fitted by eye.

On eastern areas dredge efficiency was impaired at some stations where the stalked ascidian Pyura ("Sea-tulip") was abundant (Map 9).

Dredge efficieny on western zones was reduced at several stations by dense "mullock".

On western grounds the survey dredge caught on an average more oysters than on eastern areas, whereas the commercial dredge did not catch appreciably more. On "mullock" the survey dredge sometimes outfished the commercial dredge.

On the eastern zone the calibration factor was about 25 to 1, i.e., on average grade commercial ground the commercial dredge was much more efficient than the survey dredge and a 5 minute large dredge haul yielded about 375 oysters, which was equivalent to about 15 oysters in the survey dredge.

PHASE 3 - DENSITY OF OYSTERS ON THE SEA BED

Aim

To study the density and distribution of oysters on the sea-bed in different parts of the Strait and to relate the data obtained to dredge catches on the same grounds.

Methods

Three methods were used to examine densities:

(a) Grab sampling;
(b) Underwater remote controlled camera;
(c) Diving.

(a) Grab Sampling

In May-June 1960 a large orange-peel grab was used in Area D2 (Map 5). This method was found to be unsatisfactory for reasons already outlined (page 7).

(b) Underwater Photography

An automatic underwater camera, on loan from the New Zealand Oceanographic Institute, DSIR, was used in February-March 1961 to photograph the sea bed distribution of oysters. The camera and flash units were attached to a frame. As the boat drifted the unit was suspended from the survey vessel, and raised and lowered from the bottom. Each time it touched the bottom a photograph was taken. A total of 81 prints each about 1 sq. yd. were taken. Up to six photographs were taken at each station. Map 5 shows stations where usable photographs were obtained.

Hand-held still and cine-cameras were also used to photograph the sea bed while diving. Visibility and water clarity was usually so good that flash equipment was not required.

The use of the automatic camera was discontinued because buried or almost buried oysters were not shown and live and dead oysters could not be easily distinguished. The method was also time-consuming and camera failures were frequent. No commercial dredge operations were made at these stations as oyster boats were not available for charter at the time. Several photographs were, however, taken on known commercial grounds.

On the western areas the calibration factor was about 15 to 1 as the survey dredge was relatively more effective than on eastern grounds. A survey dredge haul of 25 oysters was equivalent to a haul of 375 oysters.

Therefore on eastern areas where the survey dredge catch was more than 15, and on eastern areas where the survey dredge catch was more than 25 and if oyster size and quality were satisfactory, the bed was considered to be of commercial standard. Dense "mullock" patches were not graded in this way as the large dredge was unsuitable for use on these patches.

From this work the survey dredge data were used to indicate the commercial significance of the survey results.

(c) Diving

During 1960-61 a limited amount of diving was carried out in selected areas by a hired diver. Navy diving teams carried out surveys in 1962 and 1963 and subsequently increasing use was made of diving to obtain essential information.

Equipment included Hookah, aqualung, and oxygen/nitrogen rebreather units, but compressed air aqualungs proved adequate for diving in the Strait. Diving was found to be the best method for studies of oyster densities.

Dredge sampling using the survey dredge or commercial dredge, or both in sequence, occurred at several diving stations. Stations are shown on Map 5.

To obtain data on distribution and density of the oysters divers worked close to a weighted line from the boat to the sea bed. The boat was either anchored or drifting with the current. A one square yard frame was used to obtain random samples: all live oysters within frames were put into bags, brought to the surface, counted, and measured. All quadrats were dug out to ascertain the maximum depth of live oysters in the sediment.

To observe and photograph the sea bed and dredge behaviour divers rode the moving dredge while it was towed with the tide at current speed.

Results

(a) Grab Sampling

Results are shown on page 7.

The open grab covered an area of about 4 square feet and the number of oysters obtained was doubled to give the approximate number per square yard. For 25 grab samples at five stations in Area D2 on commercial grade oyster ground, an average of 2.3 takeable oysters per grab was obtained, which represents an average of about five takeable oysters per square yard.

(b) Underwater Photography

Arrows show camera drift stations on Map 5.
Appendix 4 shows all underwater camera results. The Table below summarises this data. Only clearly discernible photographs are represented.

TABLE 6 UNDERWATER CAMERA RESULTS

Area Station	No. of Exposures	Mean No. of T.S. oysters per exposure	(Range)	Predominant Sediment type
A 1, 10, 11, 12	16	2.1	(0-5)	Sand - shell - pebble
A-B 3, 13	6	11.3	(5-15)	Sand - shell - pebble
B 4, 15	6	3.7	(1-6)	Shell - pebble
E1 7, 9	7	3.4	(0-8)	Sand - shell
G 2, 6, 18, 19	15	10.6	(2-25)	Sand - shell
Total	50	6	(0-25)	

Each exposure covered an area of about one square yard and most of the stations represented were on commercially exploited oyster grounds.

(c) Diving Results

Map 5 shows diving stations, which were at the centre of the circle. Appendix 5 shows data obtained by diving and dredging at these stations together with a commercial evaluation of the grounds.

The Table below summarises area data on grounds which were of commercial grade.

SUMMARY OF DIVING RESULTS 1960-64

Area	No. of Stations & sq. yd samples	Mean No. of T.S. Oysters	(Range)
A	5/15	9.8	(1-24)
B	6/24	6.8	(1-13)
C	2/7	5.5	(1-10)
D	3/12	5.3	(1-27)
E	3/13	6.6	(1-13)
F	1/4	8.0	(2-15)
G	3/10	6.3	(1-14)
H	1/3	6.0	(2-11)
Total Area	24/88	6.7	(1-27)

The size of samples is small and therefore these show only approximate mean densities of takeable size oysters on the sample areas at the time and are therefore not conclusive.

The maximum number of takeable size oysters recorded by diving was 27 per square yard at Station 16 in Area D in 1962. These were piled several inches deep in depressions in the sea bed. Twenty-four takeable size oysters were recorded for one square yard sample in Area A in 1960.

At nearly all stations live oysters occurred either on the surface or lightly covered by coarse sediments sometimes to a depth of about 3 inches and occasionally to depths of 5" in loose pebble substrate. Some oysters were embedded in hard sand bottoms bit one valve was normally exposed.

Figure 20 shows oyster length frequencies at selected diving stations.

The large numbers of small oysters at several stations in Areas A, B and D suggest a high potential recruitment rate perhaps following recent successful spatfalls. Most of the young oysters were attached but small oysters under one inch in length were often found free living in the sediments.

Figures 21 and 22 show the number of takeable size oysters per square yard as observed by divers, plotted against 5 minute survey dredge and 10 minute commercial dredge catches on the same grounds. Results are complicated due to variable dredge efficiency and difficulties of dredging exactly over the diving stations. However, regression analysis revealed a slight correlation.

Results and observations suggest that about four takeable size oysters per square yard is the population density on marginal grade commercial oyster ground.

For further notes see (p.31).

Conclusions

Results from all methods show the mean densities of takeable oysters on good commercial grade oyster grounds as about 6 per square yard, and on marginal grade grounds as about 4 per square yard.

Most oysters occurred on the surface or were lightly covered by sediments.

There is some correlation between oyster densities and dredge catches on the same ground.

Considerable variation in oyster densities occurred over short distances on the sea bed.

Highest densities were recorded in the centre of oyster beds, against obstacles and in depressions on the sea bed.

PHASE 4 - COMMERCIAL DREDGING

Aims

To assess the commercial value of the ground at sampled areas and to study dredge efficiency and the effects of dredging.

Methods

On oyster boats during the season the dredging site was noted and a progressive tally of sacks of oysters was kept throughout the day. Oysters were examined for spat attachment, condition, stages of contained spawn or larvae, presence of parasites; other fauna in the dredge were also recorded.

It was noted that catch rates were fairly constant if each tow was on the same site, but changes of tide and sea conditions and slight changes in position frequently resulted in changes in catch rates. However, these changes were not usually such as to change the assessment of whether or not a bed was of commercial grade.

During the surveys from chartered vessels the number of takeable oysters for single 10 minute hauls with one commercial dredge was recorded, together with other relevant data including sea and tide conditions. Stations are shown on Map 6. Arrows (Stations A-Y) show single 10 minute hauls with one large stern dredge (width 11'). Stations marked A or B refer to two different commercial dredging positions in one day.

Dredge efficiency was studied by diving observations of three types of commercial dredge, all 11' wide, on different grounds. Densities of takeable oysters on the ground were recorded before dredging and after dredging by making counts in the dredge track. Oysters taken in the dredge were counted (Stead 1966).

Results

Appendix 6 shows station data.

The table below summarises the data obtained using the commercial dredge for single 10 minute tows.

TABLE 11 COMMERCIAL DREDGE RESULTS 1962-1963

Area	No. of Hauls	Range No. of T.S. Oysters in Dredge	Mean No. of T.S. Oysters in Dredge
A	4	50-508	274
B	11	165-1422	521
C	4	0-732	248
D	4	154-550	304
E1	8	70-749	404
E2	6	129-1170	491
F	6	0-1874	341
G	23	0-2088	457
H	7	13-116	56
Whole Strait	73	0-2088	344

These results show that dredging was on all grades of oyster ground in each area. No conclusions can be drawn as with low sample sizes the mean value would relate the number of hauls on each type of ground. The results were useful in plotting the position of beds of varying grades.

Stations (Map 6) marked with an arrow (A-Y) were mainly on sand areas sparsely populated with oysters, or on densely aggregated epifauna. Very few oysters were taken in the stern dredge at these stations and the best catch was 232 oysters for a ten minute tow.

A report (Stead 1966) has been published on the underwater observations of commercial dredge behaviour.

In some areas the dredge pushed forward a ridge of sediment. Oysters meeting the front of the sediment bank often passed over or to the sides of the dredge. Some fell into depressions and were missed by the dredge. Changes in warp tension often caused jerky movements of the dredge which frequently rode over the sediment ridge missing many accumulated oysters. Thus dredging sometimes formed patches or strips of oysters, though varying numbers were removed from the dredged area. Oysters missed by the bit were often spread by the steel ring bag which also flattened sediment ridges. Clumps of oysters were often broken up and small oysters were sometimes damaged by dredges on hard bottoms, but large oysters were rarely damaged. Dredging levelled and graded the sea bed in many areas and large quantities of fine sediments and organic material were thrown into suspension by the dredge and carried over the sea bed by the currents.

In Areas E1 and G the dredge often missed oysters embedded in the firm sand but many were dislodged by the dredge. Such oysters often had sand clumps on the shell. On densely aggregated epifauna ("mullock") areas the dredge filled quickly and meshes were choked, thus reducing efficiency. Sometimes oysters were exposed by the dredges removing the epifauna. The "mullock" was usually jettisoned but dredging did break up many of the clumps into smaller aggregations.

In some areas close to Ruapuke Island, fouling of the dredge bit by the stalked ascidian Pyura reduced dredge efficiency, but this often exposed underlying oysters to subsequent dredging.

As the dredge container filled, the bit came out of contact with the sea bed more often, thus dredge efficiency declined towards the end of the tow.

"Dunking" of dredges just before landing often broke up clumps of oysters and small oysters fell through the bag meshes.

Sinking oysters from the dredge and culching benches side-slipped through the water, falling slowly to the sea bed. Thus they were usually dispersed widely by tidal currents and movements of the boat.

Dredge efficiency was affected by the nature of the bottom, density and distribution of oysters and other benthic fauna, depth of water, towing speed, currents, surface conditions, and design characteristics of the dredge. Six underwater observations of dredging on different grounds, using three different types of commercial dredge, suggested that the nature of the bottom was the most important factor influencing dredge efficiency in Foveaux Strait. Dredge efficiency was low (3 to 7 per cent) on soft bottoms, but it was much higher on hard bottoms (8 to 18 per cent).

Conclusions

Most commercial dredge sampling occurred in 1962-1963 when poor catches were being taken by commercial boats.

Some very good catches were taken, however, in Areas B, E2, F and G (see Appendix).

The highest mean Area catch for single 10 minute tows was taken in Area B and the lowest was in Area H.

There was only slight correlation between single dredge oyster counts and daily commercial dredge catches on the same grounds, presumably due to variable oyster densities over short distances on the sea bed, but the results were useful in allowing the general status of the bed to be assessed.

Commercial dredging results are included in the distribution map (Map 7).

Mean efficiency of the standard commercial dredge was about 10%.

SUMMARY OF RESULTS FROM ALL PHASES

To summarise the combined results from all lhases of the 1960-1964 survey, the distribution and commercial evaluation of all sample areas are shown on Map 7.

To correlate the results from different methods, the table below shows the commercial grading system employed. Dredge calibration results and diving observations were used to group the data into approximately equivalent sections or Grades 1-5.

SHOWING COMMERCIAL GRADING SYSTEM REPRESENTED IN MAP 7

Number of Takeable size Oysters

GRADE	Survey Dredge 5 min tow	Commercial Dredge 5 min tow	Commercial Dredge 10 min tow	Average Density of Oysters per Square Yard	Nu ber of Sacks of Oysters Per Day
1 Good	> 25	> 500	> 720	> 5	> 60
2 Average-Good	16-25	301-500	431-720	3-5	41-60
3 Poor-Average	6-15	100-300	150-430	1-3	20-40
4 Poor	1-5	< 100	< 150	< 1	< 20
5 No Takeable Oysters	0	0	0	0	0

Circles and shaded discs on Map 7 show the commercial evaluation of sample areas. Grades 1 and 2 represent grounds estimated to yield commercial catches during the 1960-1964 period.

Map 8 shows square mile areas containing Grade 1 commercial ground marked with cross hatching. A single diagonal line shows marginal or Grade 2 oyster grounds.

The table below shows the number of square nautical miles in each statistical area which contained Grades 1 and 2 oyster grounds.

NUMBER OF SQUARE MILE AREAS CONTAINING COMMERCIAL OYSTER GROUNDS

Grade	Eastern Zone							Western Zone				
	A	B	C	D2	E2	I	J	D1	E1	F	G	H
1	5	10	4	8	7	1	1	2	10	5	36	4
2	2	1	1	4	-	-	-	-	7	6	4	3
TOTALS	Grade 1 - 36 square miles							57 square miles				
	Grade 2 - 8 square miles							20 square miles				

Foveaux Strait Totals. Grade 1 - 93 square miles

Grade 2 - 28 square miles

Total 121 square miles

However, even within square miles containing Grade 1 and 2 beds these beds did not take up the whole square area. Dredging showed densities and abundance to vary rapidly and showed that beds are frequently small in area, therefore probably only about 50% of the 121 square miles is of commercially useful grade.

The main characteristics of each statistical Area obtained by diving, dredging and the use of underwater cameras, are briefly outlined below.

Area A

On most oyster beds a layer of pebbles overlies sand. The bottom is uneven in places, with 18 inch high ridges 10-20 feet apart oriented north-south.

Oysters are generally and lightly distributed in many commercial areas, but more dense groups do occur in shallow troughs and depressions. Large oysters usually lie flat valve down. Clusters of oysters are frequent. At one spot 3 cm long oysters were found buried 5 inches deep among pebbles. Most oysters were of good shape, with hard shells and intact conchiolin; flesh quality was usually good. Dead oyster shells were not abundant.

Other animals were not generally abundant but Pectinura and Coscinasterias were common. "Mullock" patches occur off North Head (Ruapuke Island).

Area B

The bottom is coarse sand, mixed with pebbles and broken shell. Pebble areas are generally smaller than in Area A. In most areas the bottom is fairly flat and the sediments were loose to a depth of several inches, but depressions and ridges occur in places. Occasional rock outcrops, extensions of the Ruapuke Fast, occur to the south.

Small patches of oysters occur widely in this Area. Large numbers were seen in depressions and at the base of sand ridges and rock outcrops. On the open areas many oysters were lightly covered by coarse sediments.

Oysters were generally of good shape and quality with an intact conchiolin. Dead oysters, many still articulated, were abundant on most commercial grounds.

Many Pectinura occur on the oyster grounds, and Coscinasterias is also common. Most animals were widely distributed over the sea bed. Polyzoa, sponges, and red algae were frequently present on live oyster shell.

Area C

Mainly pebbles overlying coarse sand, with larger cobbles in some areas close to Ruapuke Island. Surface sand is more prevalent in areas north of Bird Island. The sea bed is uneven in places and rock outcrops are common.

Diving generally showed fairly distinct patches or beds of oysters surrounded by barren areas but north of Bird Island oysters are more generally distributed.

A previously unexploited bed of oysters was examined in 1964. This bed, of several hundred square yards, was elliptical in shape, and was oriented in a NE-SW direction.

An average density of 9-10 marketable oysters per square yard was recorded; density was highest in the centre of the bed. Most oysters were on the sediment surface, but some were lightly covered by coarse particles. Oysters were in various attitudes but most were lying flat valve down. Few clusters of oysters were present or seen. Most oysters were of good shape, with an intact conchiolin and good quality flesh. Many articulated dead oysters were present in densely populated parts of the bed but old white shells were not numerous. (See also Cranfield 196).

In Area C patches of the stalked ascidian Pyura (often attached to pebbles and on oysters) are frequent. Coscinasterias and Pectinura are common. Many oysters bear plumose or laminate red algae.

Area D1

The bottom is mainly soft coarse sand with broken shell and some gravel and pebbles in the upper layers. Round, shallow depressions occur in some places.

Oysters are fairly sparse and randomly distributed, but many were seen in depressions on the sea bed, e.g., at Diving Station 16. Many oysters were lightly covered by sediments. Many clusters were seen. Shell and flesh quality was generally good. Many dead oyster shells were taken by the dredges at some stations.

Pectinura and *Coscinasterias* are common.

Area D2

The bottom is predominantly pebbles in the north and south, with more sand and shell in central areas.

Small patches of oysters occur throughout the Area. Many oysters were seen against sand ridges and in depressions. Oysters were often lightly covered by sediments. Many oyster clusters are present, but there were more large single oysters to the south. Large numbers of dead shells, many articulated, occurred on the oyster grounds.

Pectinura and *Coscinasterias* are common. *Longimactra* shells are abundant. Red algae were seen on many live oysters in the south.

Area E1

The bottom sediments are firm sand mixed with broken shell, with pebbles in some areas. The bottom is fairly level, but large sandbanks are present in the south.

Highest densities of oysters are in the north of the Area, where most commercial dredging in this Area occurs. Elsewhere, isolated beds of oysters were located. Many oysters were seen near sand ridges and "mullock" and in depressions on the sea bed. Most open sand areas were only lightly populated and oysters were often firmly embedded in the sediments, with only the lip of the shell showing. Relatively few "wings" (small oysters attached to a large live oyster) were seen. In general mature oysters were smaller than those from eastern areas, and had thickened blunt shells, reduced conchiolin, and were often coated with orange bryozoa. Large amounts of white dead oyster shell were taken by dredges at many stations.

Mullock occurs in some areas.

Area E2

In the north of E2 there are extensive pebble areas overlying coarse sand and shell, while in the south there are large areas of firm sand. Sandbanks occur in the south.

Oysters are most abundant and widely distributed in the north-west of the Area. Elsewhere there are extensive barren areas with isolated beds of oysters.

An unexploited oyster bed (Diving Station 19, Map 5) was examined in December 1962. In the densely populated parts of the bed oyster density averaged 7 marketable oysters per square yard. Oysters were evenly distributed and lying in all attitudes; some were half buried. Most were single but some small clusters were seen. Many articulated dead oyster shells occurred among the live oysters. Most oysters were deep shelled with intact conchiolin; flesh quality was generally good. This bed of oysters was about 500 yards long and 200 yards across at its widest point. Its long axis was east-west. The bed was on a slight rise and surrounding areas bore few oysters.

Another previously unexploited patch was found about 1½ miles E.S.E. of North Island in about 14 fathoms on a pebble bottom. No diving was done, but dredging indicated commercial quantities of good quality oysters similar in appearance to oysters from Area A.

Pyura is common on pebbles in the N.E. of the areas, and "mullock" patches occurred in western and southern parts; elsewhere the animals were well distributed.

Area F

In the north and west of Area F the bottom is of clean pebble-cobbles; in the south and east sand and shell is more common.

In the northern regions few oysters are present; occasional patches of high oyster density occurred over the rest of the Area. Oysters are mostly deep-shelled and of good quality on open ground but many stunted oysters were dredged in crowded areas. Clumped oysters were not numerous.

The benthic fauna is generally sparse on the pebble areas in the North, but elsewhere large "mullock" patches are frequent.

Area G

In area G there are large areas of coarse sand mixed with broken shell and some pebbles in the south, central and eastern regions, with pebbles and cobbles to the north and west. Large sandbanks occur in the south and a trench 42 fathoms deep, about 1,000 yards long and oriented north to south, was recorded at 46° 39'.00"S: 168° 01'.03"E.

Many densely populated oyster patches of variable shape and extent were located, and diving revealed many oysters close to "mullock" patches, sandbanks, and in depressions on the sea bed. Many single stunted oysters were seen beneath "mullock" near Saddle Point. Most areas of high oyster density are surrounded by wide areas thinly populated, by or lacking, oysters.

Most oysters occurred on the sediment surface but in places many were embedded in sand.

Many oysters were coated with bryozoa and had lost part of the conchiolin. Shells of many large oysters were infected by the boring sponge *Cliona sp*. Flesh quality was usually poor in highly congested areas but was variable elsewhere.

Relatively few "wings" or clusters of oysters were seen. Large amounts of dead shell, often bearing *Cliona* tunnels, were taken by dredge.

Large patches of "mullock" are frequent. Elsewhere benthic fauna was light and generallydistributed. *Coscinasterias* and *Pectinura* were abundant.

Area H

The bottom in Area H is mainly pebble/cobbles. There are extensive firm sand areas to the north and south.

In 1963 diving on a previously unexploited area (Diving Station 28, Map 5) revealed average densities of 6 marketable oysters per square yard, distributed over the flanks and crest of a ridge on the sea bed. The sediment was a deep layer of pebbles. Oysters were most common on the west facing slope at about 17 fathoms. The ridge rose from 21 to 15 fathoms and lower densities were seen above and below the 17 fathom line. The densely populated area was oriented east-west and was estimated to be about 1,000 yards long. Most oysters were large, deep-shelled, often well worn in the centre of the left valve, but with an intact conchiolin and of good flesh quality. Oysters occurred on the sediment surface in all attitudes and oyster spat were seen on several oysters. Many articulated dead oysters occurred on the densely populated areas. Live oysters found in "mullock" at the foot of the ridge in 21 fathoms were mostly stunted and of poor quality. Survey dredging elsewhere in Area H revealed extensive pebble/cobble substrates only thinly populated or devoid of oysters, though patches of marginal commercial value were located in depths below 22 fathoms. Many of these oysters were large, but were flatter than usual and contained only average quality flesh.

The benthic fauna was generally sparse, but there are occasional "mullock" patches. Many "seven-armed starfish" (Astrostole) occurred on some oyster patches, and Coscinasterias was also common.

Area I

The survey did not fully explore this area. In areas close to Ruapuke Island the bottom is of pebble-cobbles; elsewhere extensive areas of firm sand with pebble patches occur. Rock outcrops are numerous.

One patch of good quality oysters was located on pebble bottom south of Ruapuke Island (Square X29). Other small beds were dredged near the Hazelburgh Islands, but elsewhere the surveys indicated fairly barren areas.

Pyura were common on the pebble grounds near Ruapuke Island; elsewhere fauna was generally sparse on the sand areas.

Area J

The survey did not fully investigate this area. The bottom in area J is mainly firm sand with few pebble patches. Sandbanks and rock outcrops are numerous in the south.

Small patches of good quality oysters were dredged near the Ta-Marama Islands. Those in "mullock" patches were of poor quality.

Plates 3-5 show oyster ground in different parts of Foveaux Strait. Map 9 shows areas of aggregated epifauna ("mullock") and Pyura (Sea Tulips).

CONCLUSIONS

The results of 1960-1964 surveys showed that:

(1) About 93 square nautical miles in Foveaux Strait contained oyster grounds of commercial standards classed as good or Grade 1, and another 28 square miles contained grounds classed as marginal or Grade 2.

(2) Oyster density showed great variation over short distances in many places and beds and patches were generally well defined. Because of this it is estimated that the beds only covered about half of the 93 and 28 square miles in which they occurred.

The mean densities of takeable size oysters on sampled Grades 1 and 2 oyster grounds were 6 and 4 per square yard respectively.

At 6 oysters per square yard for 50% of Grade 1 areas (93 ÷ 2 = 46.5 sq. n. mls) and 4 per square yard for 50% of Grade 2 areas (28 ÷ 2 = 14 sq. n. mls), the estimated standing crop of marketable oysters on commercially fishable beds was about 1,340 million.

(3) Before 1961 most dredging occurred in Areas A-E, the bulk of the annual catches being taken in Areas A, B, D and E1. These frequently exploited grounds were estimated to cover a total area of some 30 square nautical miles. Thus only about one third of the total available commercial area was being exploited before 1961. Fishing effort was not distributed on each area in proportion to the resources available.

(4) Standing crop estimates for these intensively dredged areas suggest that 15-20% fishing mortality occurred. Growth and recruitment will vary in different areas and years but a tentative estimate for mean annual recruitment is about 10%. Natural mortality was variable but up to 50% of adult oysters died in 1962-1963 and catches declined sharply.

(5) There was evidence of depletion by intensive and prolonged over-fishing on Area A, and parts of B and D, shown by a declining catch rate and thinly populated grounds.

DISCUSSION

Distribution

Results of surveys in 1906, 1926 and 1945 (Sorensen 1968), showed that most oysters in Foveaux Strait occurred in well defined areas or beds, many of which were named and dredged by oystermen.

The 1960-64 survey showed a similar distribution in areas previously unexploited by commercial dredging. In well dredged parts of Areas A, B, D and E, oysters were often more evenly but more thinly spread over wide areas. Unexploited beds in these Areas were, however, more sharply defined. Commercial dredging is thus suggested as the main cause of wide random oyster distribution in heavily exploited areas.

It is assumed that the predominant distribution pattern before commercial dredging occurred was that of a series of discrete oyster populations surrounded by unpopulated areas.

Diving showed that several beds were elongate and oriented in the direction of tidal currents, with highest oyster densities in the centre of the bed. Cranfield (1968) describes a previously unexploited oyster bed east of Ruapuke Island (Square E.32 - Map 8). This bed, like other unexploited beds described in this report, was elliptical in shape with high densities of oysters in the centre but thinly populated peripheral areas. The elongate shape and alignment of these beds suggests that tidal action influences them.

Most oyster beds occurred along the middle of the Strait. Tidal action is also suggested as the cause of the presence of many oysters being piled up against sand-banks and other obstacles and in depressions on the sea bed.

Most oyster beds in Foveaux Strait are on firm, coarse sediments, suggesting that distribution is also influenced by the nature of the bottom (Cullen 1962). This mixed coarse sediment occurred widely along the middle regions of the Strait (Map 2).

Most oysters were on the sediment surface or were only lightly covered. The fleshy mantle edge of the oyster keeps hard particles out of the shell cavity. Oysters were often buried by sediments raised by currents or dredge action but this scouring action also exposed burried oysters. Oysters were moved over firm bottoms by tidal currents, explaining the quantities against sea bed obstructions.

The observations may explain the rapid changes in apparent abundance and distribution of oysters from time to time in different areas.

The distribution Map 7 summarises the 1960-1964 situation.

Oyster Populations

Population samples from many unexploited Strait areas were comparable with a large proportion of oysters over 6.4cm. in length (takeable) but relatively few smaller oysters. For example Figure 10A which mainly contains samples from new grounds shows a mode at 8.5cm; the reserve of takeable stock in these grounds is large. Other similar examples were recorded in unexploited parts of Areas F, G and H. By contrast Figure 4A from the heavily exploited Area A grounds shows a lower proportion of takeable to immature stock and the size range of the former suggests heavy fishing mortality. The falling catch rate on Area A suggests that dredging was exceeding the recruitment rate. The histogram for Area B (Fig. 5) the Ruapuke Beds, shows a greater proportion of takeable stock than on Area A, but there were also many recruits, attached to parent oysters. Area B had not been dredged as intensively as Area A.

The large numbers of recruits on heavily exploited grounds in Areas A, B and D, and the fairly rapid growth rate have possibly enabled these grounds to withstand intensive dredging for many years but many oysters are being taken as soon as they reach the minimum takeable size, and the catch rate has shown a steady decline.

Studies suggest that there is variation in growth rate, recruitment and natural mortalities in all parts of the Strait and these factors complicate any assessment of the optimum yield. Stead (1971) includes much biological data on O. lutaria.

Oyster Quality

There were relatively more young oysters in samples on eastern grounds than on unexploited western grounds. Shell and flesh condition was generally better in eastern areas. Many old oysters on western grounds had thickened, friable shells and reduced glycogen reserves. Thus quality may be related to the amount of exploitation. Oystermen have commented on improved oyster condition on many western areas after a few seasons dredging. Apart from the culling of old stock and dispersal of oysters, dredges may raise oyster food material from the sea bed. Oysters in dense "mullock" were often small and in poor condition but oysters on nearby open ground were usually fat. This suggests that competition for food is a significant factor.

Commercial Aspects

The proportion of takeable oysters removed by dredges is important in assessing optimum yields. Assuming an oyster boat tows two 11" wide dredges at 2 knots for 10 minutes, 40 times a day, the area covered daily by dredges would be about 190,000 square yards. For a day's catch of 80 sacks at 800 oysters per sack, about 64,000 oysters would be taken from the dredged area, i.e., about 1 oyster for each 3 square yards each time over the ground. Taking commercial bed density at 6 oysters per square yard dredge efficiency is about 5-6%. The bed would be depleted to below the marginally profitable density of 4 oysters per square yard by the time the dredge has covered the ground 8-10 times. A skilled skipper can work within very close areas and where beds are small these can be fished until they are no longer profitable; the boats then move onto another bed. The danger of local overfishing exists when beds are worked regularly and the competition for beds increases. The relatively low dredge efficiency assists in conservation when dredging is spread over a wide area.

In 1960 about 100 million oysters were taken, mainly from Areas A-E which contain about 50% of the available ground in the Strait. For an estimated standing crop of 500 million oysters for A-E in 1960, a yield of 100 million represents 20% fishing mortality.

For Area A assume a mean density of 6 oysters per square yard on 5 square miles, i.e., 120 million oysters as the standing crop. The mean annual yield for Area A from 1950-1959 was about 40,000 sacks or 32 million oysters. This represents a mean annual fishing mortality of 27% of the standing crop unless mean densities were originally much higher. Since 1962 the number of boats has increased and most of the surveyed areas in the Strait have been dredged. Oyster grounds in Areas F, G and H have yielded commercial catches of good quality oysters. These catches, however, represent the yield from a previously unfished stock and the ability of these grounds to withstand continuous intensive dredging in future is not yet known. This will depend on the relationship between recruitment, and natural and fishing mortalities.

The obvious detrimental effects of commercial dredging on a bed include: removal of takeable oyster stocks and therefore spawning potential, loss of many spat and "wing" oysters attached to the oysters taken reduced chances of cross-fertilization and settlement by removal and dispersal of large oysters, damage to young oysters and displacement of spat, burial of oysters, and modification of the environment. Some possible beneficial effects of dredging include: reducing overcrowding, exposing buried oysters and clean shell surfaces for spat settlement, removing oyster predators and parasites, breaking up aggregated epifauna ("mullock"), grading the sediments, and by raising fine organic food material from the sea bed.

The total area populated by oysters is often increased by dredging and mixture of populations may be genetically beneficial.

In Foveaux Strait a certain amount of commercial dredging is beneficial, depending on local conditions. One result of delicensing and control by quotas since 1962 is a more even distribution of dredging over the whole area and a reduction of fishing intensity in previously heavily exploited eastern areas. Frequent westerly gales in Foveaux Strait usually reduce available dredging time during the season and rough surface conditions reduce efficiency. Thus weather is an important factor in conservation of oyster stocks. The effect of heavy seas on the sea bed is not thought to be significant due to the depth of water over the beds, but prolonged westerly gales may increase flood tide velocity through the Strait or disturb bottom deposits in shallow water.

Statistics of the Fishery

Figures 23-26 show oyster fishery statistics.

Figure 23 shows annual catches 1913-1968, the number of boats dredging, and the catch per hour rate. The increasing catch trend occurred as diesel power replaced steam and sail, as dredges increased in size, and as more boats entered the fishery. The steady decline in catch rate for 1946-1957 applies mainly to Areas A-E. The number of boats increased sharply after fisheries delicensing in 1962.

1962 Estimate of the Maximum Sustainable Yield

An estimate of the yield was made in October 1962 after the exploratory and dredge calibration (Stead 1962) Phases 1 and 2 of the study had been completed. Diving and underwater photography (Phase 3) also supplied some data on oyster densities.

The total area containing commercial grounds was estimated to be about 110 square nautical miles, only about half of which, mainly in Areas A-E, had been exploited.

The declining catch per hour rate for 1946-1957 indicated overfishing on Areas A-E. Comparison of catches taken in any one season with catches two years later showed that, in most cases, whenever the annual catch was below 85,000 sacks, an increased catch was taken two years later, whereas when the annual catch was over 85,000 sacks, a diminished catch was taken two years later. It was thought that the effect of dredging was as much by the removal and damage to just undersized oysters as by removal of takeable oysters - hence the 2 year time lag before the effects of over-dredging appeared. Although results were complicated by weather on the amount of fishing they did suggest that the maximum yield which could safely be taken from Areas A-E in future was about 85,000 sacks. At the 1960 catch rate this represents about 8,500 hours dredging.

The 1960-1962 surveys showed that oysters were generally more abundant in Areas F-H than in Areas A-E, but due mainly to the unworked state of many western grounds, commercial dredges were less efficient. During 1961 however, 34,480 sacks of oysters were dredged in Area G at a higher than average catch rate of 10.87 sacks per hour. This showed that population density would support commercial dredging and that the rough grounds could be worked by standard commercial dredges. Using survey results and catch figures the maximum sustainable yield for the whole Strait was assessed at twice the estimated 85,000 sack safe yield capacity of Areas A-E, and was therefore 170,000 sacks, provided that dredging effort was rationally spread over all available Strait oyster grounds. Insufficient commercial data for Areas F-H were available to regard this as more than a provisional estimate of yield. To assess all the parameters of the resource more data were required.

In 1962 a Parliamentary Select Committee on the Fishing Industry recommended the delicensing of all fisheries, including dredge oysters. Conservation and management of the oyster fishery was to be achieved by using suitable sack quotas. The oyster fishery was delicensed in 1963 and controlled by an overall quota of 170,000 sacks. The area was divided into two zones by a line from Bluff Hill to Motunui Island - Akers Point, Stewart Island, (Map 1). The quotas for east and west zones were respectively 70,000 and 100,000 sacks.

1962-1964 Situation

Average catch per hour figures for 1960, 1961 and 1962 were respectively 10.54, 10.46 and 8.04 sacks. The number of boats remained at 12 and the annual catch declined. The decline occurred simultaneously in most Strait areas, on grounds subjected to variable levels of exploitation. Survey dredging on unexploited grounds also showed a comparable decline. The catch data, and evidence of high adult oyster mortalities due to parasites in 1962, confirmed that the sharp decline was due mainly to natural causes rather than to commercial dredging.

The number of boats increased in 1963 and the annual catch increased slightly, though the mean catch rate fell to 5.98 sacks per hour. High adult mortalities due to parasites also occurred in 1963. Poor daily catches in 1963 encouraged commercial prospecting in more remote areas and some new grounds yielded good catches.

Pre-season surveys in 1964 showed an increased catch rate, higher oyster densities on the sea bed, and improved flesh condition, indicating a recovery from the effects of the parasites and a possible future upward trend in catch rate.

It is significant that the mean catch per hour rate subsequently increased even though the number of boats increased. Possibly the reduced dredging on the traditional beds allowed good spatfalls and undisturbed growth of spat with consequent reductions in spat and small oyster mortality.

Closure of Area A

Figure 24 shows catch statistics for Areas A and B for 1950-1968. Large annual catches were taken from Area A for many years. These grounds are close to Bluff, are less exposed to westerly weather and were a source of good quality oysters. It was reported, on occasions the whole fleet of 12 boats worked Bed A before 1960. During this period of intensive exploitation a large part of the annual catch came from Area A. Consequently the catch rate fell and the size of the commercially exploitable area became reduced. Diving in Area A in 1962-1964 showed large pebble areas only thinly populated with oysters, though some good patches were seen. Commercial dredge catches were usually small but consisted mainly of live oysters with little empty shell and other fauna.

It was apparent that the limited area of oyster grounds in Area A (about 5 sq. n. miles) had been depleted by overfishing. To protect the remaining oyster grounds and to allow regeneration, closure of Area A was recommended until there was evidence of recovery. The area was closed to dredging before the 1964 season opened.

1964-1968 Situation

Figures 25 and 26 show Area catch statistics 1960-1968. The upward trend in catches continued in 1964, 1965 and 1966. The increase in catch rate was comparable and simultaneous for all Areas, despite an increase in the number of boats, and variable fishing intensity on different oyster grounds. The overall upward trend was, however, due partly to the exploitation of many new grounds and particularly Area G. It may be significant that the catch per hour rate usually remains fairly constant throughout the season and rarely shows a decline towards the end of the season, which would indicate depletion by dredging. However, the practice of moving to a new bed as soon as one becomes depleted would tend to negate this effect. The effect of depletion through the season may also be masked by recruitment of new oysters attaining takeable size or by oystermen taking progressively smaller oysters as the season progresses. No reduction in the 70,000 sack East Zone quota, to allow for closure of Area A, was advocated in 1964, for the following reasons:

(1) Discovery of new grounds in Areas C and E2 in 1960-1964.
(2) Voluntary reduction of dredging on eastern grounds; catches were often better on western beds.
(3) Daily limit catches imposed by the industry due to reduced consumer demand.

In 1965-66 however 68,619 and 50,329 sacks were taken from the East Zone with Area A closed to dredging.

The maximum safe annual yield for Area A had been assessed at 14,000 sacks, i.e., 15% of an estimated standing crop of 76 million takeable oysters. In 1967 the 14,000 sack Area A quota was deducted from the 70,000 sack East Zone quota to give a revised East Zone quota of 56,000 sacks, the West Zone quota remaining at 100,000 sacks.

During the 1964-1968 seasons dredging occurred in most Strait Areas with results as shown in Figures 25 and 26. Many good catches were taken in the West Zone. In 1966 and 1967 annual Strait yields for Areas B-H were respectively 160,382 and 164,340 sacks. These were close to the maximum sustainable yield of 170,000 sacks for Areas A-H as assessed in 1962 even though Area A was closed. The mean catch per hour rate in 1966 for Areas B-H was 10.50 sacks, while that for the exploited areas in 1960-1961, the main survey period, was 10.06 sacks. It is unlikely that all available surveyed commercial oyster grounds in Foveaux Strait had been dredged or worked to capacity by 1966-1967. In 1967 the annual catch increased but the catch per hour rate fell to 9.32 sacks. The downward trend continued to a mean of 7.73 sacks per hour in 1968. The decline was comparable and simultaneous in all Areas and on grounds subjected to variable fishing effort. These fluctuations may therefore be due mainly to environmental factors rather than to dredging. The sharp decline in 1962-1963 was caused by oyster parasites.

Dredging affects the catch per hour rate over long periods resulting in a steady downward trend as in 1946-57. This may be due in part to the dispersal of oysters over the sea bed by dredging, resulting in a wider but more thinly spread population and subsequent smaller dredge catches for the same effort.

Dredging also causes localised overfishing as in parts of Areas A, B and D.

The overall quota was reduced to 121,500 sacks in 1969 as a conservation measure and as an adjustment due to the change in takeable size from $2\frac{1}{8}$" to $2\frac{1}{4}$" ring size. However, in 1969 industrial disputes led to closure of the beds for much of the season. Dredging for 10,114 hours in 1969 resulted in a catch of 66,260 sacks at a mean 6.5 sacks per hour. Oyster condition improved during the 1969 season. The 1970 quota was reduced by general consent to 115,000 sacks to conserve stocks, and 113,000 sacks were taken by 1,550 hours dredging. The mean catch rate of 7.3 sacks per hour indicates a possible upward trend in future. Flesh condition for 1970 was generally good.

Management Methods

Number of Boats

After delicensing of fisheries in 1962 the number of boats dredging the oyster grounds progressively increased. In 1968 there were 22 boats operating and fears were expressed by many in the industry that any further increase would deplete oyster stocks. Industrial and Government action in 1969 restricted the number of boats to 23 pending an inquiry by a 1970 Parliamentary Select Committee. This Select Committee of the New Zealand Parliament is currently hearing submissions on this and other aspects of the oyster industry. Their findings may well effect policy with regard to management methods. Restricting the number of boats before 1962 had not prevented the depletion of Area A while many other productive beds were unexploited.

Quotas

Another method of regulating the fishery is by the provision of catch quotas.

The zone quota system adopted in 1962 after delicensing restricted annual catches from the East and West Zones to 70,000 and 100,000 sacks respectively. This was based on the 1962 estimate of the maximum sustainable yield. The East Zone quota was later reduced to 56,000 sacks to allow for closure of Area A in 1964.

In the period 1963-1968 most of the surveyed oyster grounds, and some new grounds, were exploited, to a varying degree, by the expanded fleet. Catch data have indicated the yield capacity of the oyster grounds during a period of sharp fluctuations, thus it is now possible to assess more accurately the maximum sustainable yield for the whole Strait and for each Area by comparison of actual landing data with estimates of yields from survey results. Map 7 shows the different commercial grades of sampled stations based on dredge catches and bottom counts in 1960-1964. Map 8 shows the number of square nautical mile areas containing Grade 1 and Grade 2 (marginal) commercial oyster grounds.

The mean density of takeable size oysters on Grades 1 and 2 ground was 6 and 4 per square yard respectively.

Oyster grounds were not continuous and therefore only 50% of the square mile areas was taken to be of commercial standard. Each square nautical mile is 4 million square yards. The following table shows the number of square miles and the standing crop of oysters on 50% of the area, at 6 per square yard for Grade 1 and 4 per square yard for Grade 2 (Column 3). The annual yield capacity was assessed at 10% of the standing crop (Column 4). Growth, recruitment and natural mortality studies had suggested a mean net replacement level of about 10% of takeable stock a year. Mean standard dredge efficiency has been assessed at about 10% (Stead 1966). The annual yield in sacks at 800 oysters (about 65 dozen) a sack is shown in Column 5. Columns 6, 7 and 8 show mean Area catch statistics 1963-68 for comparison.

For Grades 1 and 2 oyster grounds, the estimated annual yield for East and West Zones were respectively 62,000 and 105,500 sacks, giving a Strait total of 167,500 sacks compared with the 1962 estimate of 170,000 sacks.

With 9,500 sacks deducted for Area A the East Zone total is 52,500 sacks. There is some correlation between calculated Area yields and mean Area catch 1963-1968 for Areas C and D1. The discrepancy for Area E2 figures is largely due to the discovery and exploitation of new grounds in the Area after 1964. The estimates suggest that the optimum yield capacity for Area E1 had been exceeded for many years but that of Area G may not have been achieved (the maximum was 50,772 sacks in 1966).

TABLE 15 CALCULATION OF OPTIMUM YIELDS - FOVEAUX STRAIT OYSTERS

ZONE	AREA	1 Number of sq. n. miles Grade I Oyster Ground	2 Number of sq. n. miles Grade 2 Oyster Ground	3 Calculated Standing Crop (millions takeable oysters)	4 10% of Calculated Standing Crop	5 Calculated Annual Yield in sacks (800 Oysters per sack)	6 Mean Annual Catch in Sacks 1963-68	7 Mean Annual Hours Dredging 1963-68	8 Mean catch in sacks per hour 1963-68
EASTERN ZONE	A	5	2	76	7.6	9500	Closed	Closed	Closed
	B	10	1	128	12.8	16000	13573	1881	7.49
	C	4	1	56	5.6	7000	7346	933	8.01
	D_2	8	4	128	12.8	16000	10904	1372	7.74
	E_2	7	-	84	8.4	10500	18300	2196	8.09
	I	1	-	12	1.2	1500	81(1967)	7	11.57
	J	1	-	12	1.2	1500	164(1964)	17	9.65
WESTERN ZONE	D_1	2	-	24	2.4	3000	4404	584	7.48
	E_1	10	7	176	17.6	22000	35032	4351	7.89
	F	5	6	108	10.8	13500	4145	467	8.03
	G	36	4	464	46.4	58000	32340	3680	8.37
	H	4	3	72	7.2	9000	991	111	5.94
East Zone Totals		36	8	496	49.6	62000	50368	6406	8.75
West Zone Totals		57	20	844	84.4	105500	76912	9193	7.54
Strait Totals		93	28	1340	134.0	167500	127280	15599	8.20

TABLE 16 CALCULATION OF OPTIMUM YIELDS - FOVEAUX STRAIT OYSTERS

ZONE	AREA	1 Number of square n. miles of Grade 1 Oyster Ground	2 Standing Crop in millions of Take-able Size Oysters	3 Annual Yield as 10% of standing crop	4 Annual Yield in Sacks at 800 Take-able Size Oysters per sack	5 Annual Yield in sacks. 10% reduction for Oysters Size 2⅛" - 2¼"	6 Number of Hours Dredging at 8 sacks per hour	7 Suggested quota Adjustments in sacks	8 Suggested Equivalent Annual Hours Quota
EASTERN ZONE	A	5	60	6.0	7500	6750	843	6750	843
	B	10	120	12.0	15000	13500	1687	9500	1187
	C	4	48	4.8	6000	5400	675	5400	675
	D_2	8	96	9.6	12000	10800	1350	10000	1250
	E_2	7	84	8.4	10500	9450	1181	12450	1556
	I	1	12	1.2	1500	1350	168	2250	281
	J	1	12	1.2	1500	1350	168	2250	281
WESTERN ZONE	D_1	2	24	2.4	3000	2700	337	2700	337
	E_1	10	120	12.0	15000	13500	1687	20500	2562
	F	5	60	6.0	7500	6750	843	9750	1217
	G	36	432	43.2	54000	48600	6075	38600	4825
	H	4	48	4.8	6000	5400	675	5400	675
East Zone Totals		36	432	43.2	54000	48600	6072	48600	6073
West Zone Totals		57	684	68.4	85000	76950	9617	76950	9617
Strait Totals		93	1116	111.6	139500	125550	15689	125550	15689

To increase the safety factor a second calculation was based on Grade 1 areas only. At 6 oysters per square yard for 50% of Grade 1 areas, the second table shows the standing crop, the annual yield as 10% of the standing crop, and the annual yield in sacks for each Area at 800 oysters per sack. For this calculation the East and West Zone totals are respectively 54,000 and 85,000 sacks, the Strait total being 139,500 sacks. Deducting 7,500 sacks for the closed Area A the East Zone total is 46,500 and the B-H Strait total is 131,500 sacks. This compares with the mean 1963-68 annual catch of 127,280 sacks with Area A closed, at a minimum takeable oyster size limit of 2⅛". In 1969 the size limit was raised to 2¼" and to allow for this a 10% reduction in yield quotas was applied. This was estimated from growth and recruitment studies. Column 5 of the second table shows the estimated annual yield quotas for a 2¼" size limit. The East and West Zone totals are respectively 48,600 and 76,950 sacks, the Strait total, including 6,750 sacks for Area A, being 125,550 sacks. This is the maximum sustainable yield for the Foveaux Strait oyster resource based on the above calculations. The equivalent number of hours at 8 sacks per hour are shown in Column 6 to give the optimum dredging effort.

Columns 7 and 8 show suggested adjustments to Area yield quotas based on consideration of the following:-

Yield capacity based on available catch figures, intensity of previous exploitation, evidence of depletion, accessibility of oyster grounds, exposure to weather and rough seas, discovery of new beds, presence of aggregated epifauna and shell parasites, variable dredge efficiency, and biological factors such as the relative amount of settlement, growth, recruitment, and natural mortalities.

This shows that the overall sack and hours dredging quota should be at 125,500 sacks or 15,689 hours. Later adjustments may be necessary on the basis of results of further surveys and biological studies and on catch trends.

Sharp fluctuations in catches and presumably oyster abundance occur in Foveaux Strait. They are thought to be mainly due to variation in natural mortalities (as in 1962 and 1963 when oyster parasites were prevalent and catches were small), and recruitment. These cycles may not be related to dredging intensity. In view of this Dr D. Eggleston (pers. comm.) has suggested that any quota should vary each season with the abundance of oysters and that a more satisfactory method of regulating the fishery may be to specify the number of dredging hours rather than a sack quota. If the hours quota were fixed at 15,000 in a good year with a mean catch per hour rate of 10 the expected catch would be about 150,000 sacks. If the catch rate was 6 sacks per hour, due to lower oyster abundance on the beds the season's catch would be about 90,000 sacks. Thus the take would follow natural cycles and not be excessive in any one season.

If a varying sack quota is to be used the standing crop would have to be estimated before each season. If the stocks are not to be depleted then the total mortality (i.e., fishing mortality plus natural mortality) should not exceed recruitment.

It has been suggested that annual recruitment is normally of the order of 10% of the standing crop. The take should not, therefore, exceed 10% of the standing crop. Experience in 1962 and 1963 showed that in some years natural mortality can be high (see page 46). Similarly, if a quota of hours is to be used this should be calculated so as to allow the dredges sufficient time to take only up to 10% of the standing crop.

If the fishery is controlled by Area sack or hour quotas it would be advisable to keep the industry informed of the current area quotas throughout the season, so as to encourage rational exploitation.

Individual boat quotas may be useful in certain cases, e.g., when Area A is reopened, to ensure a fair distribution of catch per boat and to prevent intensive competition for small patches of oysters which could lead to rapid depletion.

Area Closure

Closure of Areas is a method of protecting oyster grounds. Area A was closed to dredging before the season opened in 1964 to protect the beds and to allow assessment of the recovery rate of depleted areas. Area A has remained closed as diving surveys and some sampling dredging have shown little evidence of re-generation over most of the Area. Some isolated patches have increased their populations and a day's commercial dredging in Square R.32 on 19 April 1968 resulted in a catch of 81.5 sacks in 8 hours 40 minutes, i.e., 9.4 sacks per hour. Many aggregations of young oysters were present. The mean catch rate for Areas B-H in 1968 was 7.6 sacks per hour.

Other parts of Bed A which, during the 1950's contained productive beds, remained virtually unpopulated after four years closure. This suggests that "seeding" with oysters and shell may be necessary to effect re-generation on these predominantly pebble areas.

Oyster populations in Area A may, however, support limited commercial exploitation during the next upward trend (forecast for 1970-1972) to allow its re-opening, but quotas should be small (Table 16).

Areas may be closed in rotation to assist re-generation; closure for only one season means that grounds are protected for 18 months. Area B may be the next to require protection by closure.

Return of Shell

Foveaux Strait oysters are shucked ashore, and the bulk of the empty shell is normally deposited on large shell heaps, to be crushed for poultry grit and lime. Empty shell has never been returned in quantity to the oyster beds. During 1960-1964 young live oysters, mainly attached as "wings" to shells, were seen on shell heaps, in sacks of freshly opened shell at factories, in truck loads of shell, and on oyster boats at the wharf. In 1963, counts showed an average of 174 live oysters, from 1 mm. to 7 cm. in length, per sack of empty shell. For 120,000 sacks of shell this represents about 20 million live oysters; this is equal to 25,000 sacks if all small oysters had lived to reach takeable size; the natural mortality rate of small oysters is not known. A conservative estimate would be a wastage of at least 10 million live oysters a year for many years and the situation will worsen if annual catches increase.

One point which must be established is whether or not the small oysters on the shucked shell would survive to be returned to the beds.

A sack containing 263 discarded live oysters, mixed with empty shells and bench sweepings, was taken from an opening shed on 9 April 1964. The oysters had been dredged the previous day. A random sample (108) of the oysters was measured; 72% (78) were of takeable size. The sack containing the oysters and other material was soaked in fresh water and left outdoors covered by dry sacks. The oysters were then examined daily. All survived for 4 days but 3 died 5 days after leaving the sea. Other oysters died on the 6th and 7th days. 52% had died by the 8th day. Nearly all were dead after 10 days out of water.

Conditions on dredging permits since 1964 have specified that no undersized oysters may be landed and that all such oysters be returned to the sea as soon as possible. One problem is that manual separation of oysters at sea often results in damage to small oysters.

The available evidence suggests that all freshly opened shell should be returned to productive oyster areas as soon as possible after opening, especially those shells from eastern areas where numbers of small oysters on larger oysters is high. This would be to ensure that young live oysters survive.

Dr D. Eggleston (pers. comm.) points out that -

"This is particularly important in this species of oyster as the great majority of spat appear to settle on living oysters. There is some settlement on other shells and supports but the significance of this settlement to the recruitment to the fishery is probably small. Thus if 10-15% of the standing crop is being removed each year then a similar proportion of the young oysters is removed from the beds each year. This proportion is less than the percentage of the standing crop removed as some, but by no means all, of the small oysters are removed from the oyster to which they are attached, and returned to the sea. If 10% of the small oysters are removed each year then the potential recruitment is cut by that percentage each year the undersize oysters are subject to dredging before they reach takeable size. If it takes an oyster three years (Stead 1971) to reach takeable size then at least 25% of the potential recruitment will be lost to dredging alone."

Previous observations suggest, however, that long dead "white shells" may not be ideal as supports for settling spat in strong tidal conditions, but this would have to be checked by returning shell to sea in known areas. Spat settlement could then be monitored. Small spat were seen on old shells in 1970. Studies suggest that whole and broken shell provides a favourable, firm, but permeable substrate for oysters in Foveaux Strait. The dredging of oysters from parts of Area A has removed most of the shell, leaving only pebbles, and no recovery has occurred on these areas.

Old thickened shells infected by shell parasites such as Cliona from western areas could be deposited ashore for processing, while firm shell with intact conchiolin from eastern areas could be returned to sea.

Re-distribution of Oysters

In order to assist re-generation of some areas it may be feasible to dredge oysters and culch from congested western areas, e.g., near Saddle Point, and to deposit the material on depleted, but once productive ground, in Area A for example. These oysters, together with empty shell from opening sheds and shell heaps should hasten recovery of depleted areas by forming the nuclei of oyster beds. Breeding stock and settlement surfaces (large, live oysters) would be provided, and introduced oysters from congested areas should improve in quality. The transplanting may be most effective if carried out on a large scale during the breeding period, which is also the closed season. It may be advisable to avoid the introduction of starfish, and shell parasites such as Cliona, if possible. Small scale experiments may be necessary to assess the efficiency of this method.

Takeable Size Limit

The size of oysters is checked by the use of metal rings of known interior diameter. The minimum takeable size limit was raised from $1\frac{3}{4}$" to $2\frac{1}{8}$" in February 1941 and was raised to $2\frac{1}{4}$" in February 1969.

Survey studied in 1960-1964 showed that the $2\frac{1}{8}$" size limit allowed the commercial taking of many immature oysters which had never produced larvae (Stead 1971). This may not be significant in many areas due to the high fecundity of oysters, but in some areas where adult oysters are of small size due to fishing intensity or natural causes the reserves of spawning stock may be too small to maintain recruitment. Thus an increase in the size limit would be beneficial even if it allowed oysters to spawn only once before being caught.

Studies of the shell width/mean flesh weight relationship (Figure 16) also show that an increase in shell width from $2\frac{1}{8}$" to $2\frac{1}{4}$" represents a mean increase of about one gram in flesh weight. For 65 dozen (870 oysters, about one sack), there would be an increase of about 1 lb 11 oz in flesh weight. Recent (1970) enquiries have revealed, however, that the increase in size limit has made only a small difference to the average numbers of oysters per sack. In sack counts the size variation from different Strait areas is more significant.

Closed Season

Another method of conservation is by imposing a suitable closed season when no dredging is permitted. For many years the season opened on 15 February and closed on 30 September each year. Oysters are usually incubating larvae in September and are often in a spent condition after release of eggs into the mantle cavity. In September consumer demand often declines as weather becomes warmer and with the advent of the whitebait season. Most larval settlement occurs in December-February. These factors suggest that a shorter season would be beneficial. Delaying the start of the season would allow spat more time to attach and grow. If the fishery is controlled by quotas the catch or hours dredging quota may be achieved before the end of the season, resulting in early closure.

A six month season opening on 1 March and closing on 31 August each year, or before if quotas were achieved, seemed to offer most benefits, and this was provided for under the 1969 Fisheries Regulations.

Dredges

No increase in commercial dredge size or in the number of dredges carried is advocated. The use of specially designed smaller dredges which may be more effective in congested areas, could be allowed.

Predator and Parasite Control

Starfish such as Coscinasterias, Astrostole and Pectinura and other predators if it can be proved that they eat oysters should be removed during culching and destroyed or taken ashore - possibly for use as fertiliser. This would be most effective if carried out by crews on all boats in the fleet.

Commercial dredging breaks up "mullock" and often improves areas for subsequent dredging.

Parasites such as the trematode Bucephalus and the boring sponge Cliona are most effectively controlled at present by commercial dredging which removed infected adult oysters and scatters oysters on the sea bed, thus reducing the chances of cross infection. Trawling the primary host of Bucephalus, the monk fish, or stargazer, (Kathestoma giganteum) may also help control the parasite.

Dredge Oyster Cultivation at Stewart Island

Suitable Areas

Areas investigated during the 1960-64 surveys included Paterson Inlet, Port Adventure, Lords River and Port Pegasus, all on the east coast of Stewart Island. These inlets are sheltered in most weather conditions, contain extensive shore areas in shallow water, and are free from pollution. Most beaches between rocky promontories consisted of firm coarse sand often mixed with broken shell. Substrates in the intertidal zone were usually covered by a thin layer of silt and sometimes rock debris. Soft mud occurred in deeper water. Oysters (O. lutaria) and other shellfish occurring naturally in these inlets were nearly always fat and in good condition. Most oysters were attached to rocks and mussels in the intertidal and upper sub-littoral zones but few were found on the sea bed. This may be due to silting of settlement surfaces and the abundance of the predators Stichaster australis, the reef star, below tide marks.

Growth rate, fattening, and settlement of O. lutaria in submerged cages was observed in 1960-64. (Stead 1971). Oysters were also placed on beds of oyster shell laid on mud bottoms in Peterson Inlet and progress was monitored by diving. Most of these oyster samples came from sites in the open Strait and all showed rapid growth and fattening in Stewart Island inlets.

Oysters on mud bottoms became silted up and died, or were attacked by starfish.

Most caged oysters survived, and breeding occurred in some cages with resulting heavy local spatfalls. Sometimes two spatfalls were recorded in one year. Growth of spat was rapid. (Stead 1971).

These observations suggested that sublittoral cultivation of oysters on firm bottoms in these areas was commercially feasible.

G.D. Waugh (1969) outlines methods which may be used for farming dredge oysters but the following is confined to techniques which, in the author's opinion, may be used to advantage at Stewart Island.

Oyster Farming Methods

O. lutaria can feed continuously when submerged, therefore, it is important that oysters are not exposed at low water.

Fairly level or gradually shelving areas below low water mark should be selected within the leased area. A layer, several inches deep, of empty shell should be laid over silted areas. The initial stocks of oysters may be laid on these shell beds or on firm sand/rock debris bottoms. The shell bed serves as a firm base and should also be suitable for spat settlement in calm water. Live oysters would also be available as settlement sites and other spat collectors could be placed among oysters.

Advantages of this method are that oysters can be observed and handled at low water, predators can be easily removed, and costs are reduced by not using cages or trays. Mean sea temperature is higher in these shallow inlets than in deep water in Foveaux Strait (Stead 1971).

Wild oysters were in best condition near streams or areas of fresh water seepage, suggesting that such sites would be suitable for oyster cultivation.

Shell and oysters could also be placed in deeper water and the cultivated oysters harvested by dredges (Waugh 1969), but this method may not be suitable in most Stewart Island areas due to the high incidence of starfish and soft mud bottoms often covered with weed.

Another advantage of Stewart Island as a farming area is the large available reserve of oysters and shell in Foveaux Strait to provide initial stock. Besides long term farming the shallow water sites could also be used for rapid fattening for the market of poor quality Strait oysters.

Sub-littoral cultivation should not spoil scenically beautiful areas due to the absence of surface equipment.

CONCLUSIONS

The optimum yield for the Foveaux Strait dredge oyster fishery is assessed at 125,550 sacks per year with a minimum takeable size limit of 2¼". This is equivalent to 15,689 hours dredging per year at a mean catch rate of 8 sacks per hour.

In view of the fluctuations in oyster abundance which are thought to be largely due to environmental factors, a more effective regulation of the fishery may be achieved by limiting the number of hours dredging than by sack quotas.

Evidence available suggests that most Strait oyster grounds have been commercially dredged since de-licensing of the fishery in 1962, although there may be some small isolated beds outside the main areas still unexploited.

It seems probable that the maximum yield capacity for the dredge fishery has been achieved. Depletion, due to localised overfishing, has occurred in some areas, mainly in the eastern zone, and parts of Area A have still not recovered from overfishing before 1961.

A fairly stringent management system will be required in future to prevent overfishing and to assist in the regeneration of depleted areas.

Evidence available suggests that commercial farming of the dredge oyster would be feasible, especially in the shallow sub-littoral zone of some Stewart Island inlets.

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Plate 1. Typical oyster dredging boat. Note dredges and culching benches.

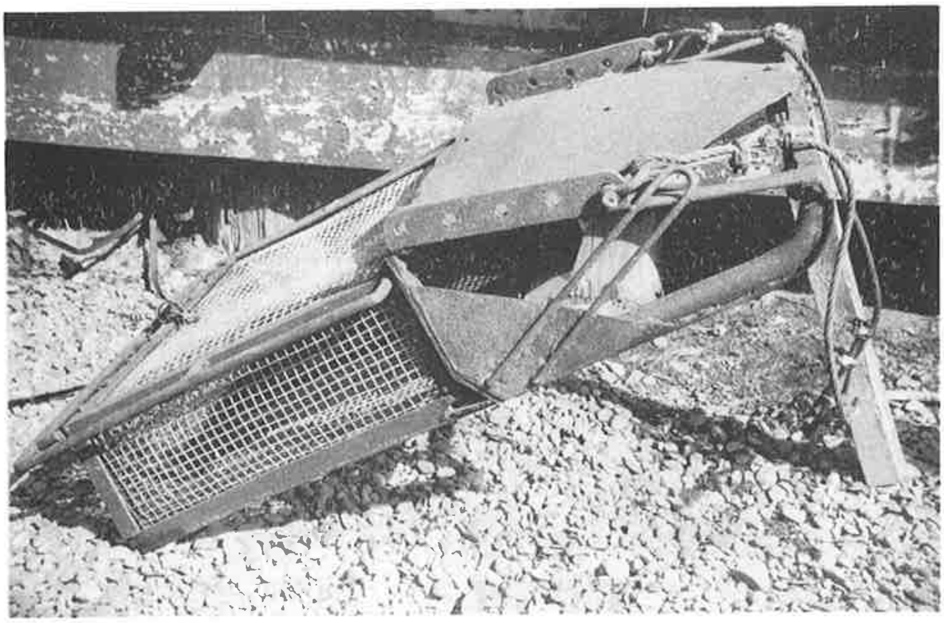


Plate 2. Dredge used during survey

Plate 3. Underwater Photograph Area D2

Plate 4. Underwater photograph Area E1. Note sponges and Pectinura.

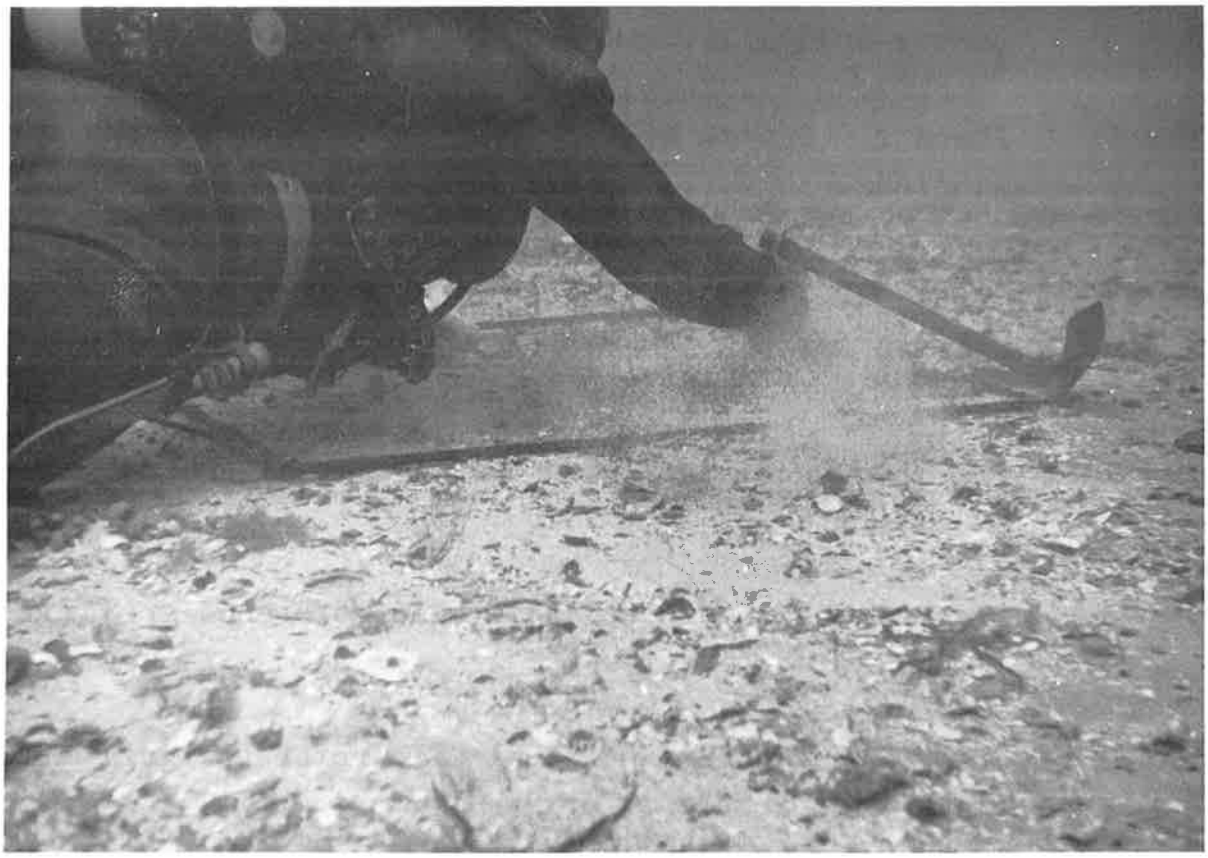
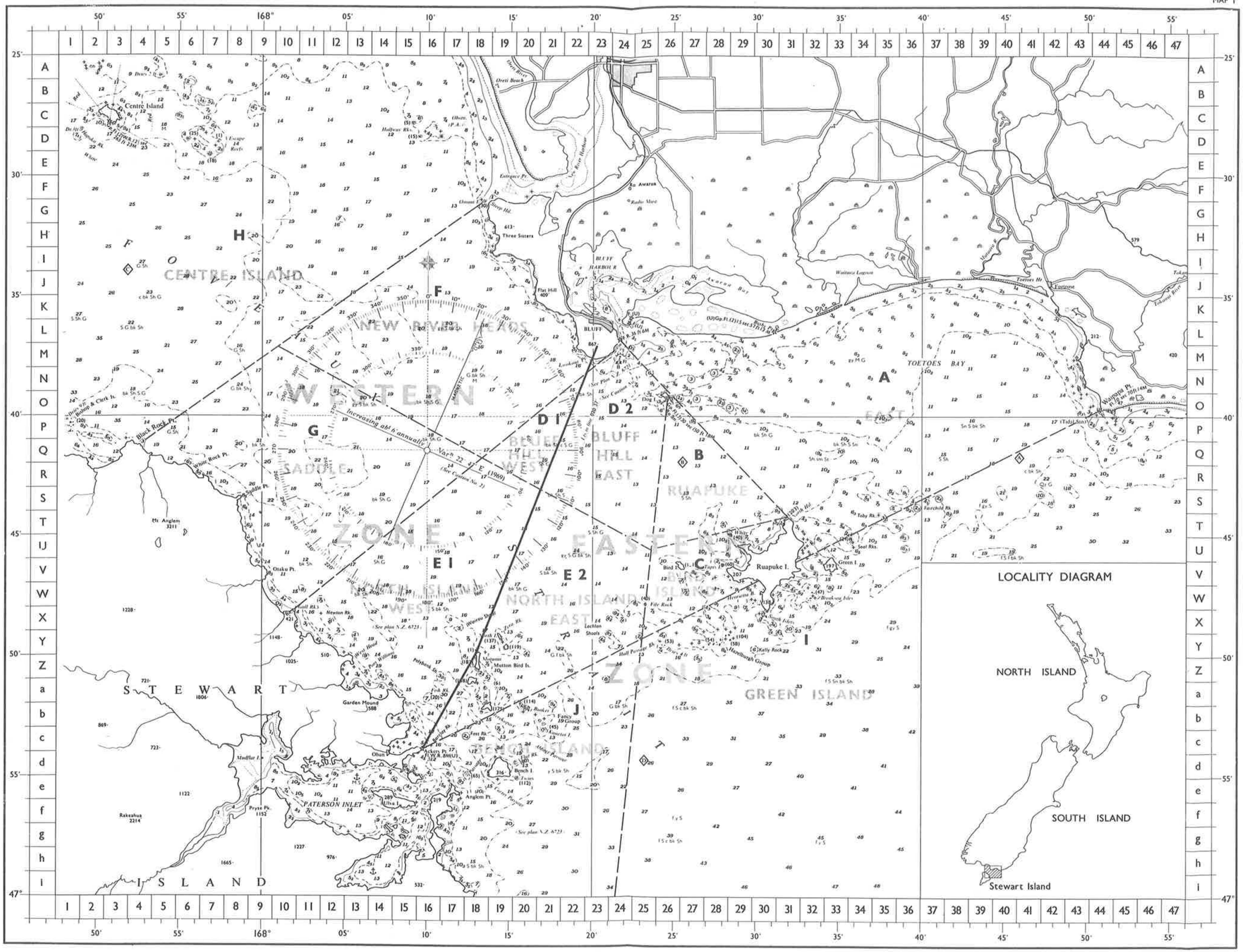


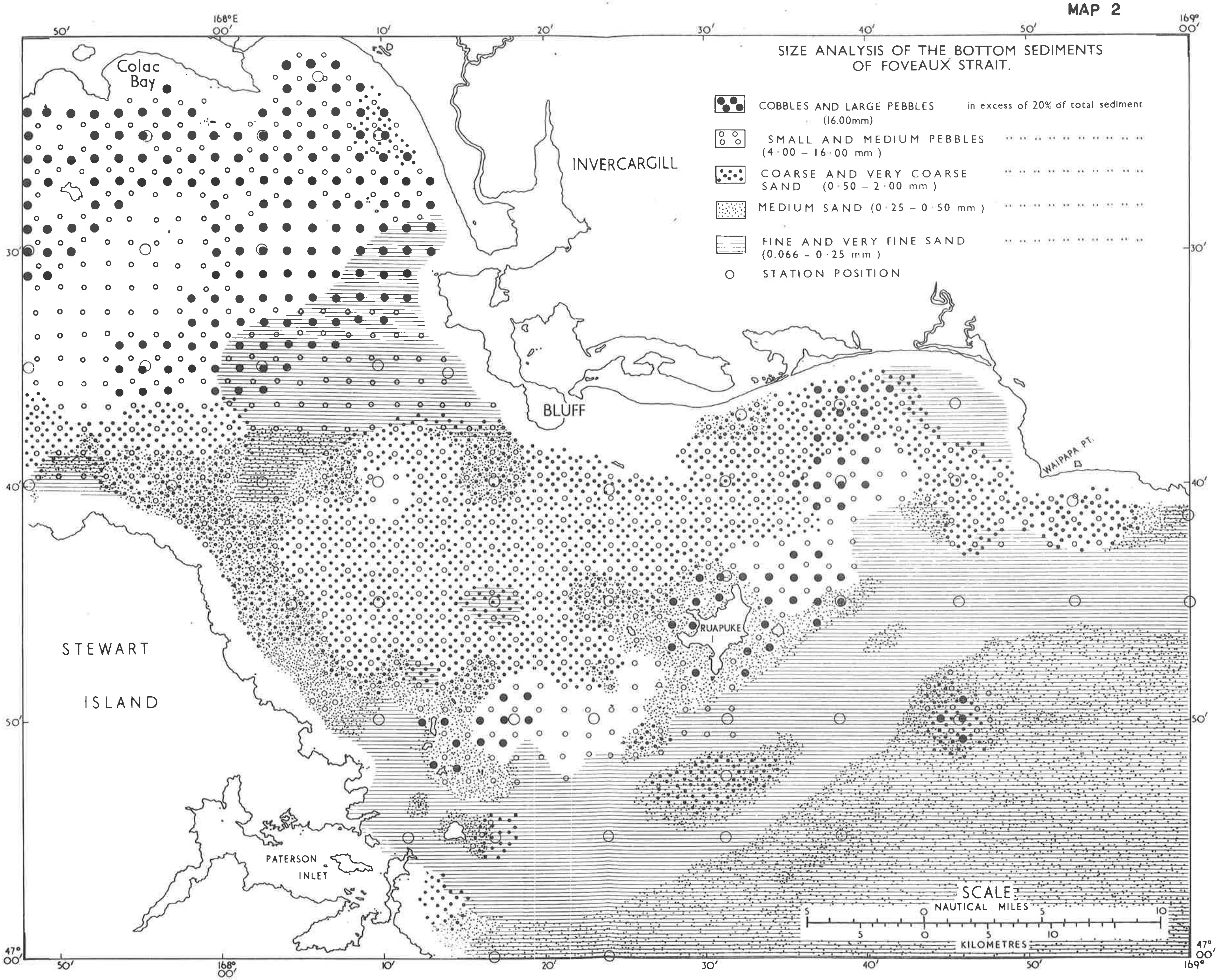
Plate 5. Underwater photograph Area G. Diver counting oysters in metre square.

MAPS

FOVEAUX STRAIT OYSTER SURVEY 1960 - 64 LOCALITY MAP SHOWING STATISTICAL ZONES AND AREAS

MAP 1

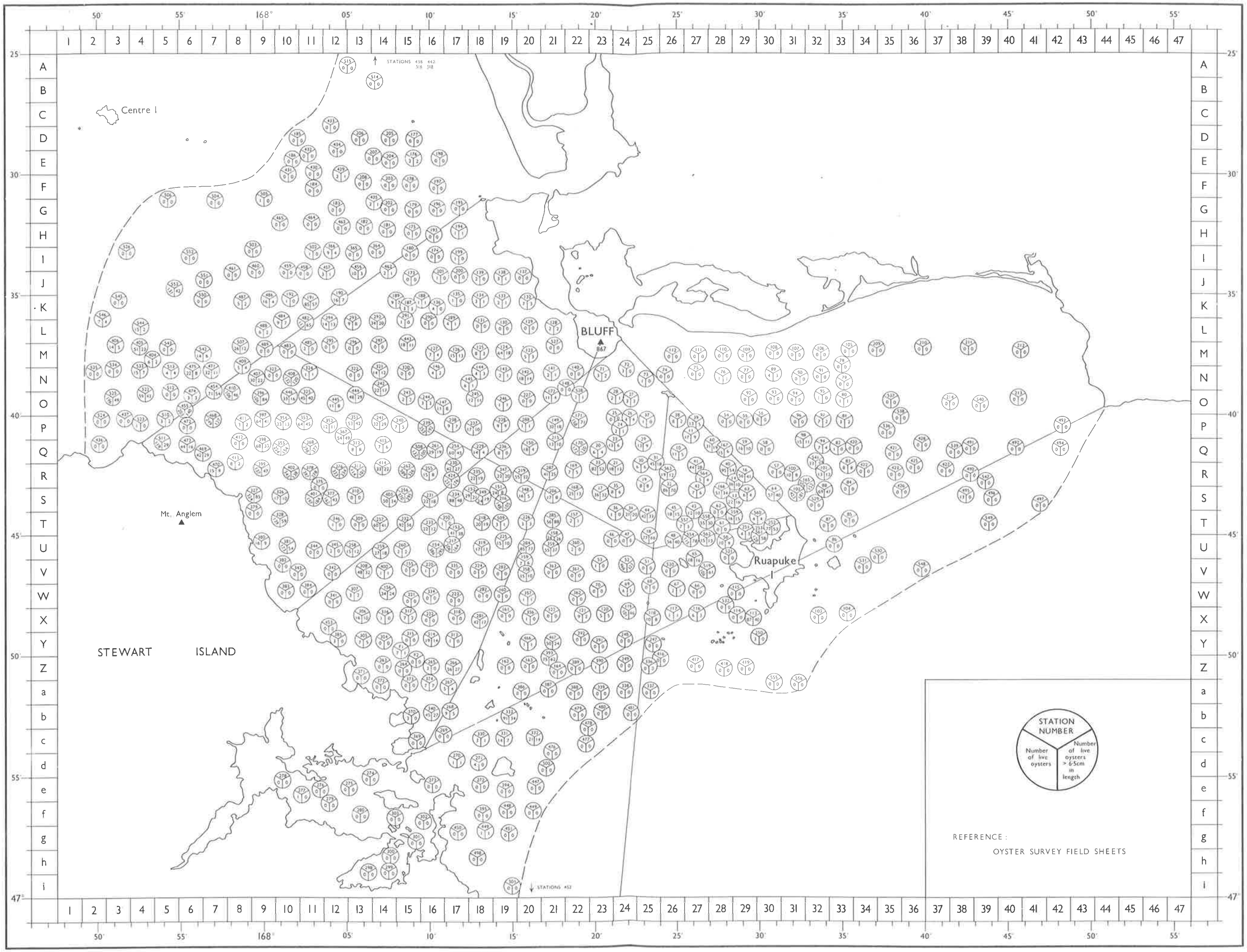




Areal distributions of particle-size groups in the bottom sediments of Foveaux Strait. .CULLEN. 1967

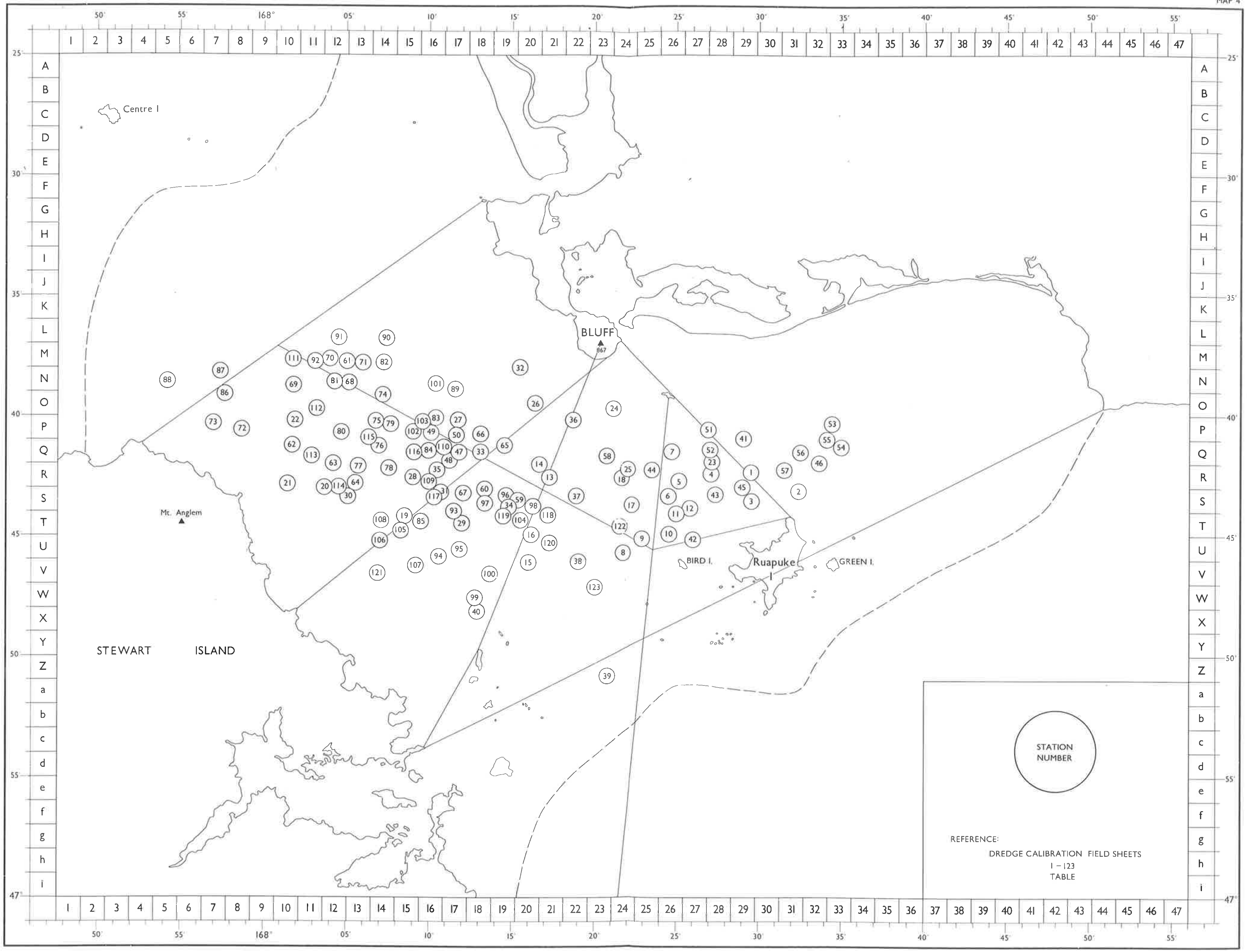
FOVEAUX STRAIT OYSTER SURVEY 1960 - 64 PHASE I EXPLORATORY SURVEY (1960-62) MAP SHOWING SURVEY DREDGE STATIONS

MAP 3



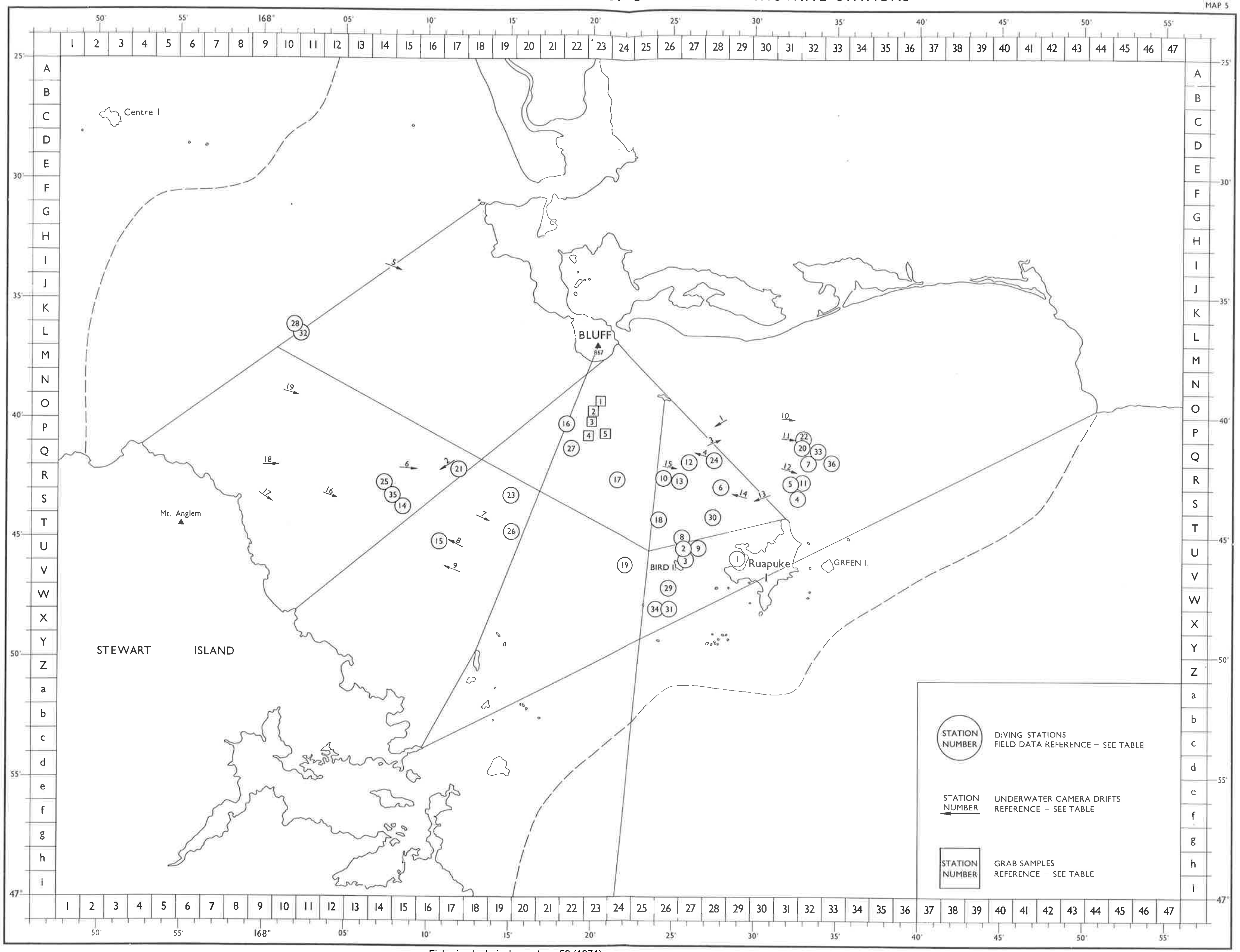
FOVEAUX STRAIT OYSTER SURVEY 1960 - 64 PHASE 2 DREDGE CALIBRATION (1961-62) MAP SHOWING STATIONS

MAP 4



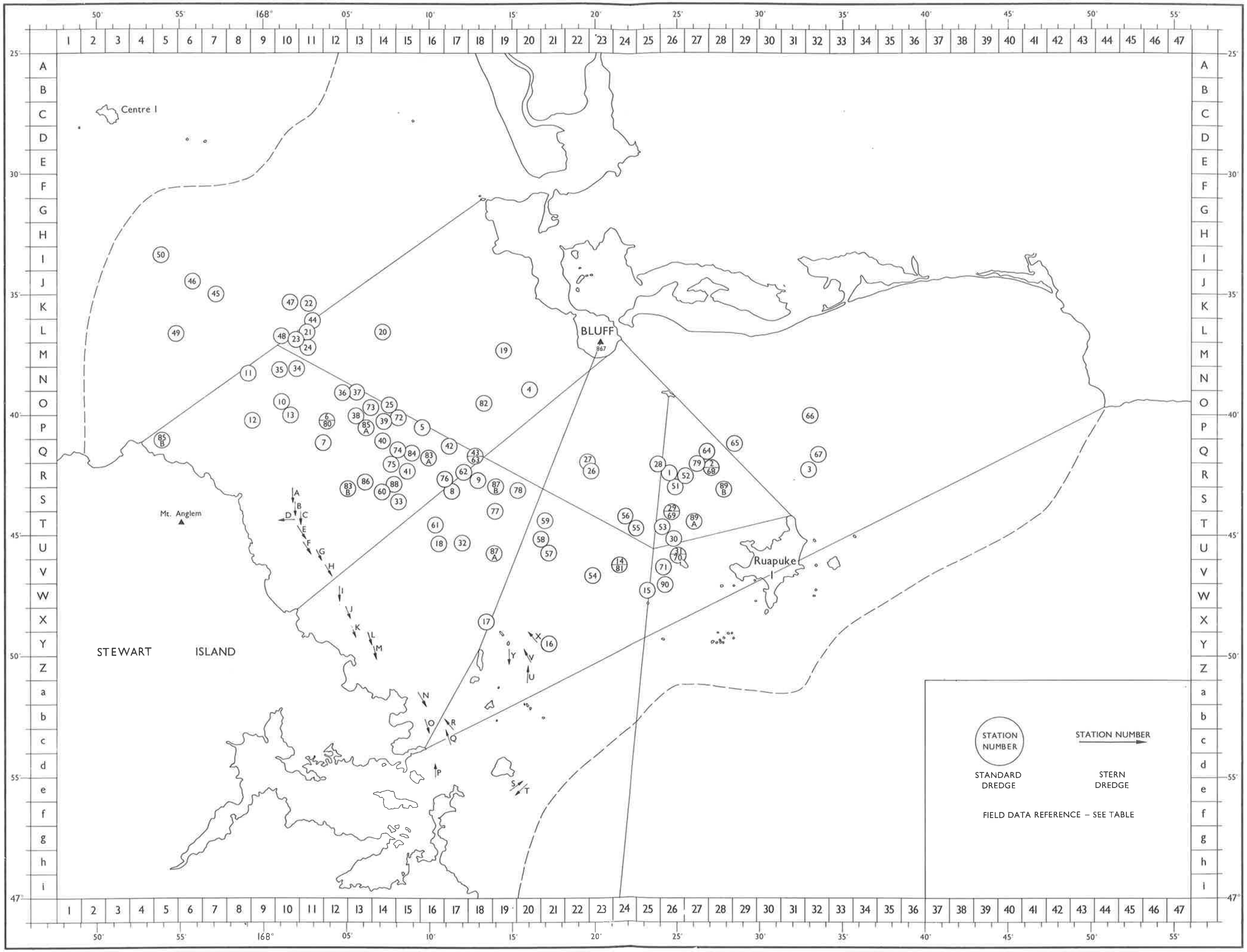
FOVEAUX STRAIT OYSTER SURVEY 1960 - 64 PHASE 3 DENSITY OF OYSTERS - MAP SHOWING STATIONS

MAP 5

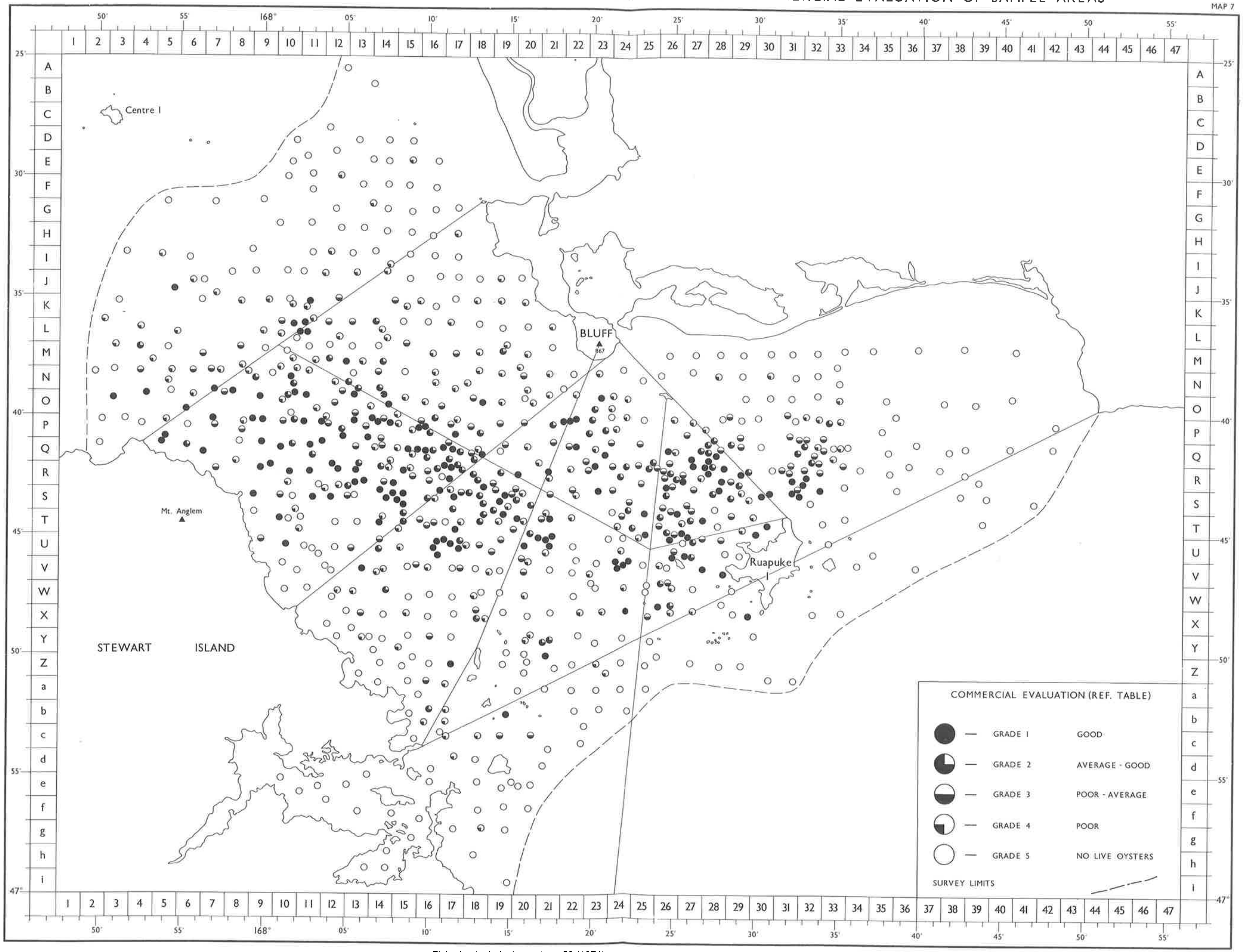


FOVEAUX STRAIT OYSTER SURVEY 1960 - 64 PHASE 4 COMMERCIAL DREDGING MAP SHOWING STATIONS

MAP 6

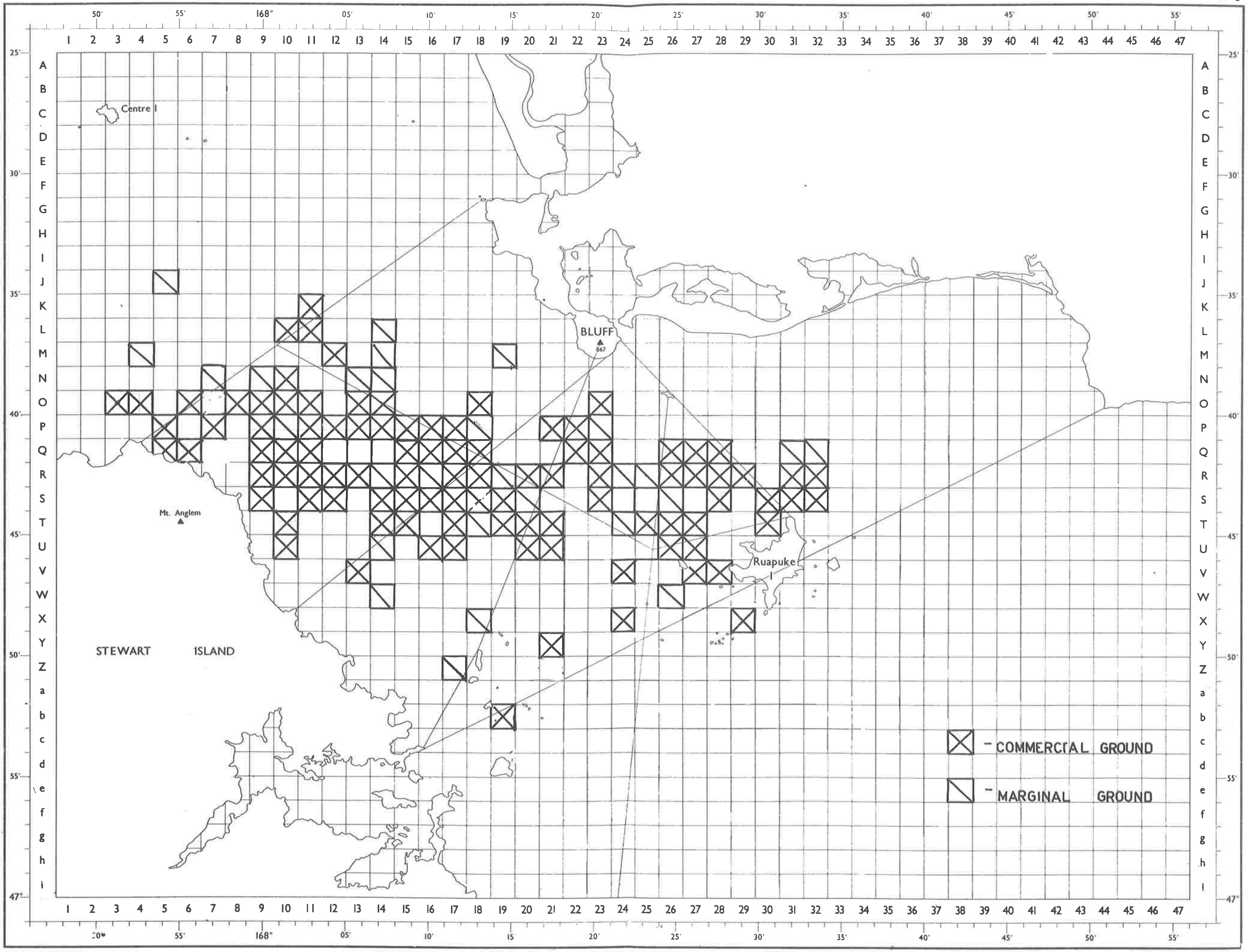


FOVEAUX STRAIT OYSTER SURVEY 1960 - 64 MAP SHOWING DISTRIBUTION AND COMMERCIAL EVALUATION OF SAMPLE AREAS



FOVEAUX STRAIT OYSTER SURVEY 1960 - 64 MAP SHOWING SQUARE NAUTICAL MILE REFERENCE GRID AND COMMERCIAL AREAS

MAP 8



FOVEAUX STRAIT OYSTER SURVEY 1960 - 64 MAP SHOWING SQUARE NAUTICAL MILE REFERENCE GRID AND FAUNA DISTRIBUTION

MAP 9

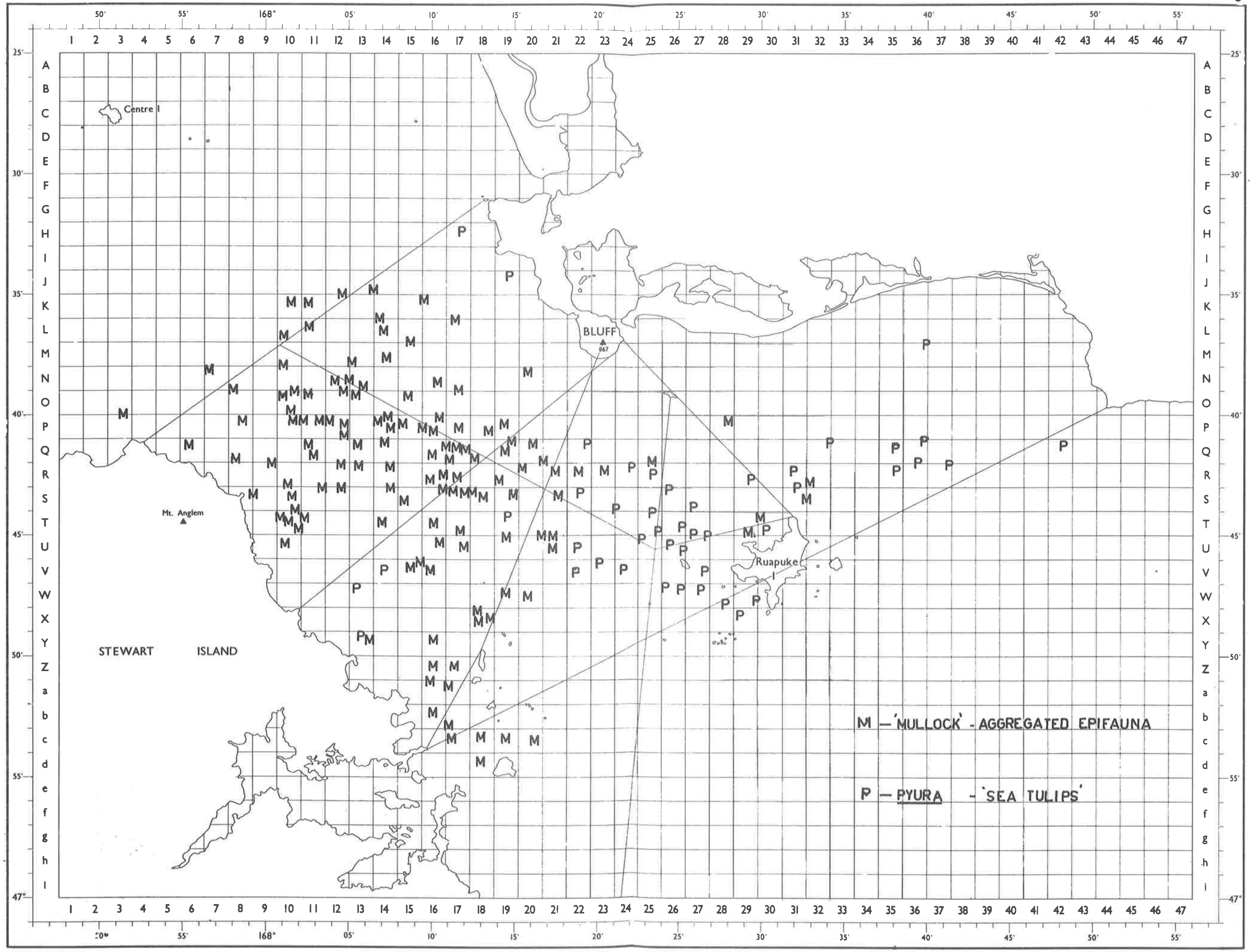


FIG. 1

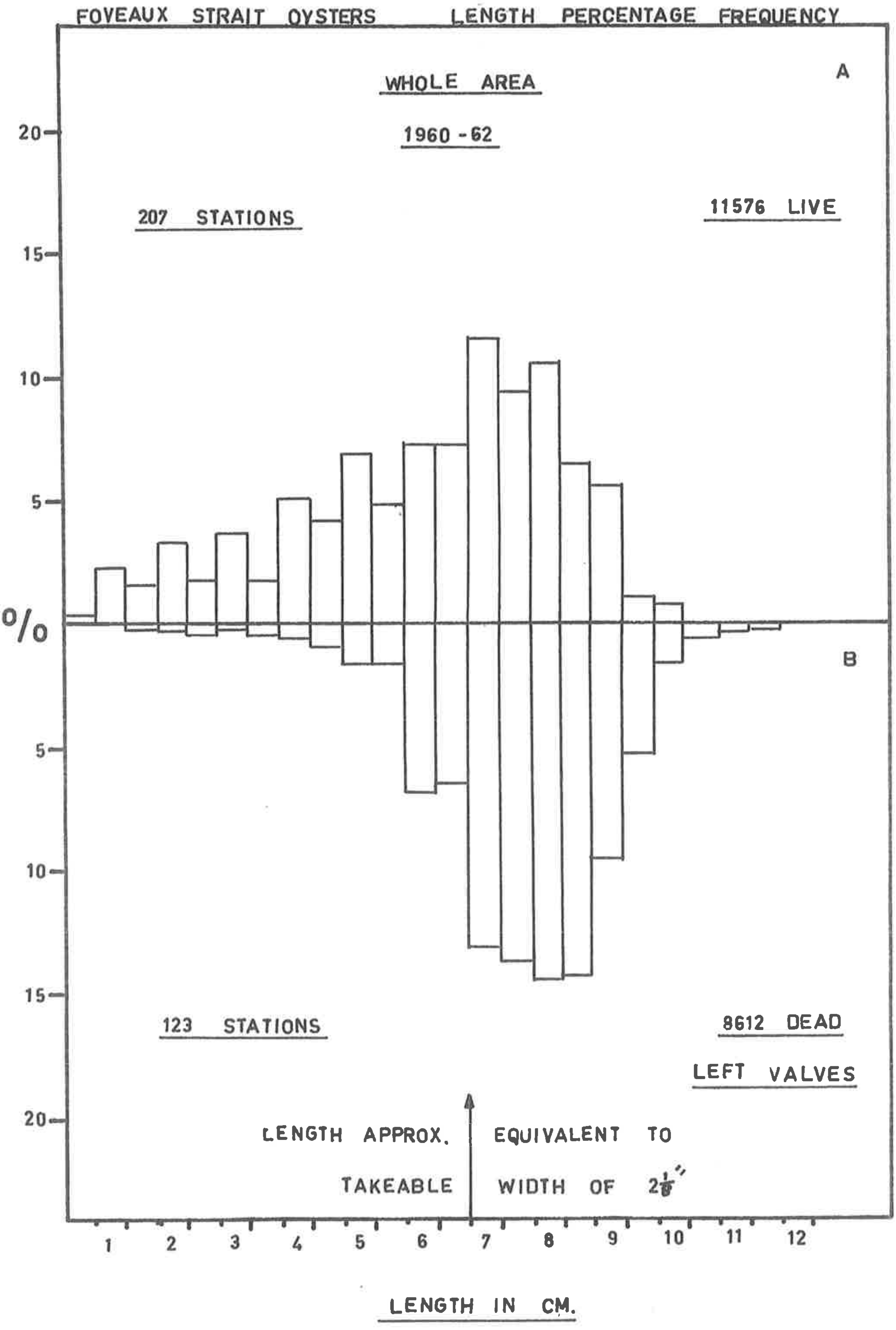

FOVEAUX STRAIT OYSTERS LENGTH PERCENTAGE FREQUENCY
A
WHOLE AREA
1960 - 62
207 STATIONS
11576 LIVE
B
123 STATIONS
8612 DEAD
LEFT VALVES
LENGTH APPROX. EQUIVALENT TO
TAKEABLE WIDTH OF 2⅛"
%
20
15
10
5
5
10
15
20
1
2
3
4
5
6
7
8
9
10
11
12
LENGTH IN CM.

FIG. 2

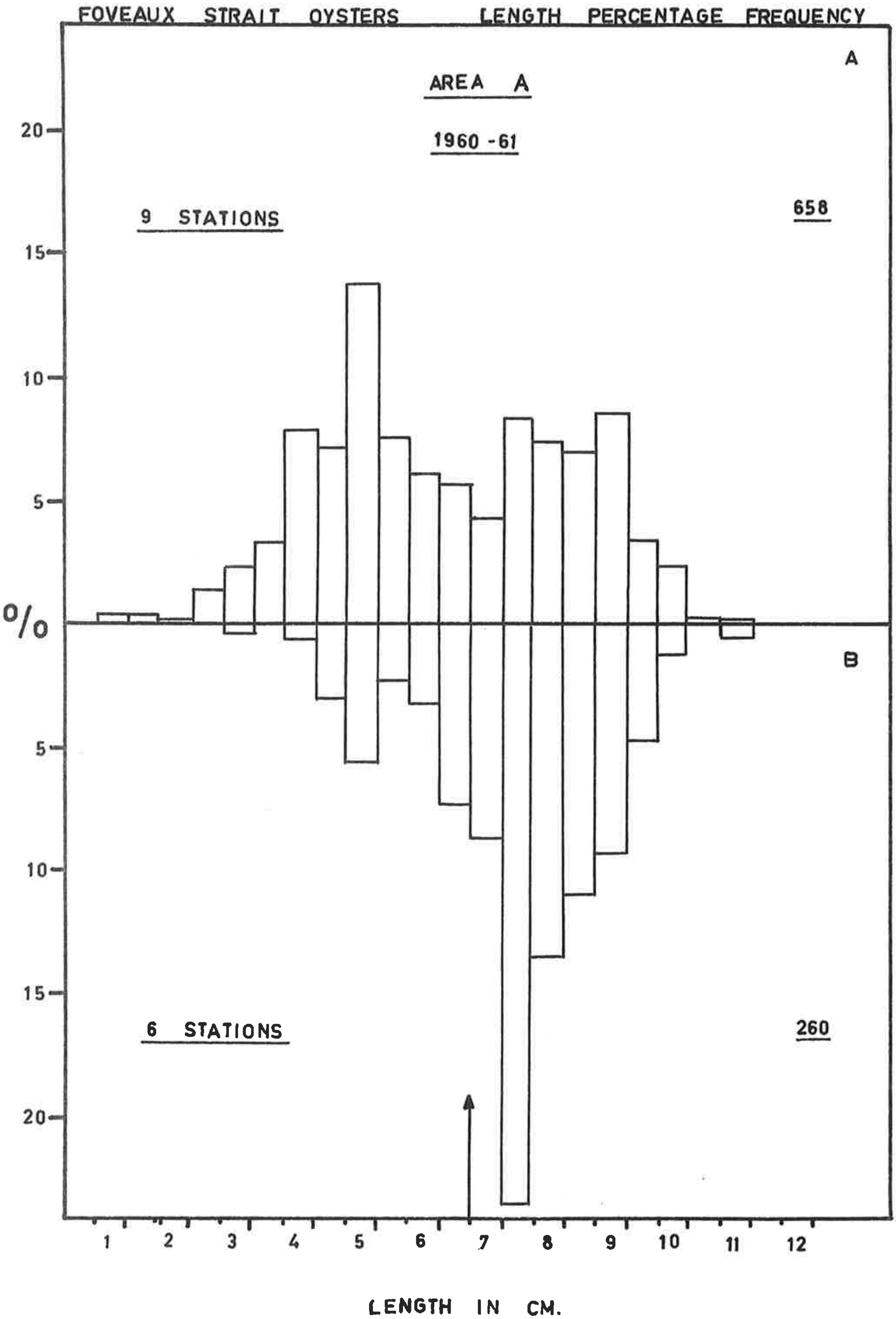

FOVEAUX STRAIT OYSTERS LENGTH PERCENTAGE FREQUENCY
A
AREA A
1960 -61
9 STATIONS
658
B
6 STATIONS
260
%
20
15
10
5
5
10
15
20
1
2
3
4
5
6
7
8
9
10
11
12
LENGTH IN CM.

FIG. 3

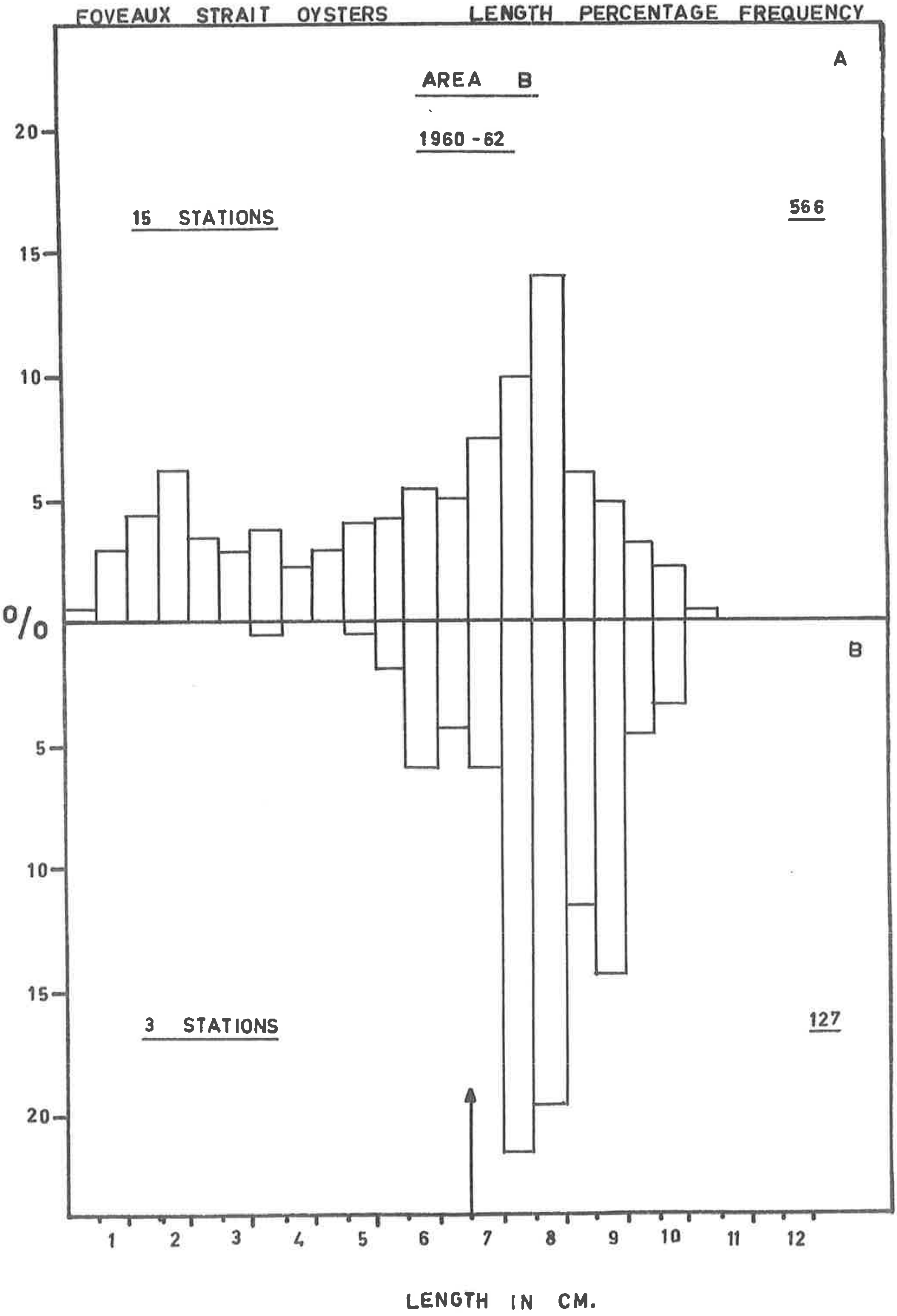

FOVEAUX STRAIT OYSTERS LENGTH PERCENTAGE FREQUENCY
A
AREA B
1960 - 62
15 STATIONS
566
B
3 STATIONS
127
%
20
15
10
5
5
10
15
20
1
2
3
4
5
6
7
8
9
10
11
12
LENGTH IN CM.

FIG. 4

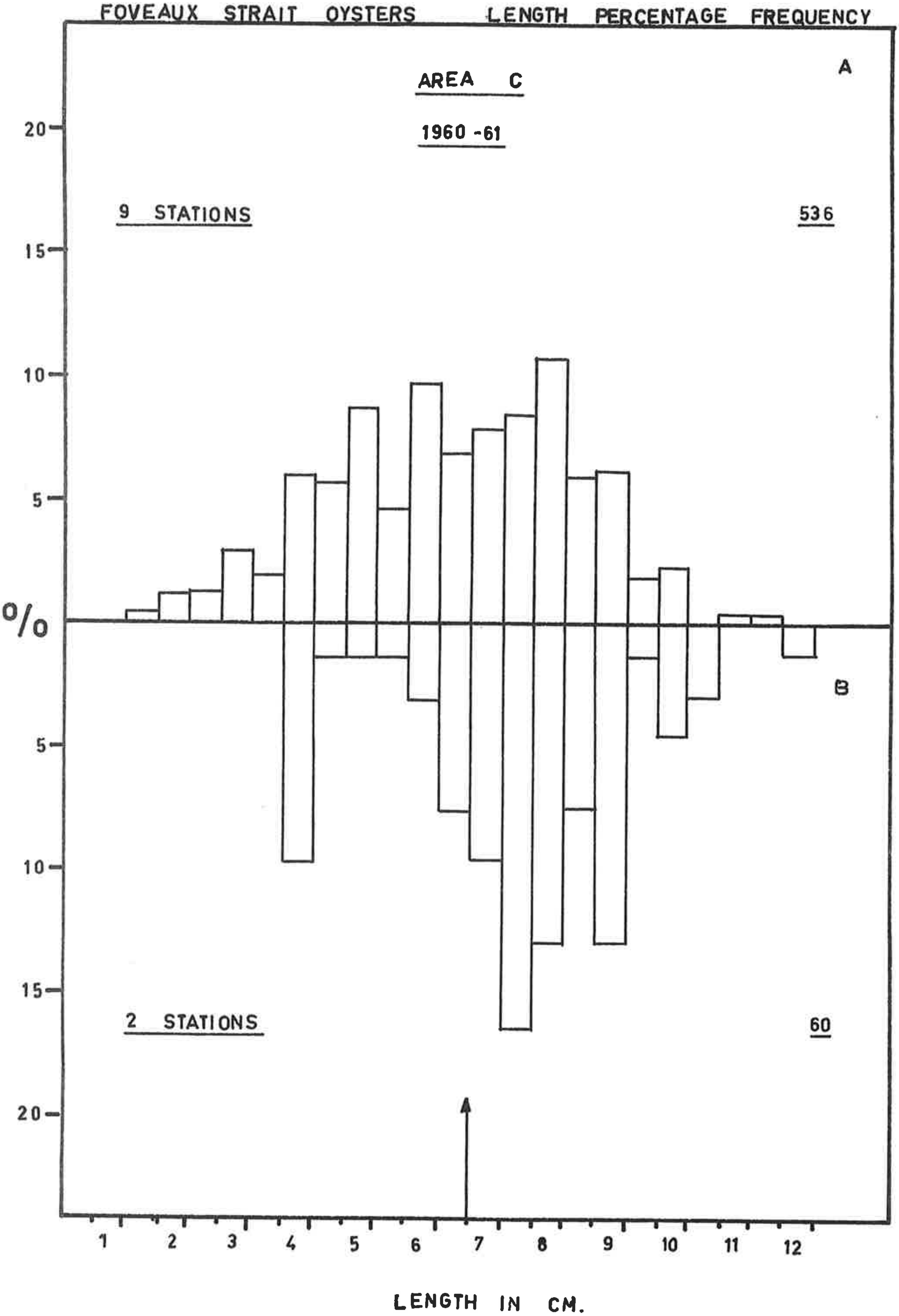
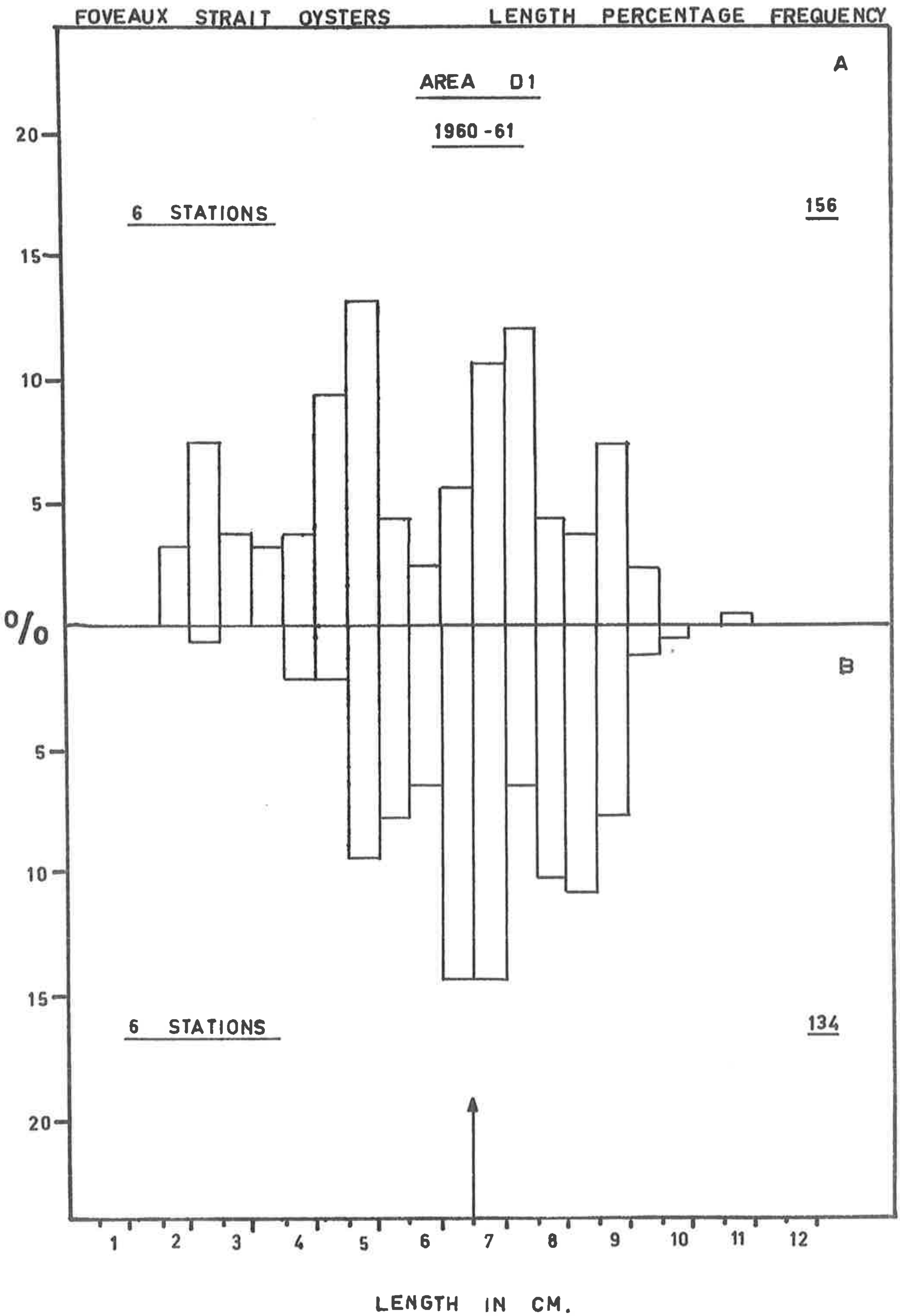

FOVEAUX STRAIT OYSTERS LENGTH PERCENTAGE FREQUENCY
AREA C
1960 -61
A
9 STATIONS
536
B
2 STATIONS
60
%
20
15
10
5
5
10
15
20
1
2
3
4
5
6
7
8
9
10
11
12
LENGTH IN CM.

FIG. 5



FOVEAUX STRAIT OYSTERS LENGTH PERCENTAGE FREQUENCY
AREA D1
1960 - 61
A
6 STATIONS
156
20
15
10
5
%
B
5
10
15
6 STATIONS
134
20
1
2
3
4
5
6
7
8
9
10
11
12
LENGTH IN CM.

FIG. 6

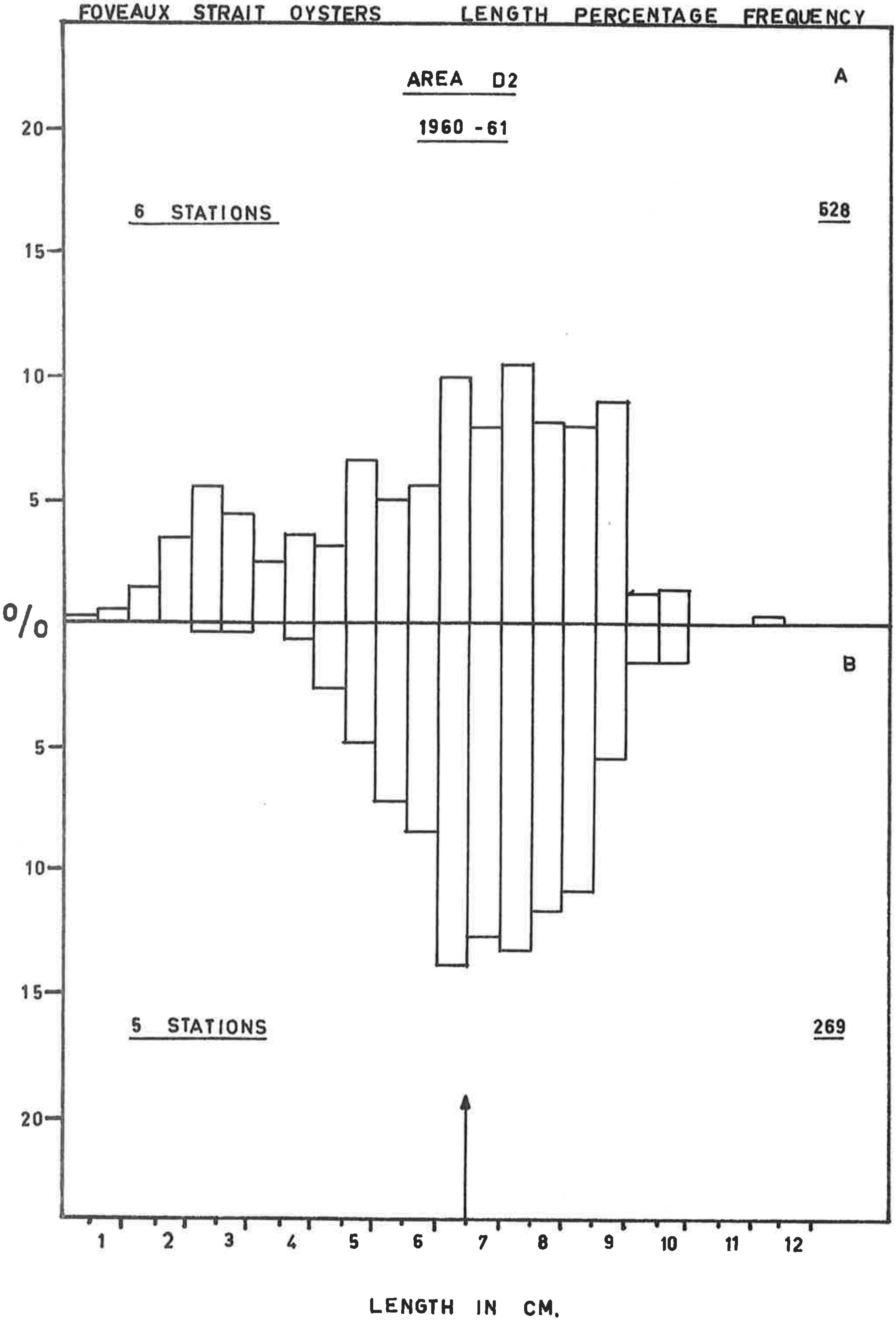

FOVEAUX STRAIT OYSTERS LENGTH PERCENTAGE FREQUENCY
AREA D2
1960 - 61
A
6 STATIONS
528
B
5 STATIONS
269
%
20
15
10
5
5
10
15
20
1
2
3
4
5
6
7
8
9
10
11
12
LENGTH IN CM.

FIG. 7

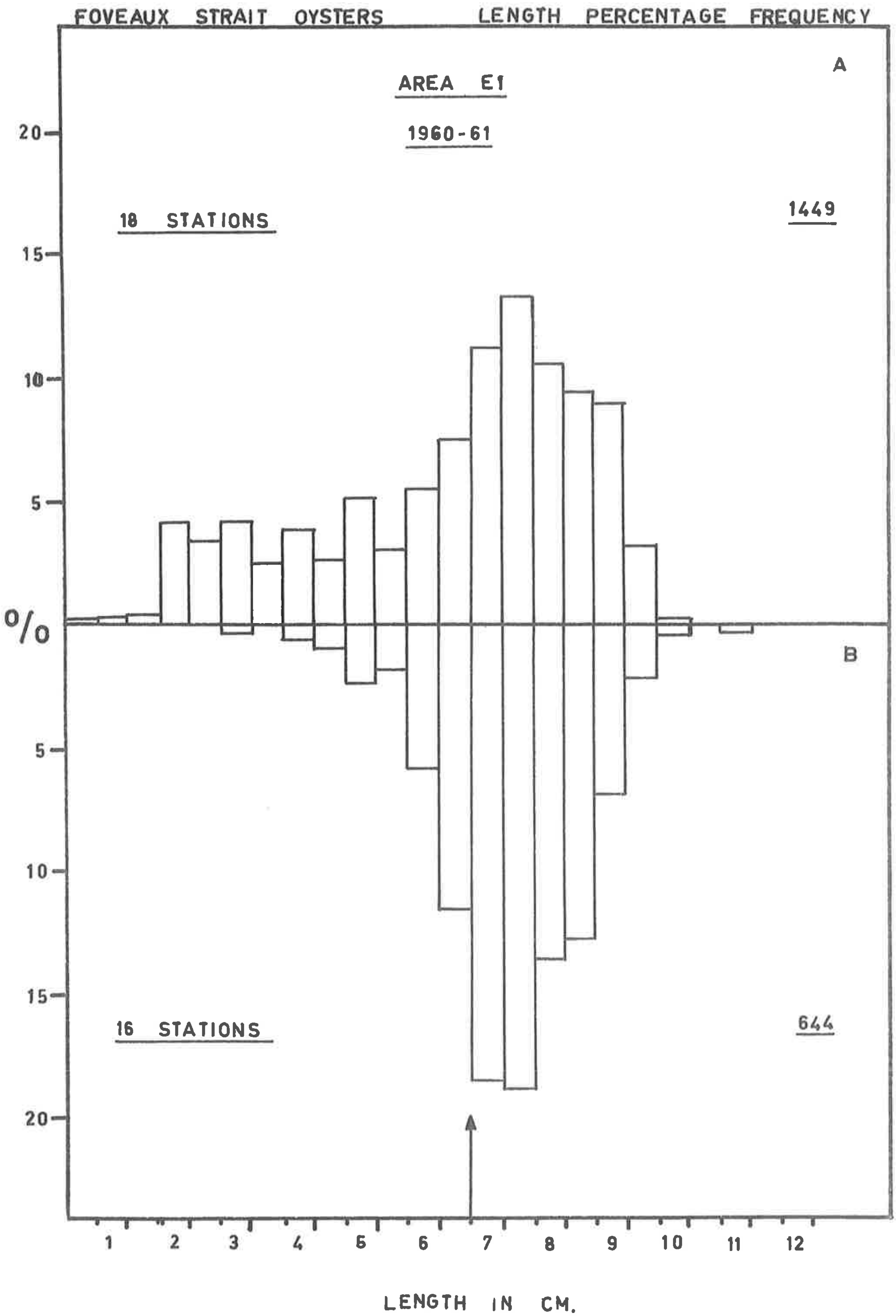

FOVEAUX STRAIT OYSTERS
LENGTH PERCENTAGE FREQUENCY
AREA E1
1960-61
A
18 STATIONS
1449
B
16 STATIONS
644
%
20
15
10
5
5
10
15
20
1
2
3
4
5
6
7
8
9
10
11
12
LENGTH IN CM.

FIG. 8

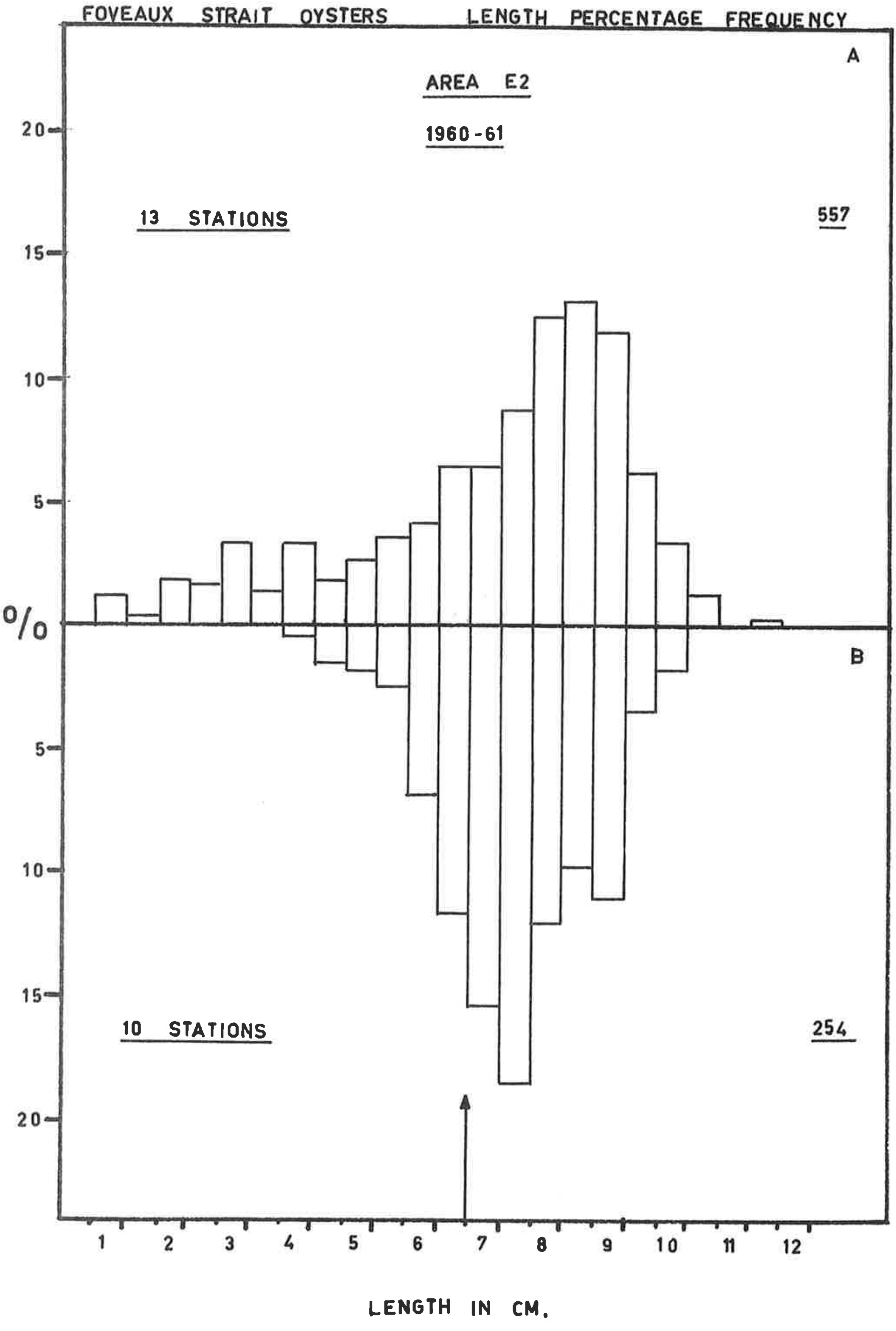

FOVEAUX STRAIT OYSTERS LENGTH PERCENTAGE FREQUENCY
A
AREA E2
1960-61
13 STATIONS
557
B
10 STATIONS
254
%
20
15
10
5
5
10
15
20
1
2
3
4
5
6
7
8
9
10
11
12
LENGTH IN CM.

FIG. 9

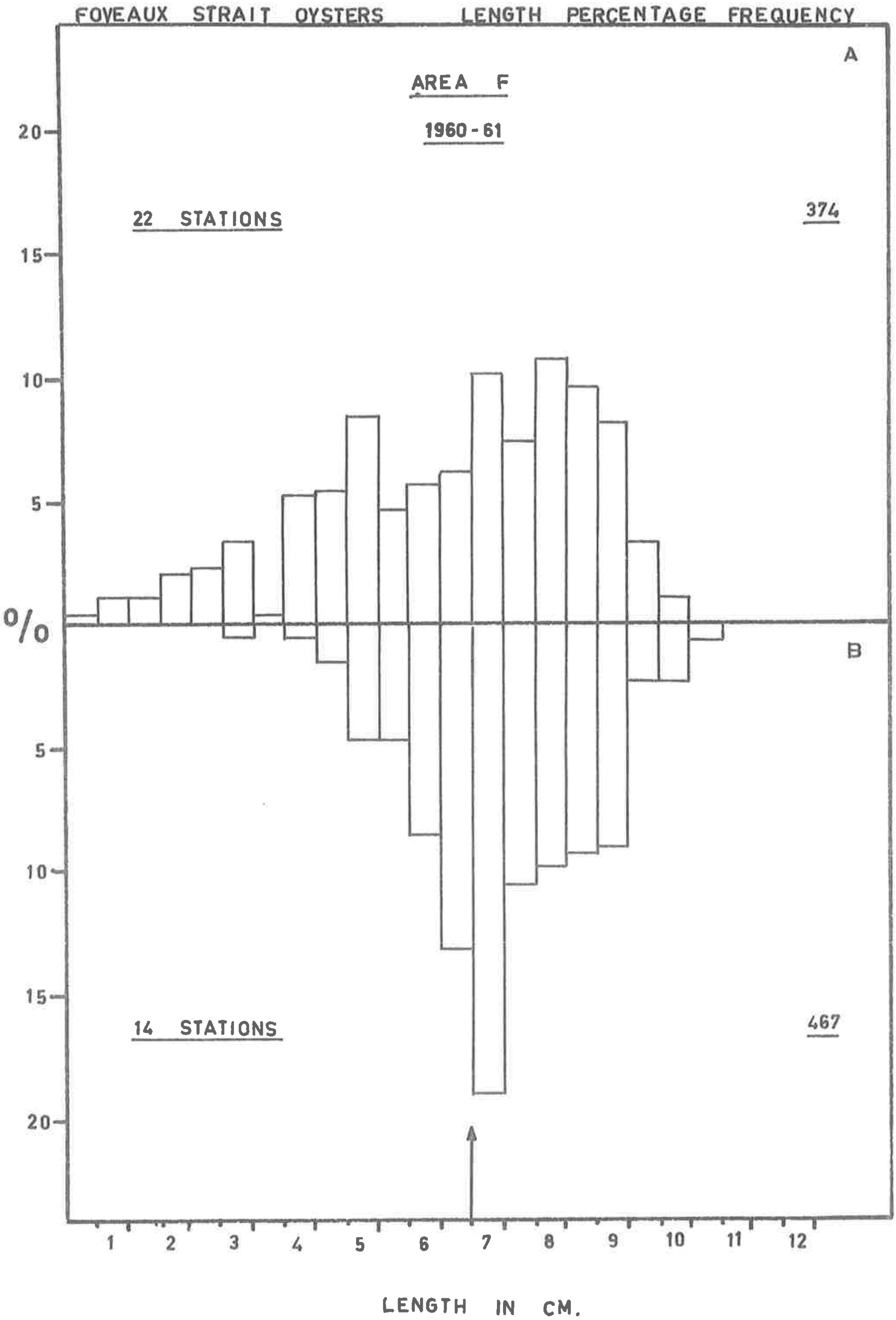

FOVEAUX STRAIT OYSTERS LENGTH PERCENTAGE FREQUENCY
A
AREA F
1960 - 61
22 STATIONS
374
B
14 STATIONS
467
%
20
15
10
5
5
10
15
20
1
2
3
4
5
6
7
8
9
10
11
12
LENGTH IN CM.

FIG.10

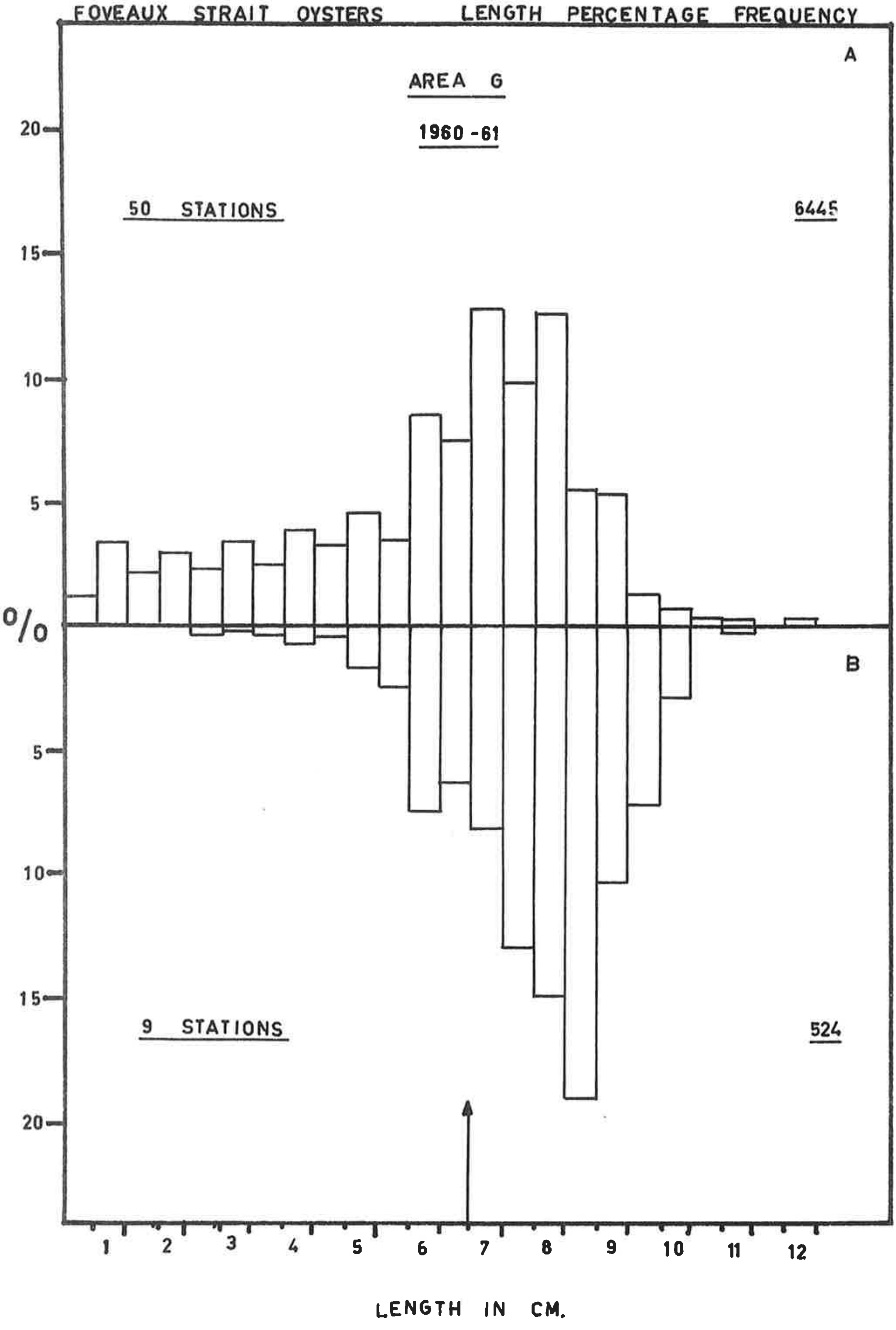

FOVEAUX STRAIT OYSTERS LENGTH PERCENTAGE FREQUENCY
A
AREA G
1960 -61
50 STATIONS
6445
20
15
10
5
%
B
5
10
15
9 STATIONS
524
20
1
2
3
4
5
6
7
8
9
10
11
12
LENGTH IN CM.

FIG. 11

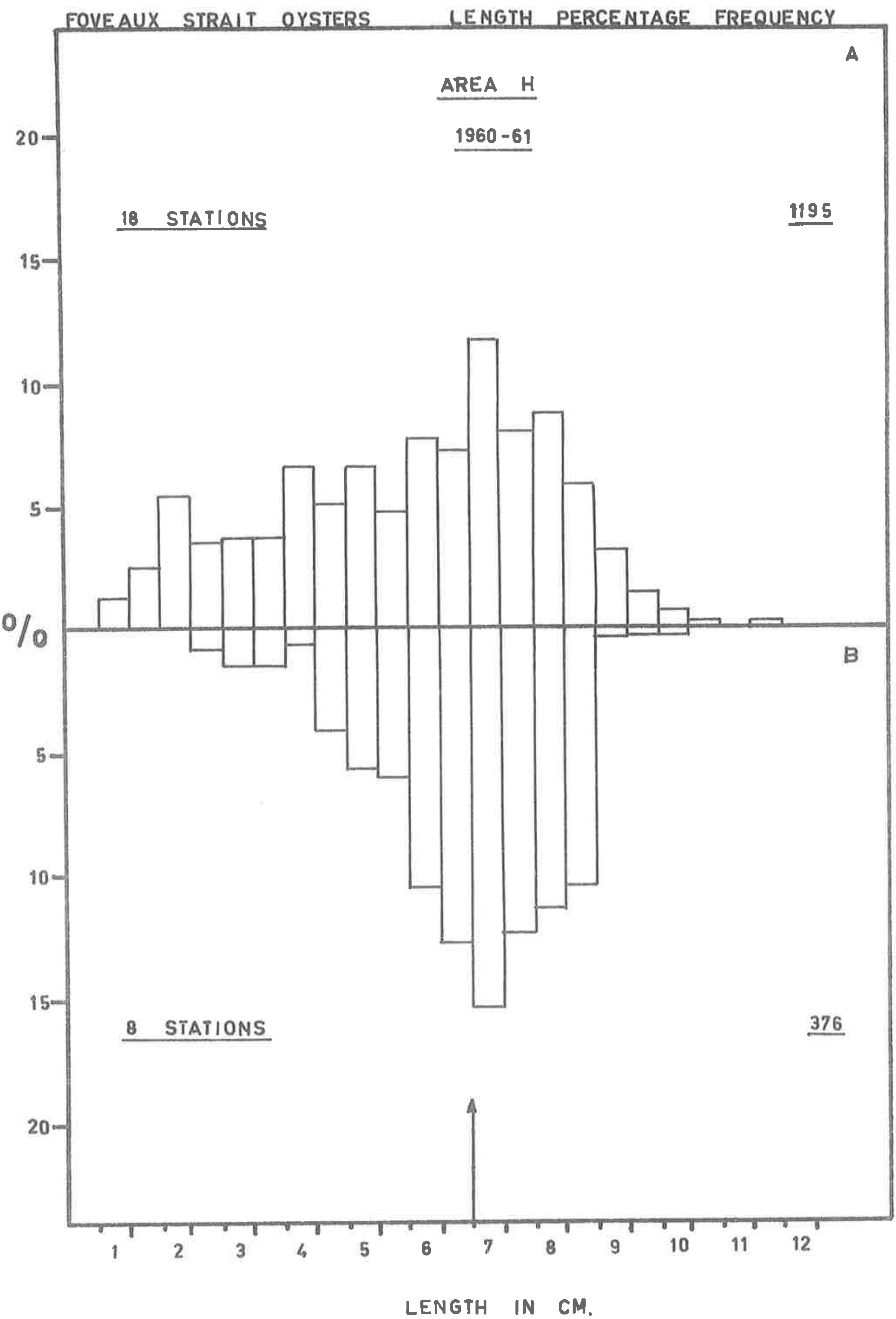
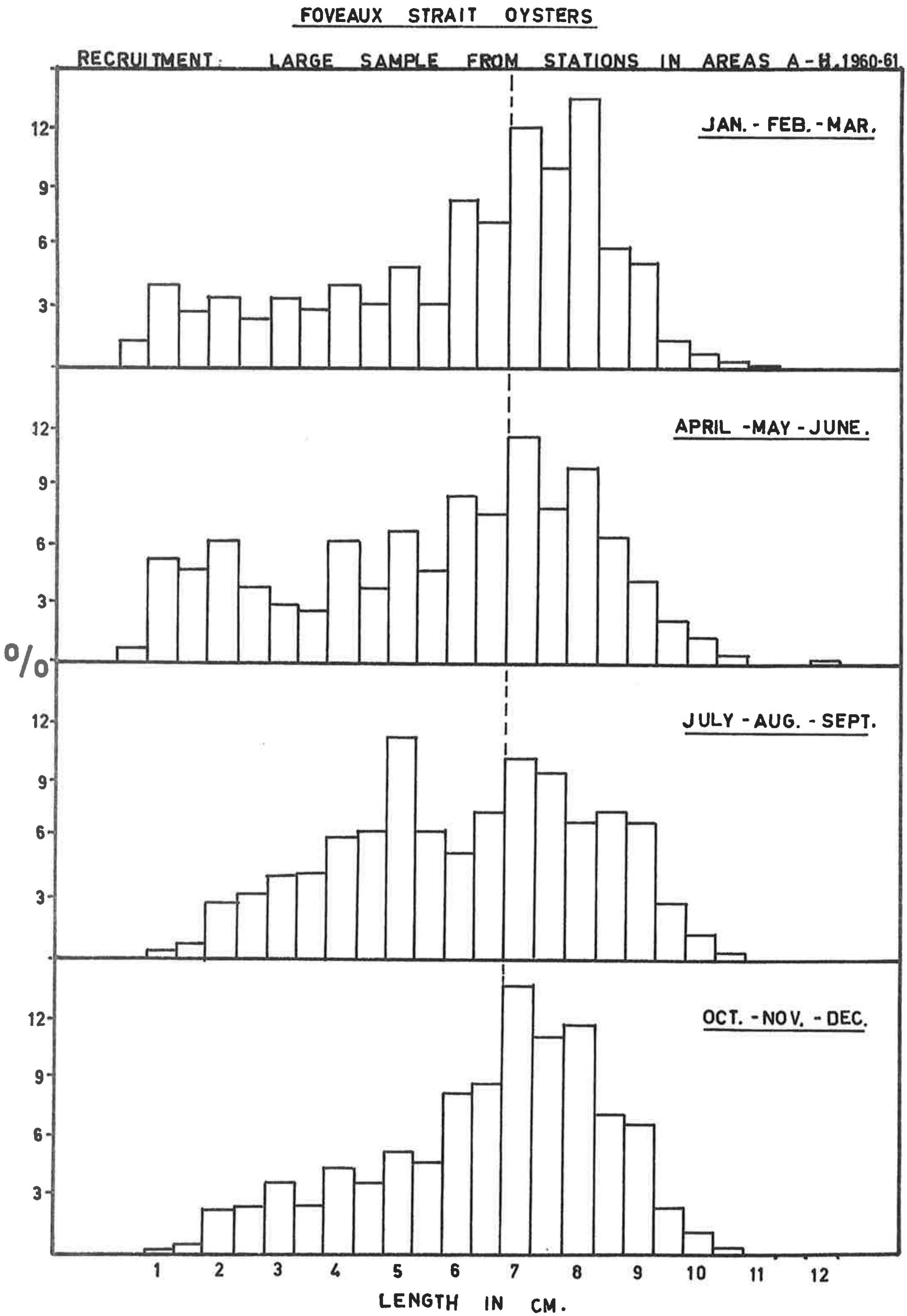
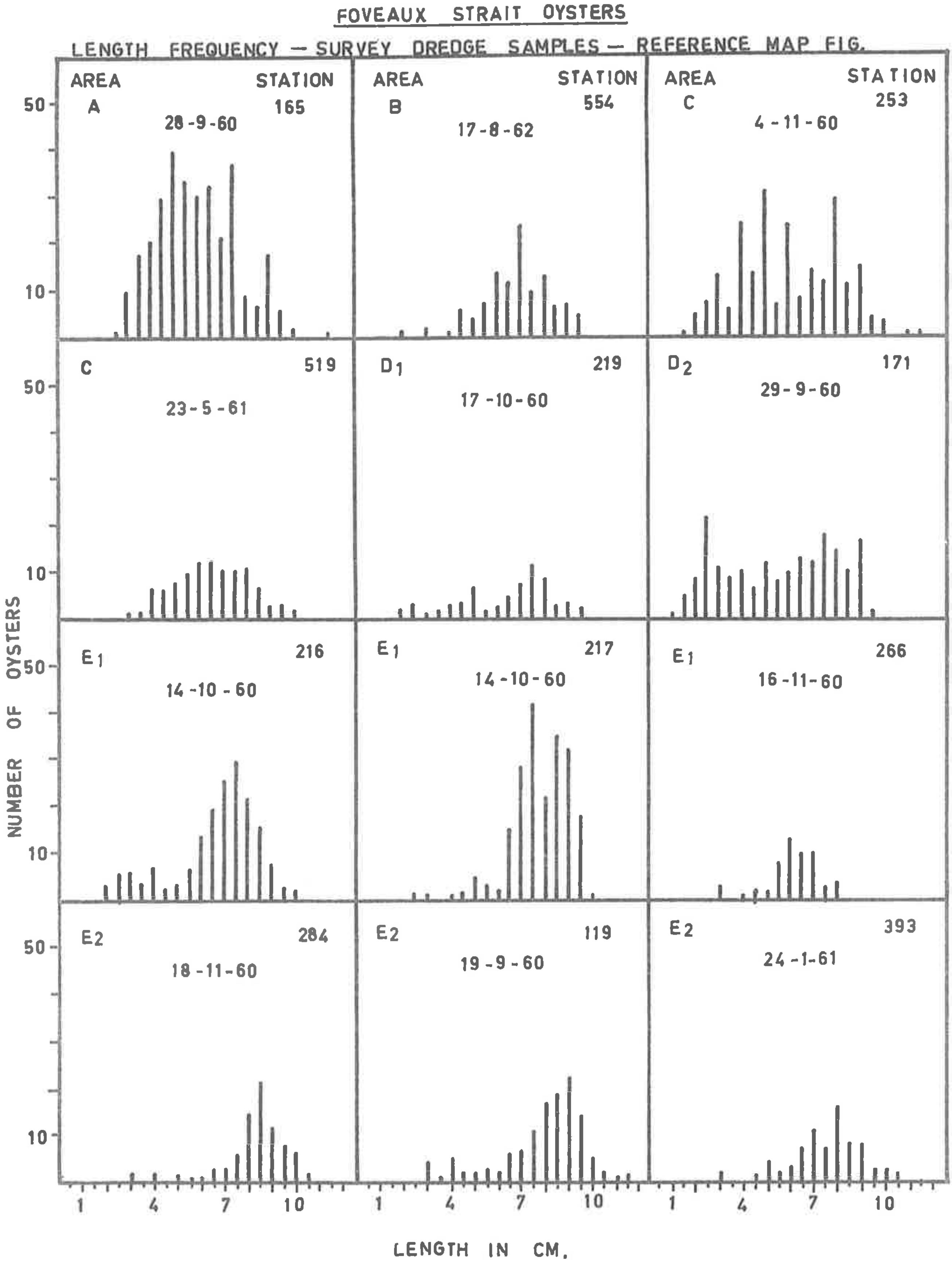

FOVEAUX STRAIT OYSTERS LENGTH PERCENTAGE FREQUENCY
A
AREA H
1960-61
18 STATIONS
1195
20
15
10
5
%
B
5
10
15
20
8 STATIONS
376
1
2
3
4
5
6
7
8
9
10
11
12
LENGTH IN CM.

FIG. 12



FOVEAUX STRAIT OYSTERS
RECRUITMENT: LARGE SAMPLE FROM STATIONS IN AREAS A-H, 1960-61
JAN. - FEB. - MAR.
APRIL - MAY - JUNE.
JULY - AUG. - SEPT.
OCT. - NOV. - DEC.
%
3
6
9
12
1
2
3
4
5
6
7
8
9
10
11
12
LENGTH IN CM.

FIG. 13


FOVEAUX STRAIT OYSTERS
LENGTH FREQUENCY — SURVEY DREDGE SAMPLES — REFERENCE MAP FIG.
AREA A STATION 165 28-9-60
AREA B STATION 554 17-8-62
AREA C STATION 253 4-11-60
C 519 23-5-61
D1 219 17-10-60
D2 171 29-9-60
E1 216 14-10-60
E1 217 14-10-60
E1 266 16-11-60
E2 284 18-11-60
E2 119 19-9-60
E2 393 24-1-61
50
10
NUMBER OF OYSTERS
1 4 7 10
LENGTH IN CM.

FOVEAUX STRAIT OYSTERS

FIG.14

LENGTH FREQUENCY — SURVEY DREDGE SAMPLES — REFERENCE MAP FIG.

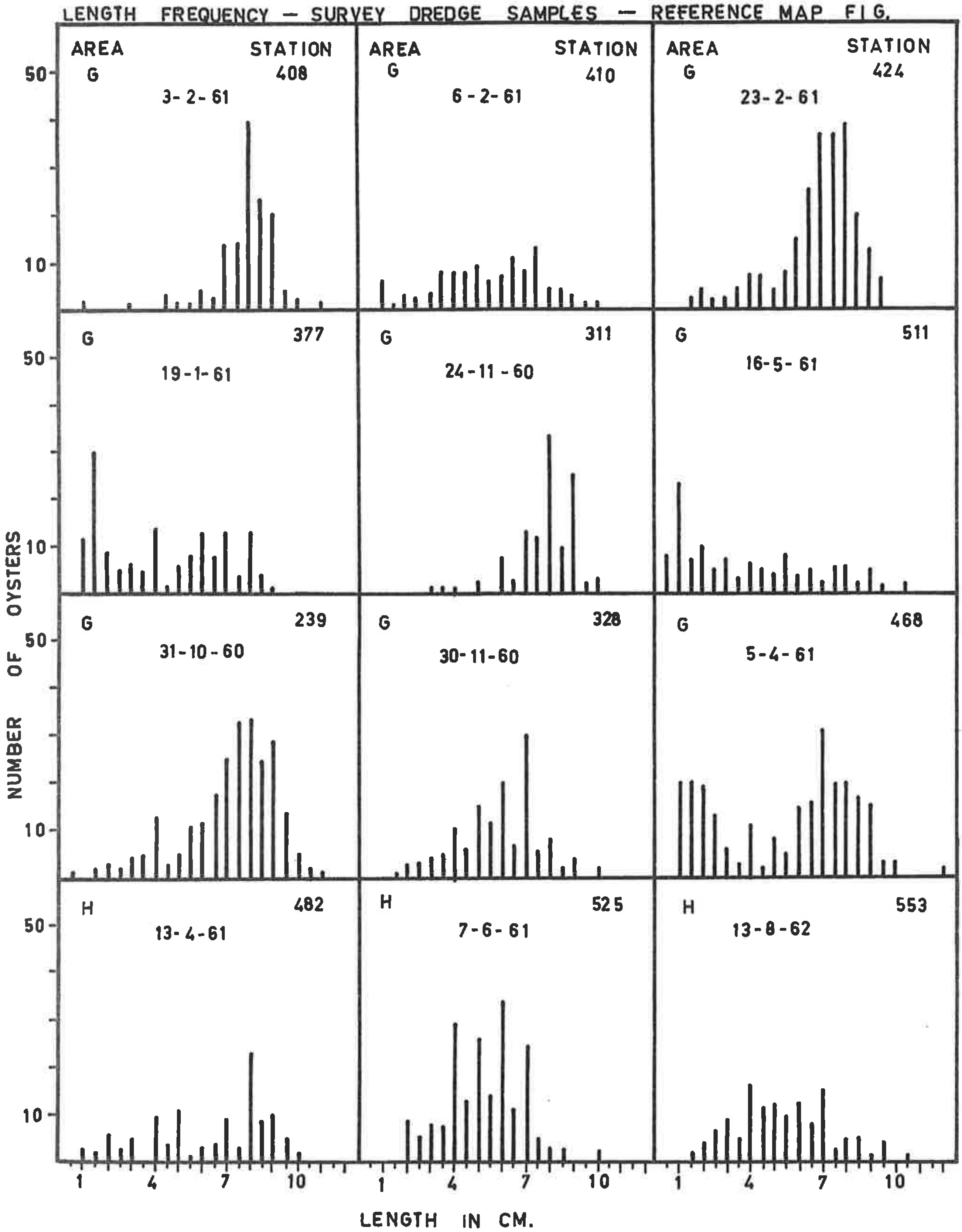


FIG.15

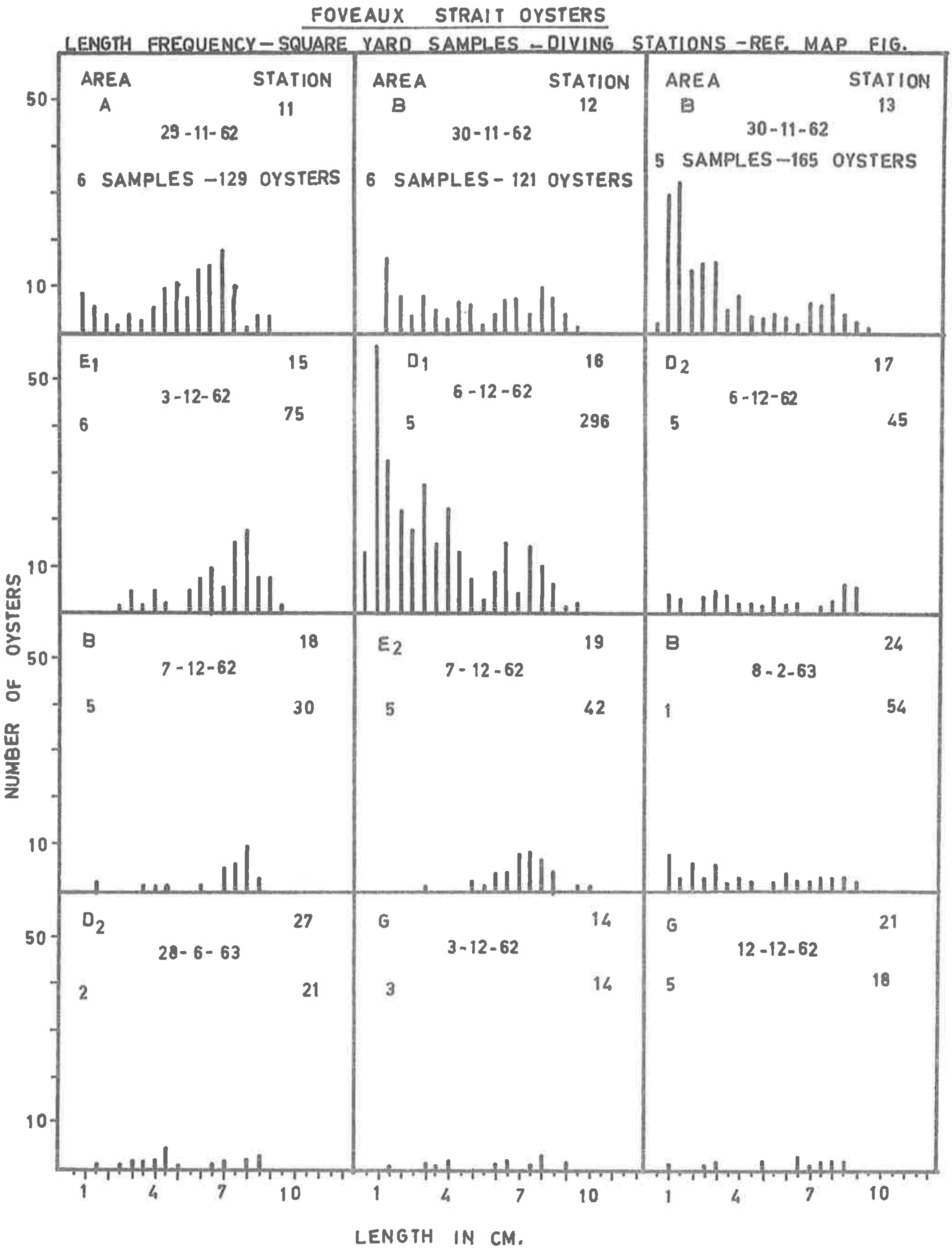

FOVEAUX STRAIT OYSTERS
LENGTH FREQUENCY – SQUARE YARD SAMPLES – DIVING STATIONS – REF. MAP FIG.
AREA A STATION 11
29-11-62
6 SAMPLES – 129 OYSTERS
AREA B STATION 12
30-11-62
6 SAMPLES – 121 OYSTERS
AREA B STATION 13
30-11-62
5 SAMPLES – 165 OYSTERS
E1 15
3-12-62
6 75
D1 16
6-12-62
5 296
D2 17
6-12-62
5 45
B 18
7-12-62
5 30
E2 19
7-12-62
5 42
B 24
8-2-63
1 54
D2 27
28-6-63
2 21
G 14
3-12-62
3 14
G 21
12-12-62
5 18
50
10
NUMBER OF OYSTERS
1 4 7 10
LENGTH IN CM.

FIG.16

FOVEAUX STRAIT OYSTERS

SHELL LENGTH/SHELL WIDTH RELATIONSHIP

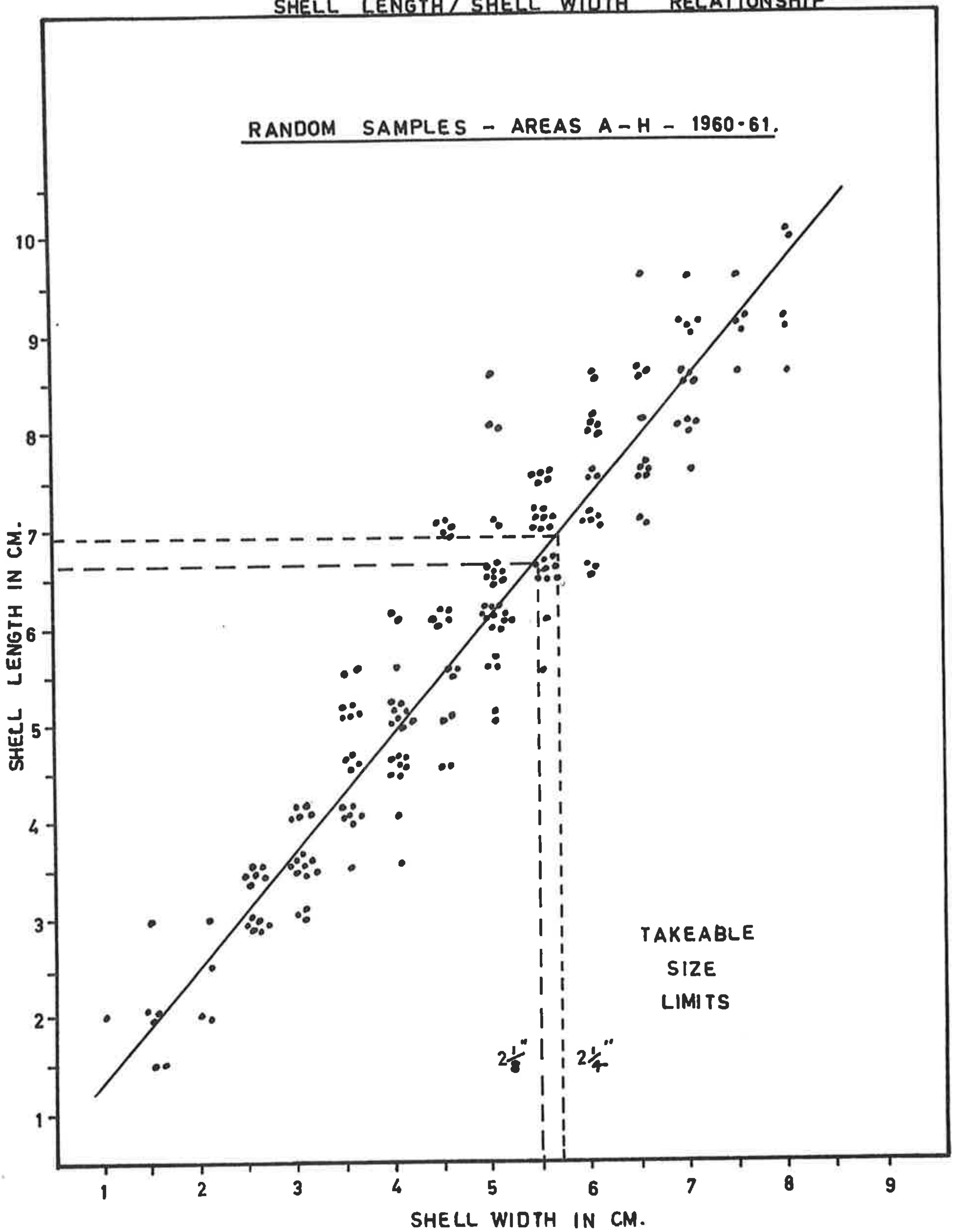


FIG. 17

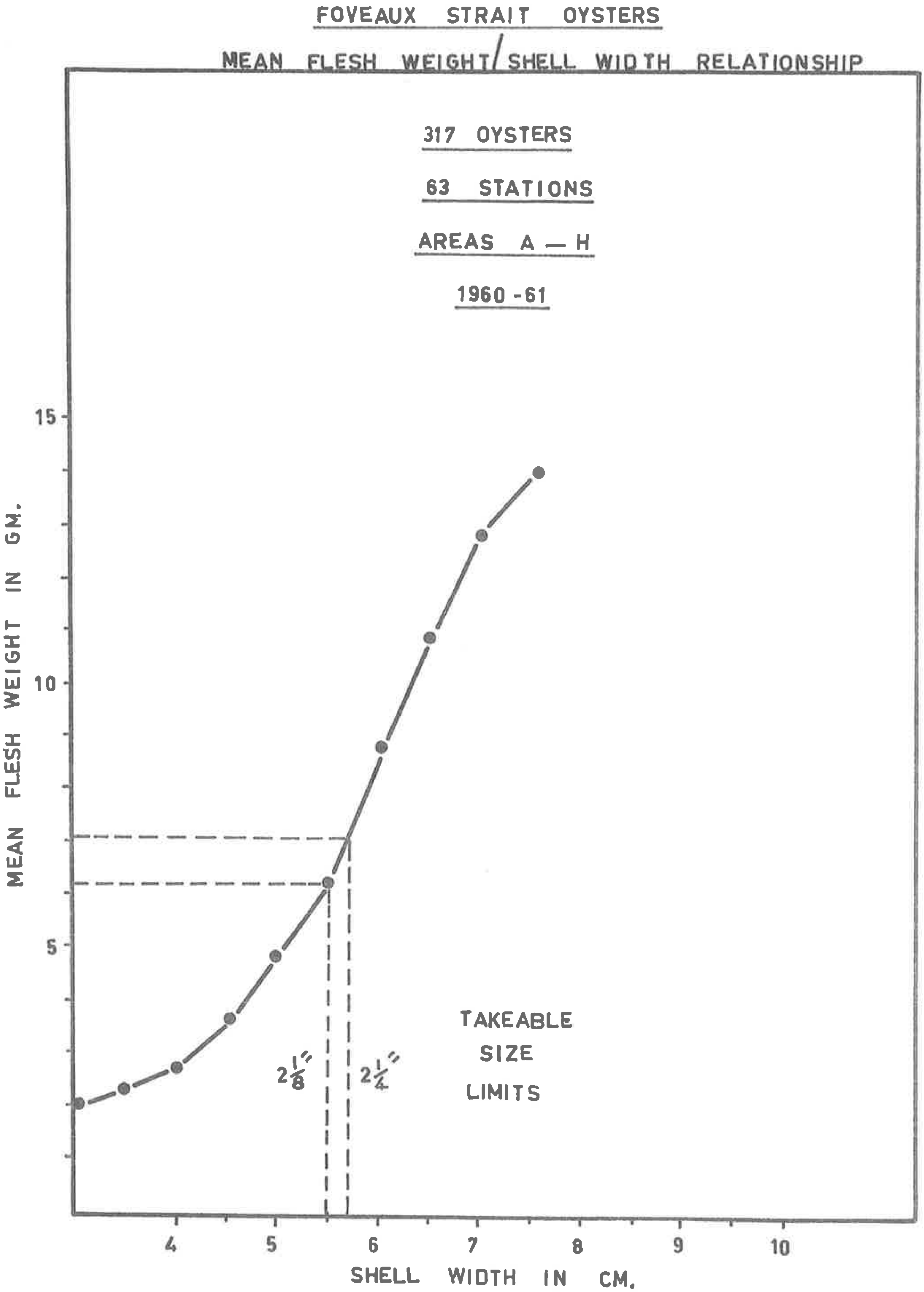

FOVEAUX STRAIT OYSTERS
MEAN FLESH WEIGHT/SHELL WIDTH RELATIONSHIP
317 OYSTERS
63 STATIONS
AREAS A — H
1960 -61
MEAN FLESH WEIGHT IN GM.
15
10
5
2 1/8"
2 1/4"
TAKEABLE
SIZE
LIMITS
4
5
6
7
8
9
10
SHELL WIDTH IN CM.

FIG. 18

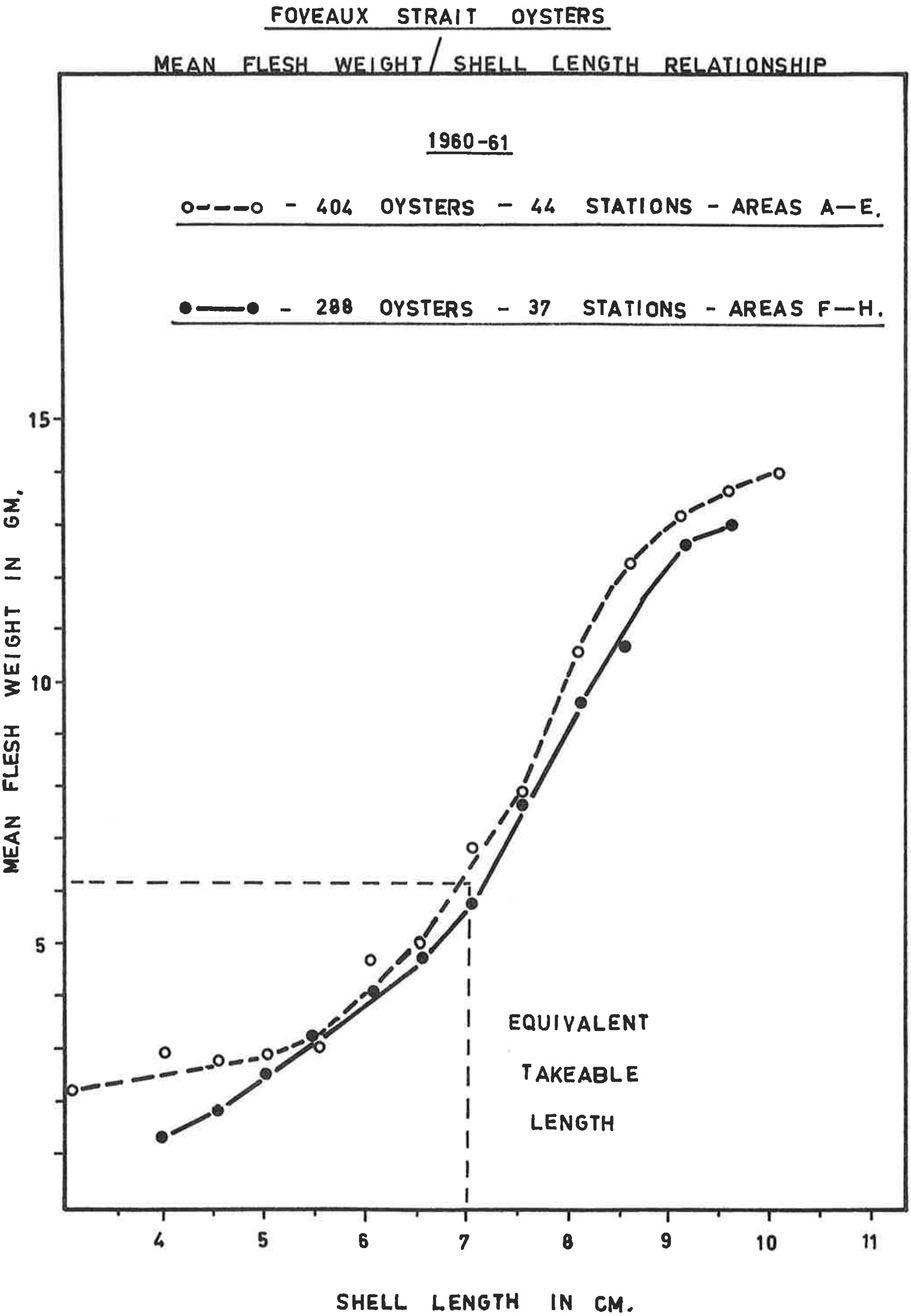
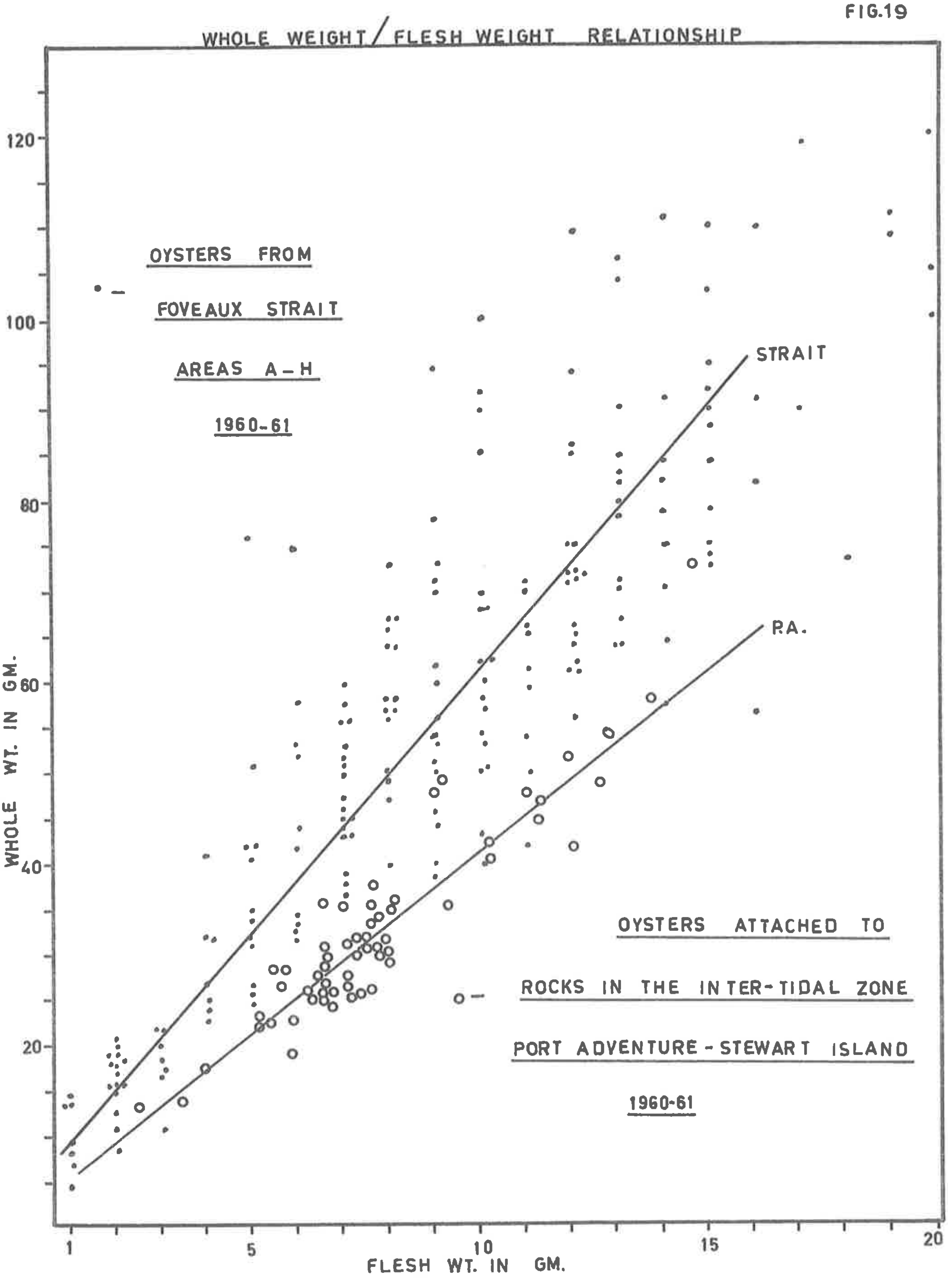

FOVEAUX STRAIT OYSTERS
MEAN FLESH WEIGHT / SHELL LENGTH RELATIONSHIP
1960-61
o---o - 404 OYSTERS - 44 STATIONS - AREAS A—E.
●—● - 288 OYSTERS - 37 STATIONS - AREAS F—H.
MEAN FLESH WEIGHT IN GM.
15
10
5
EQUIVALENT
TAKEABLE
LENGTH
4
5
6
7
8
9
10
11
SHELL LENGTH IN CM.

FIG.19


WHOLE WEIGHT/FLESH WEIGHT RELATIONSHIP
OYSTERS FROM
FOVEAUX STRAIT
AREAS A – H
1960-61
STRAIT
P.A.
OYSTERS ATTACHED TO
ROCKS IN THE INTER-TIDAL ZONE
PORT ADVENTURE - STEWART ISLAND
1960-61
WHOLE WT. IN GM.
FLESH WT. IN GM.
120
100
80
60
40
20
1
5
10
15
20

DREDGE CALIBRATION

FIG. 20

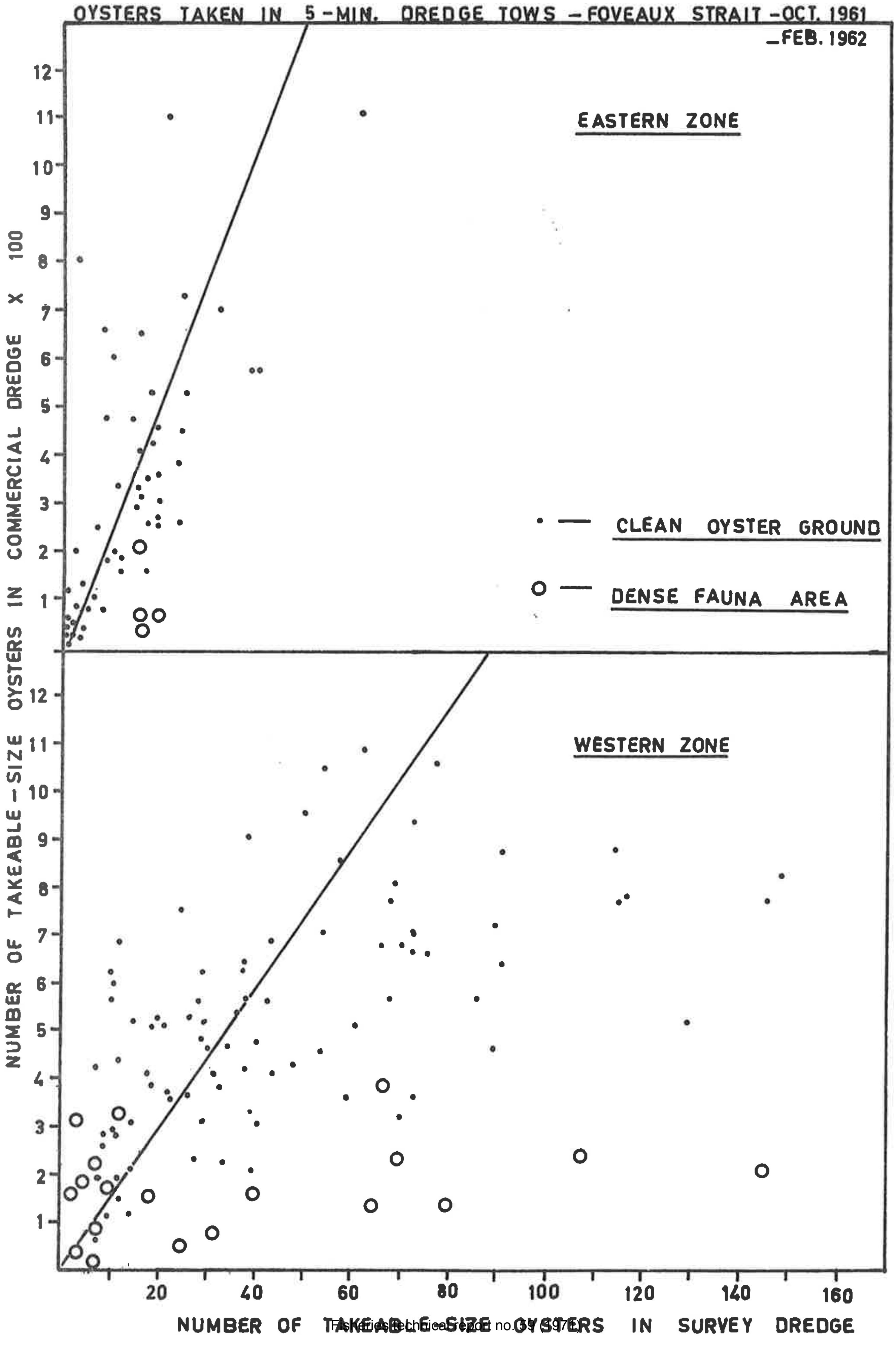


FIG. 21

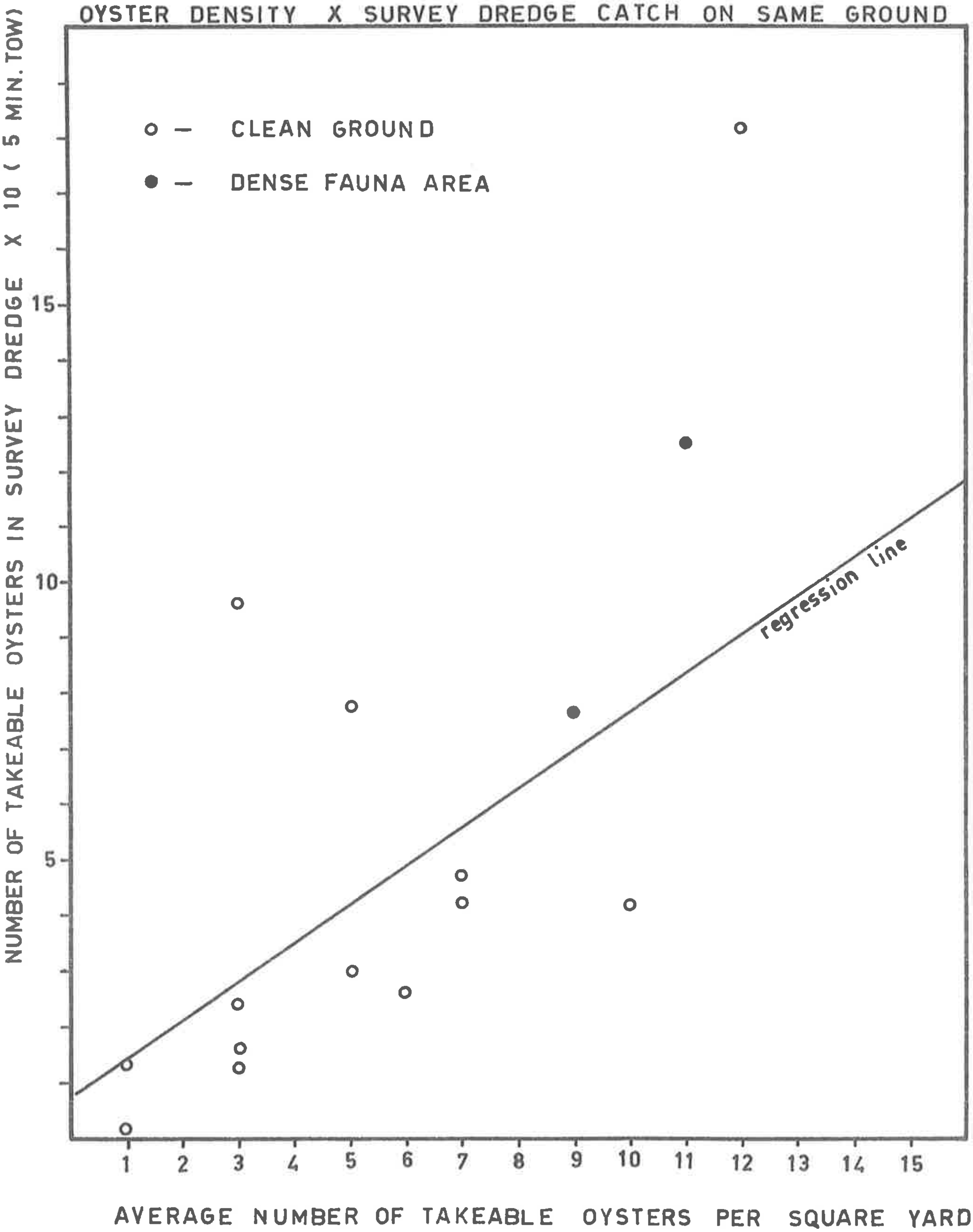
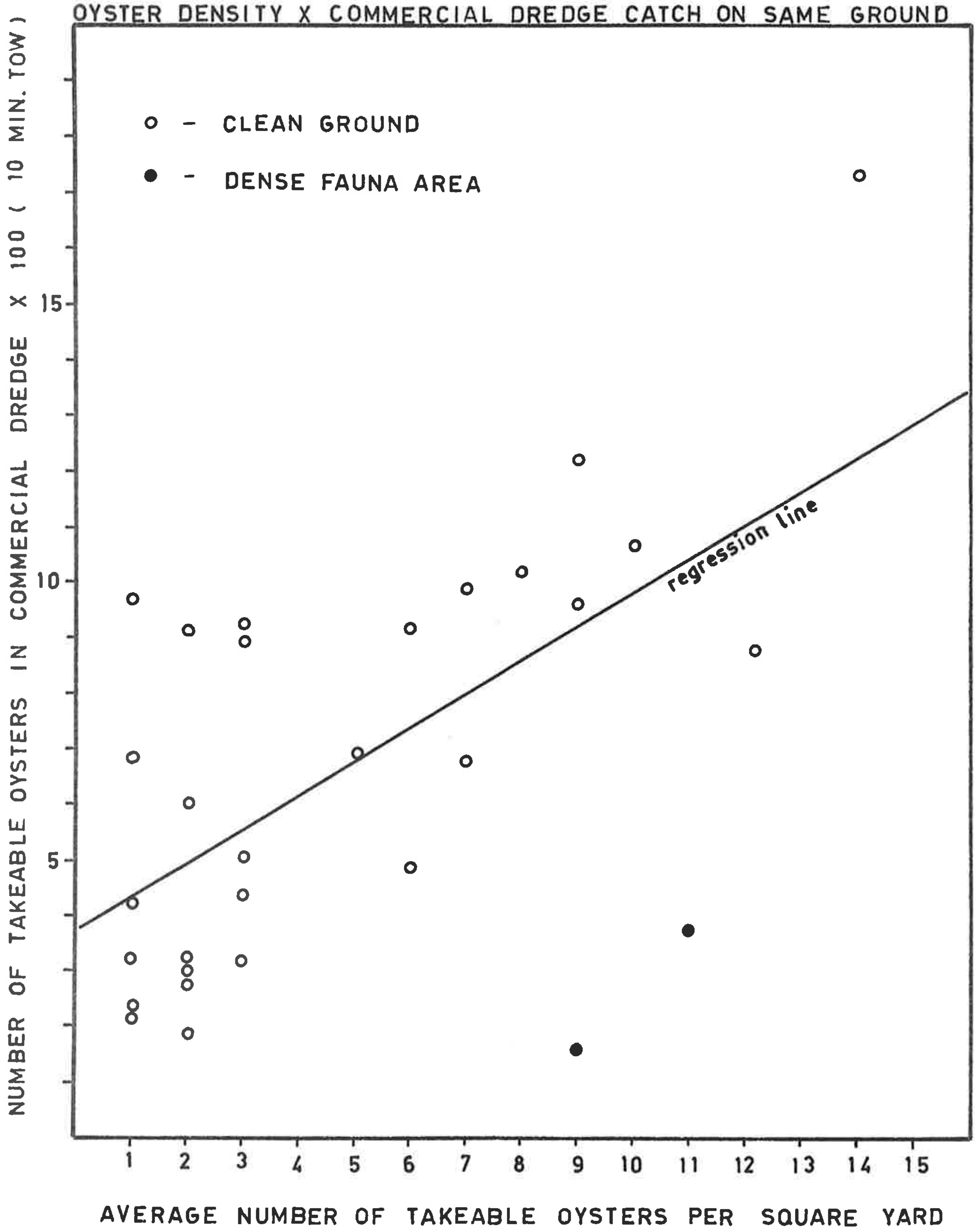
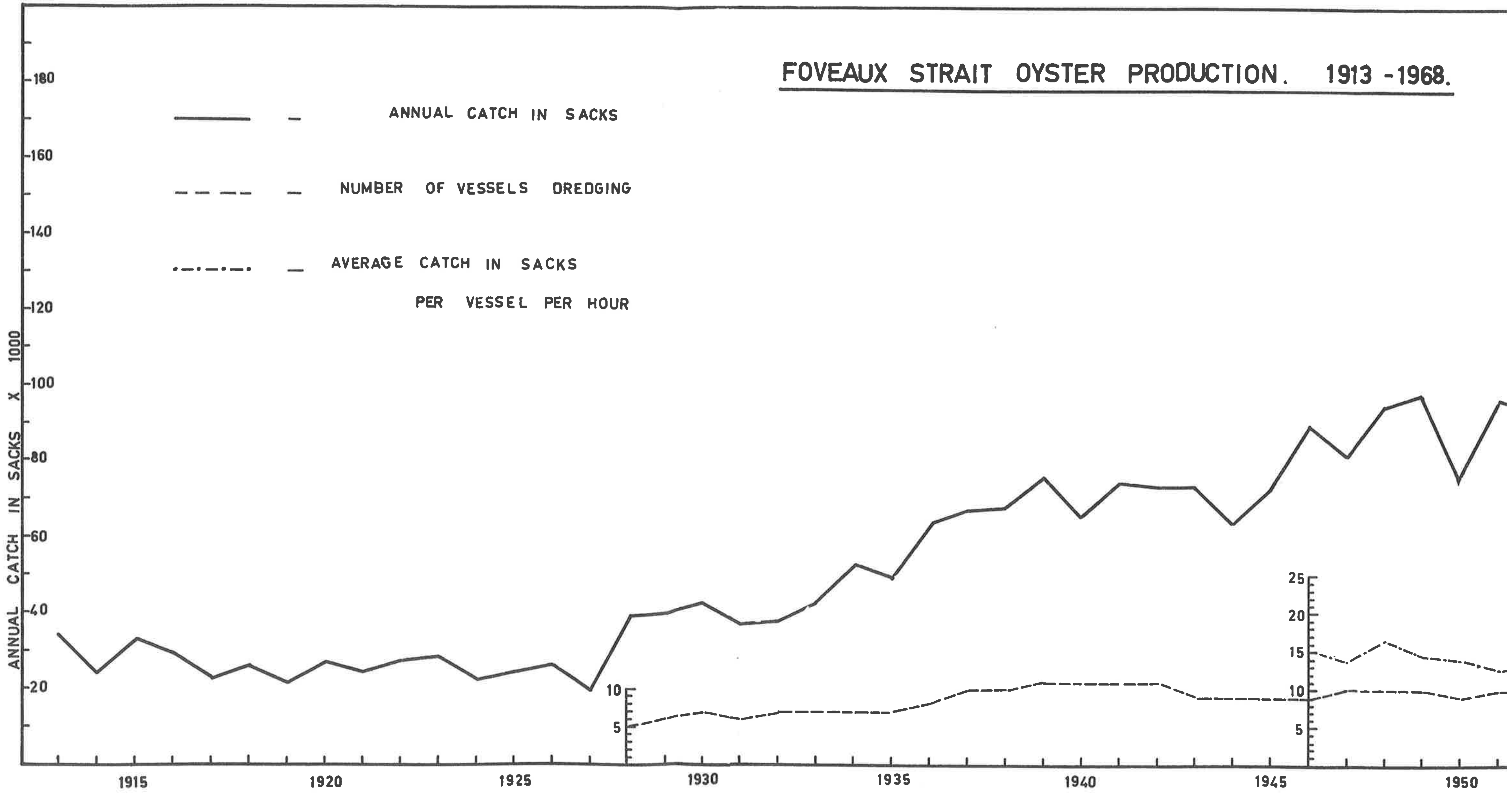

OYSTER DENSITY X SURVEY DREDGE CATCH ON SAME GROUND
NUMBER OF TAKEABLE OYSTERS IN SURVEY DREDGE X 10 (5 MIN. TOW)
15
10
5
o – CLEAN GROUND
● – DENSE FAUNA AREA
regression line
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
AVERAGE NUMBER OF TAKEABLE OYSTERS PER SQUARE YARD

FIG. 22

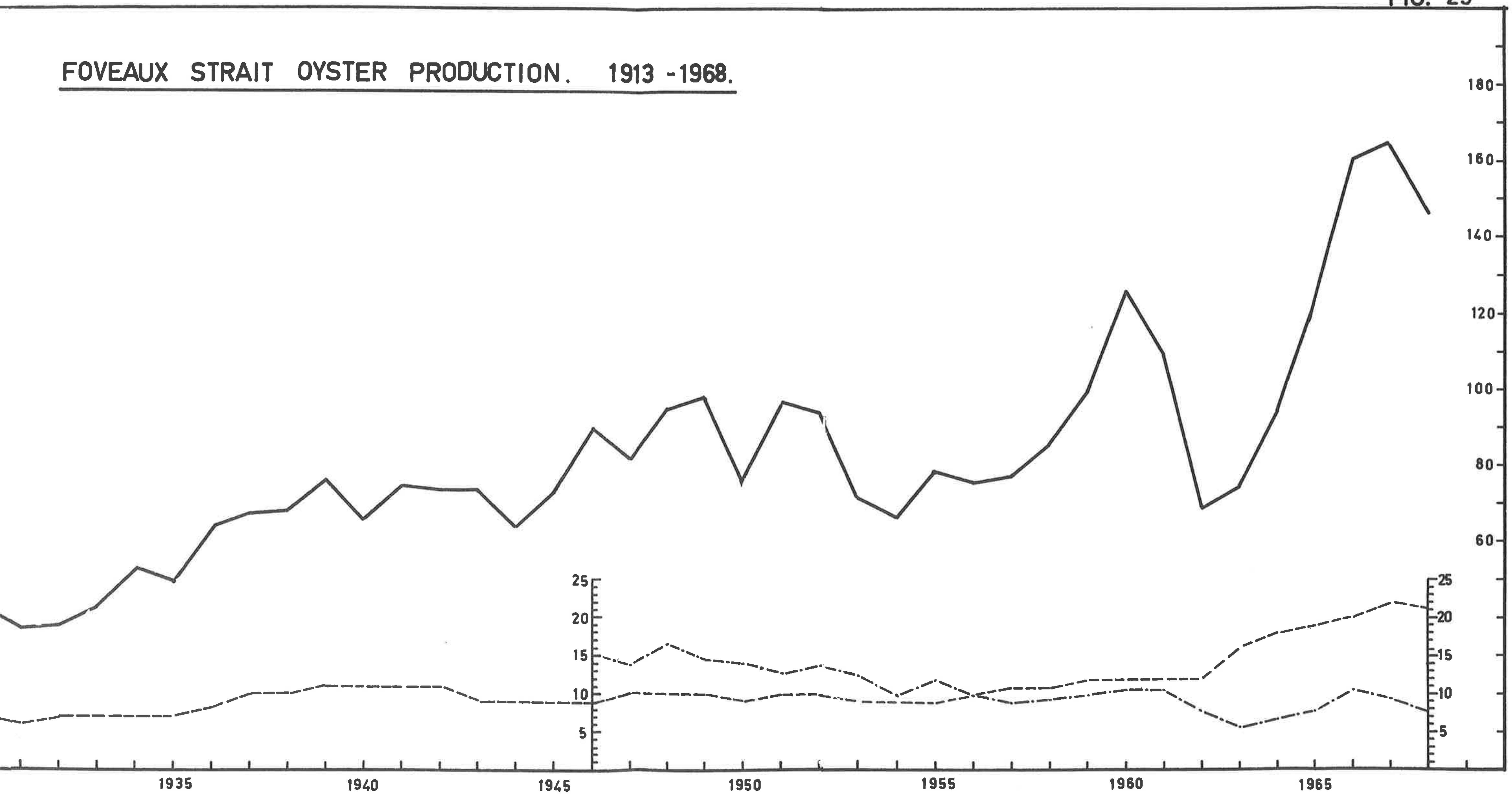
OYSTER DENSITY X COMMERCIAL DREDGE CATCH ON SAME GROUND

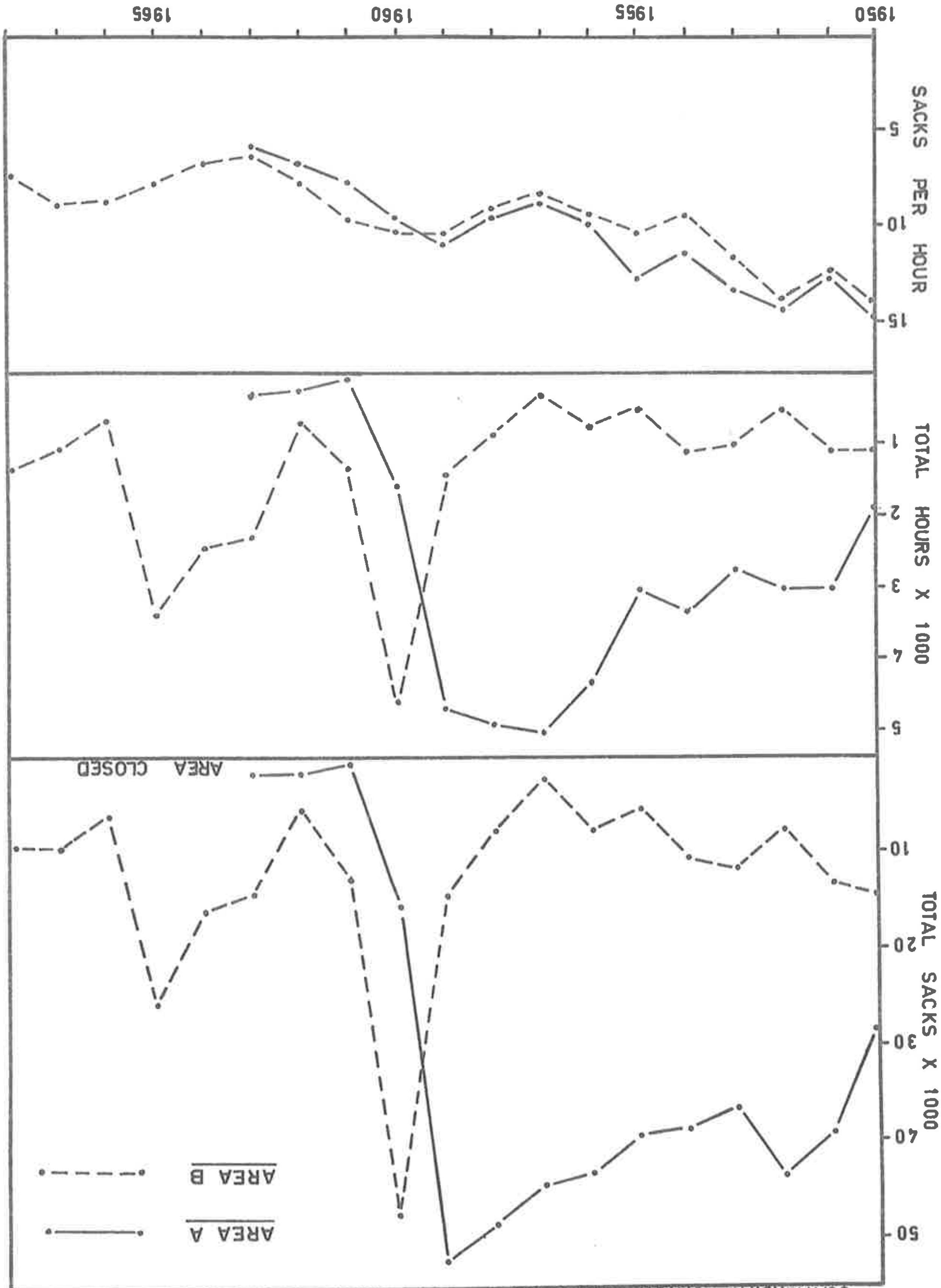




FOVEAUX STRAIT OYSTER PRODUCTION. 1913 -1968.
ANNUAL CATCH IN SACKS
NUMBER OF VESSELS DREDGING
AVERAGE CATCH IN SACKS PER VESSEL PER HOUR
ANNUAL CATCH IN SACKS X 1000
180
160
140
120
100
80
60
40
20
5
10
5
25
20
15
10
5
1915
1920
1925
1930
1935
1940
1945
1950

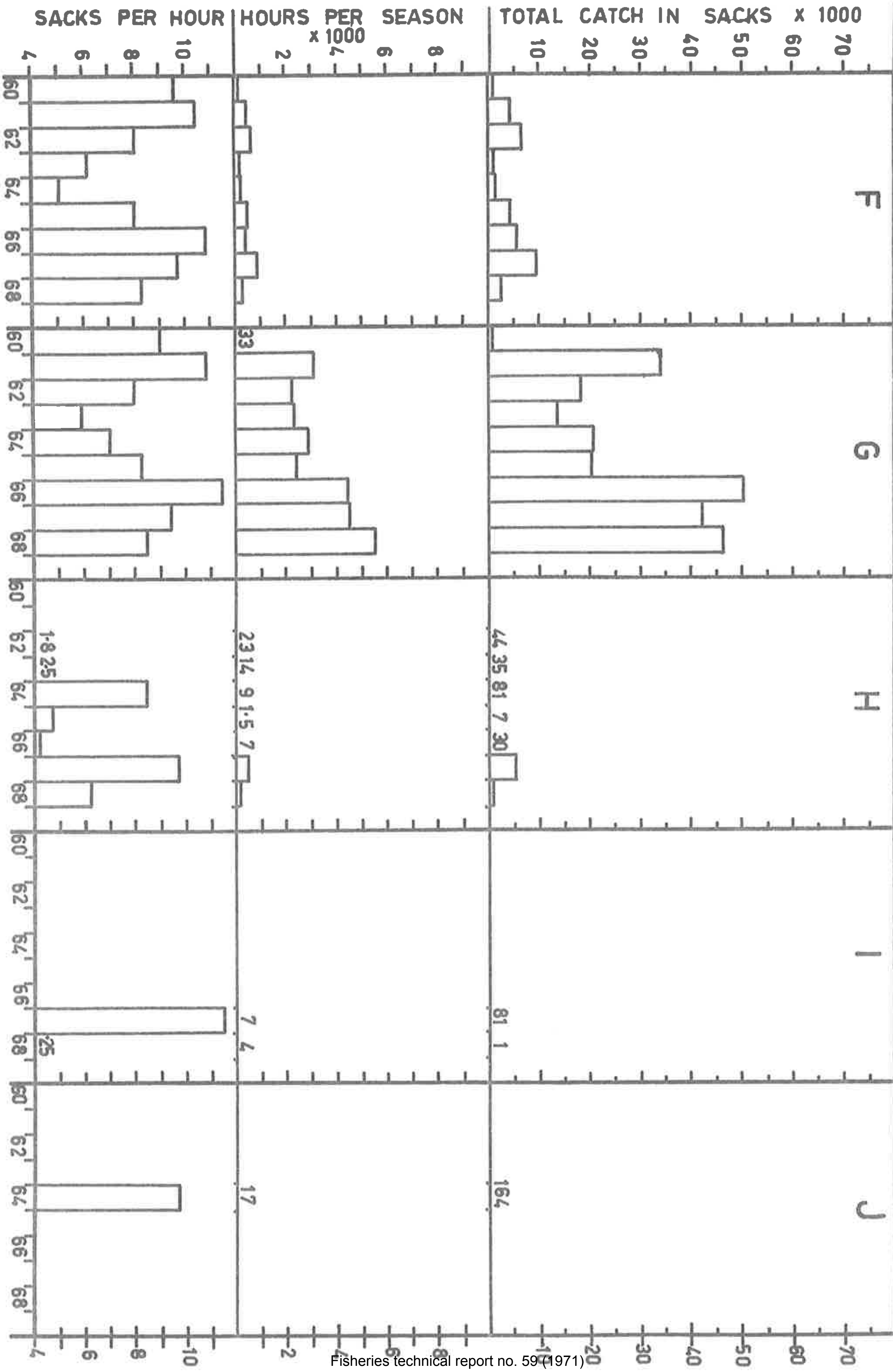
FIG. 23


FOVEAUX STRAIT OYSTER PRODUCTION. 1913 -1968.
180
160
140
120
100
80
60
25
20
15
10
5
1935
1940
1945
1950
1955
1960
1965



COMMERCIAL CATCH STATISTICS AREAS A and B 1950-68

FIG. 24



OYSTER AREA STATISTICS — FOVEAUX STRAIT. 1960-68. FIG. 26

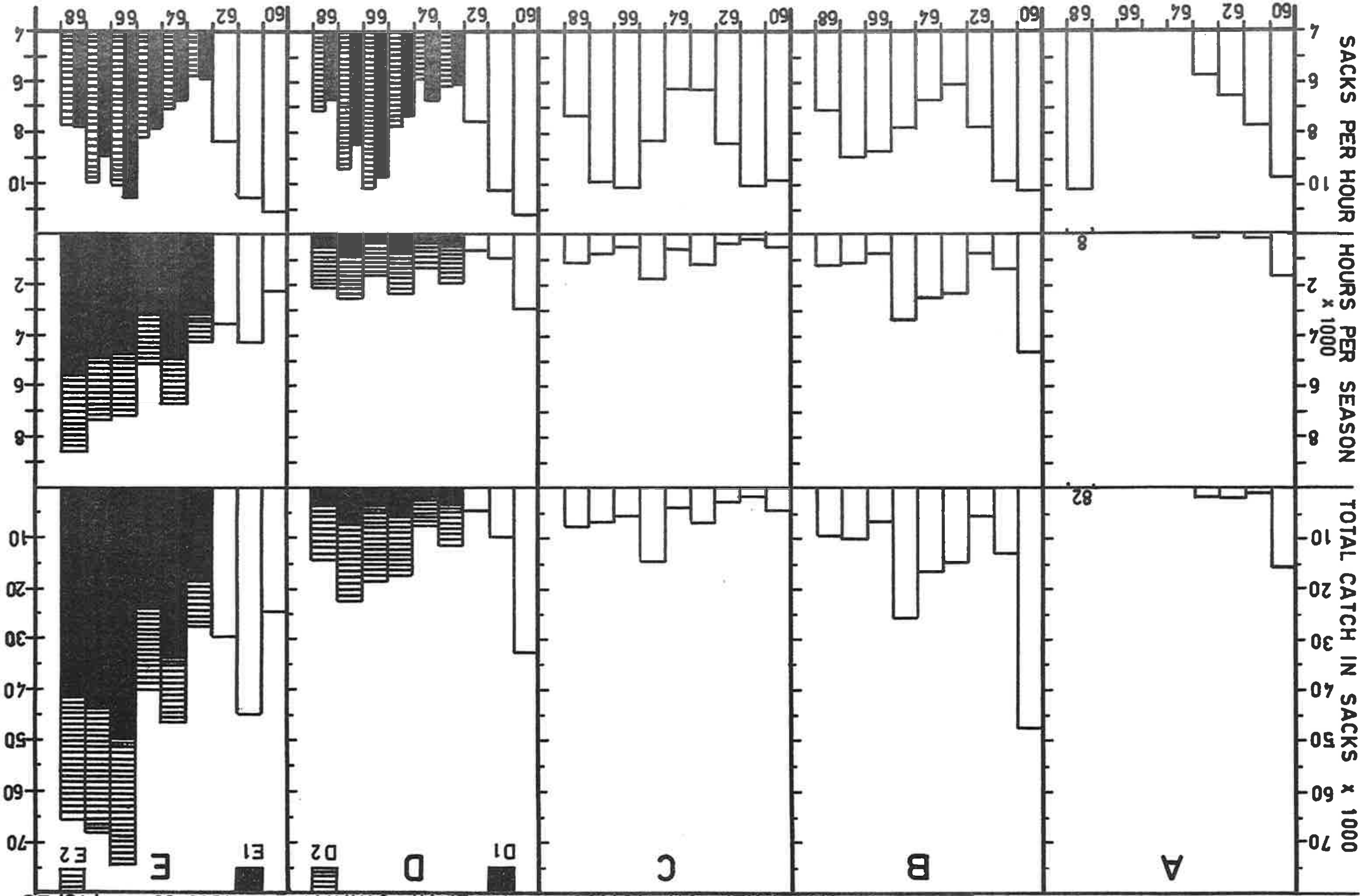
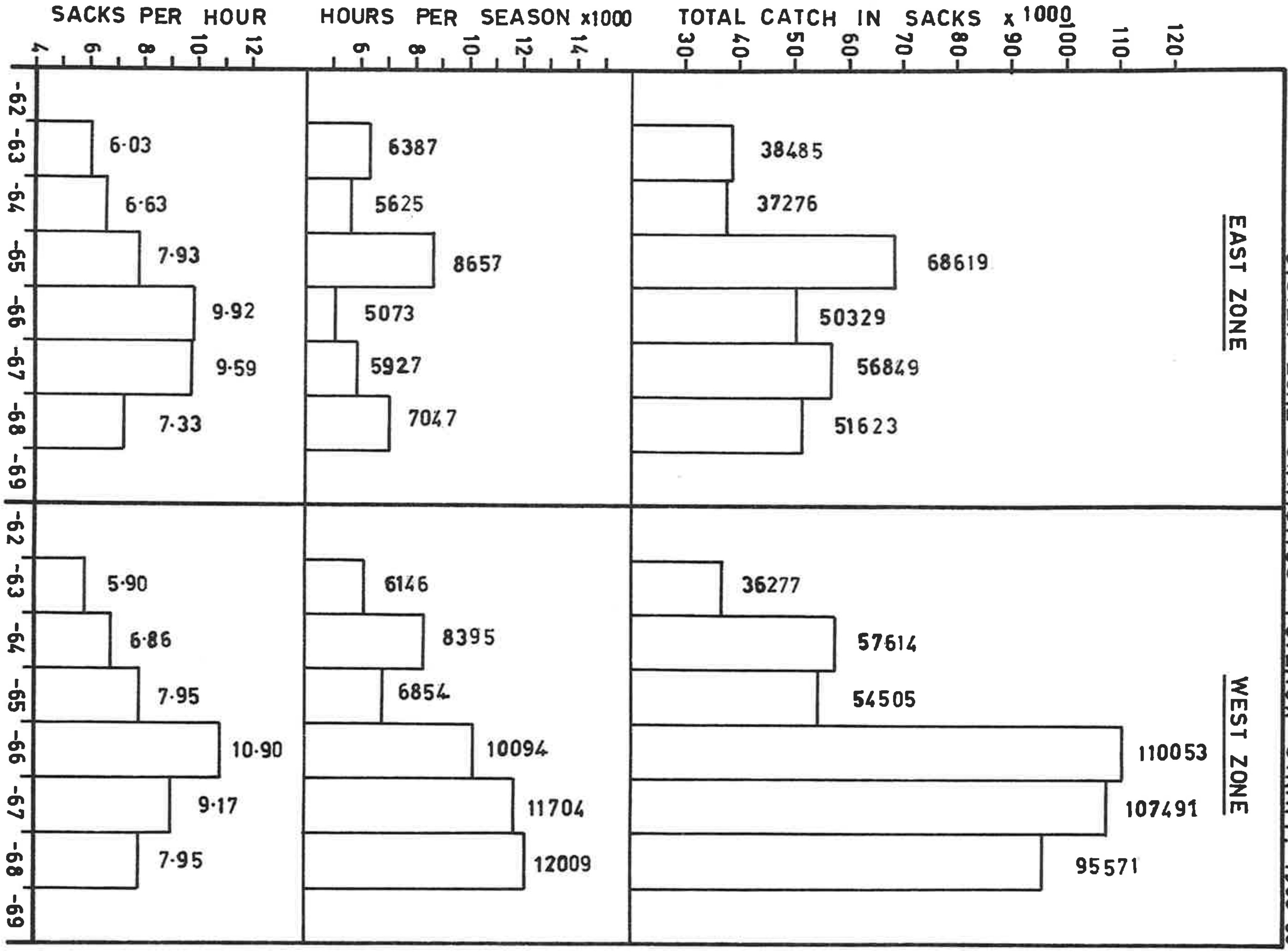


FIG 25 OYSTER AREA STATISTICS — FOVEAUX STRAIT, 1960-68


OYSTER ZONE STATISTICS - FOVEAUX STRAIT, 1963-68
SACKS PER HOUR
HOURS PER SEASON x1000
TOTAL CATCH IN SACKS x 1000
EAST ZONE
WEST ZONE
-62
-63
-64
-65
-66
-67
-68
-69
6·03
6·63
7·93
9·92
9·59
7·33
6387
5625
8657
5073
5927
7047
38485
37276
68619
50329
56849
51623
5·90
6·86
7·95
10·90
9·17
7·95
6146
8395
6854
10094
11704
12009
36277
57614
54505
110053
107491
95571
FIG. 27

APPENDICES

BOAT CHARTERS

APPENDIX 1

Vessel Used	Date	Available Charter Days	Sea Time Days	Stations	Nature of Work
Viti Freighter N.Z.O.I. D.S.I.R. Charter	24.5.60 to 1.6.60	9	7	O.I. 5 mile grid B215 to B278 Grab 1-5	Standard sampling. Hydrology. Grab sampling
Matai Marine Dept Ferry	23.6.60 to 1.9.60	17	9	1 mile grid 1 - 72	Standard sampling. Grab and survey dredge.
Marjorie Maude Fishing Vessel	23.8.60 5.9.60 to 16.12.60 16.1.61 to 17.7.61	1	1	1 mile grid 73 to 535 Diving 1-6 U.W.Photography 1-19	Survey - standard sampling. Growth. Settlement. Hydrology Oyster density.
Toiler Oyster Boat	2.10.61 to 10.11.61	29	14	Dredge Calibration 1-53	Comparison survey commercial dredge. Hydrology. Plankton. Growth. Settlement.
Medora Oyster Boat	15.11.61 to 20.12.61	26	18	Dredge Calibration 54-100	Dredge comparison. Hydrology Plankton.
Marjorie Maude Fishing Vessel	17/18.5.62 31.7.62 to 24.8.62	2 20	2 12	1 mile grid 536-564 Fill-in F1-F27 Diving 7-10	Survey - standard sampling. Biology. Hydrology. Oyster distribution and density.
Ariel Oyster Boat	15.1.62 to 2.2.62	15	11	Dredge Calibration 101-123	Dredge comparison. Spawning. Growth settlement. Hydrology.

BOAT CHARTERS

APPENDIX 1 (Cont'd)

Vessel Used	Date	Available Charter Days	Sea Time Days	Stations	Nature of Work
Lucy Star Oyster Boat	15.10.62 to 2.11.62	14	10	Commercial 1-46	Ground evaluation. Spawning. Biology. Hydrology.
Karaka Oyster Boat	26.11.62 to 21.12.62	20	15	Diving 11-21	Oyster distribution and density. Dredge sampling. U.W. photography
Waitangi Oyster Boat	21.1.63 to 8.2.63	15	9	Diving 22-24 Commercial 47-79	Oyster density. Observation of dredges. Ground evaluation. Hydrology.
Catherine Oyster Boat Stern Dredger	19.6.63 to 9.7.63	15	11	Diving 25-30	Oyst r density. Dredge efficiency. Ground evaluation.
Hakuturi Forest Service Launch	6.8.63 to 8.8.63	3	3	-	Survey potential oyster cultivation areas - Stewart Island
Nightingale Fishing vessel	26.8.63 to 30.8.63	5	4	-	Growth studies.
Karaka Oyster Boat	4.11.63 to 22.11.63	15	6	Diving 31 Standard Sampling 1-3	Oyster density. Dredge efficiency. Spawning.
Miro Oyster Boat	10.2.64 to 14.2.64	5	5	Diving 32-35	Oyster density. Dredge efficiency. Populations. Spawning.
Harmony Oyster Boat	13.5.64	1	1	Diving 36	Oyster distribution and density. Testing new dredge.

APPENDIX 2

DIMENSIONS AND WEIGHTS OF SELECTED OYSTER SAMPLES FROM SURVEY DREDGE STATIONS

AREA A

	Shell Dimensions (in cm.) Length x Width x Depth	Weight (in gm.) Whole	Shell	Flesh
Station 101 13/9/60	9½ - 7 - 2½	147	124	20
	9½ - 7½ - 2½	145	123	19
	9 - 5½ - 2	83	67	13
	9½ - 6½ - 1½	67	54	13
	9 - 5½ - 2½	72	60	12
	9 - 5½ - 2	61	50	11
	9½ - 5½ - 2	72	60	12
	6½ - 5½ - 1½	53	46	7
	5½ - 5 - 2	50	40	10
	5 - 3 - 1	25	20	5
Station 102 13/9/60	8 - 6½ - 1½	56	48	8
	9½ - 6½ - 2½	110	98	12
	6½ - 5 - 2	62	52	10
	5½ - 4½ - 1½	50	43	7
	9 - 6½ - 2	67	59	8
	8 - 5½ - 1½	52	47	5
	8 - 5½ - 2	67	59	8
	4½ - 4 - 1½	22	19	3
	4½ - 4 - 1	19	17	2
	4½ - 4 - 1½	21	19	2
Station 98 12/9/60	9 - 6½ - 2	56	47	9
	9 - 5½ - 2	60	50	10
	9½ - 6½ - 2	72	60	12
	7 - 6½ - 2	50	40	10
	9 - 7 - 2	66	54	12
	8 - 5½ - 2½	64	51	12
	6½ - 5½ - 1½	41	36	5
	4 - 4 - 1½	22	19	3
	4½ - 2½ - 1	16	14	2
	6½ - 5 - 1½	32	28	4

	Shell Dimensions (in cm.) Length x Width x Depth	Weight (in gm.) Whole	Shell	Flesh
Station 32 19/6/60	9 - 7½ - 2	72	59	13
	9 - 7 - 4	62	53	9
	8 - 6 - 2½	75	61	13
	9 - 7 - 2	60	52	8
	7½ - 5½ - 2½	72	61	11
	7½ - 5 - 2	65	55	10
	7 - 5 - 2	49	39	9
	6½ - 5 - 1½	32	25	7
Station 60 29/8/60	8 - 6½ - 1	58	43	10
	7 - 6½ - 2	57	45	10
	7½ - 5½ - 2	50	39	9
	8½ - 7 - 1	55	42	10
	7 - 5½ - 2	40	30	8
	6½ - 5 - 1	30	21	7
	7½ - 5½ - 2	40	20	6
	6½ - 5 - 2	25	21	4
	7 - 5 - 1	33	26	6
	5 - 4 - 1	14	12	2

AREA C

Appendix 2 cont.

	Shell Dimensions (in cm.) Length x Width x Depth	Weight (in gm.) Whole	Shell	Flesh
Station 65 30/8/60	9 - 7½ - 2	79	65	13
	7½ - 6½ - 1	34	29	4
	6½ - 4½ - 1	19	16	3
	9 - 7½ - 2	83	67	13
	9 - 7½ - 2	111	83	26
	9½ - 6½ - 2	87	72	14
	8½ - 6½ - 2	67	54	10
	8½ - 7 - 1	73	55	14
	5½ - 5 - 1	21	17	3
	5 - 5 - ½	11	9	2
Station 118 19/9/60	9½ - 8 - 2½	136	116	20
	8½ - 6½ - 2	70	60	10
	7½ - 7 - 1	50	41	8
	8½ - 6½ - 2½	78	63	13
	7½ - 5½ - 2	43	33	10
	7½ - 6½ - 2½	70	61	9
	7½ - 6½ - 1	42	37	5

	Shell Dimensions (in cm.) Length x Width x Depth	Weight (in gm.) Whole	Shell	Flesh
Station 149 23/9/60	8½ - 7½ - 2	68	58	10
	9½ - 9 - 2	86	74	12
	9 - 7 - 1	51	46	5
	6½ - 6½ - 1	25	20	5
	7 - 5 - 1	22	18	4
Station 150 23/9/60	7 - 5 - 1	37	30	7
	7 - 5½ - 1	24	20	4
	6½ - 5 - 2	31	25	5
	5½ - 5½ - 2	27	23	4

AREA D2

	Shell Dimensions (in cm.) Length x Width x Depth	Weight (in gm.) Whole	Shell	Flesh
Station 170 29/9/60	8½ - 5½ - 2	73	60	13
	9½ - 5½ - 2	68	58	10
	7½ - 6½ - 1	50	41	9
	8½ - 5½ - 2	48	40	8
	7½ - 5 - 1	36	30	6
	5½ - 5 - 1	22	19	3
	5½ - 4½ - 1	16	14	2
Station 34 20/6/60	9½ - 8½ - 2½	117	89	20
	9 - 7½ - 2½	89	69	19
	9½ - 6½ - 2½	109	88	15
	10 - 8½ - 2	96	70	19
	9½ - 6½ - 2½	65	50	14
	10 - 9½ - 2½	116	80	25
	7½ - 6½ - 2½	67	54	11
	7½ - 5 - 2½	50	42	8
	6½ - 5 - 2	33	28	4
	5½ - 5 - 1	16	15	1

	Shell Dimensions (in cm.) Length x Width x Depth	Weight (in gm.) Whole	Shell	Flesh
Station 348 8/12/60	8½ - 7 - 1½	83	73	7
	7½ - 6½ - 2	80	69	10
	7 - 6 - 1½	41	35	5
	6½ - 5½ - 1	27	22	5
	7½ - 6½ - 1	35	29	6
	6 - 5½ - 1	20	14	5
Station 218 14/10/60	7½ - 5½ - 1	47	39	8
	7½ - 6½ - 1	41	35	6
	7½ - 5½ - 1	40	36	4
	7½ - 5½ - 2	57	49	8
	6½ - 5 - 1	35	31	4
	7 - 5½ - 1	40	34	6
	6½ - 5 - 1	25	21	4
Station 308 24/11/60	8 - 6½ - 1	73	53	20
	8 - 8 - 1	58	48	10
	9 - 8½ - 1	73	52	20
	7 - 6 - 1½	61	47	14
	6½ - 5½ - 1	33	26	7
	5 - 4½ - 1	17	13	4
Station 266 16/11/60	7½ - 6 - 1	41	35	6
	6½ - 5 - 1	21	17	4
	6½ - 5 - 1½	20	17	3
	6½ - 5 - 1½	27	24	3
	6½ - 5 - 2	30	24	6
	6 - 5 - 1½	27	24	3
	5½ - 4½ - 1	18	14	4
	6 - 4½ - 1½	30	26	4
	6 - 4½ - 1	22	19	3
	5 - 4 - 1	9	7	2

	Shell Dimensions (in cm.) Length x Width x Depth	Weight (in gm.) Whole	Shell	Flesh
Station 359 13/12/60	11½ - 9½ - 1½	145	120	22
	9 - 7½ - 2½	160	135	20
	7½ - 7 - 1½	64	51	12
	8½ - 7½ - 1½	77	62	15
	8½ - 4½ - 1½	56	46	9
	7 - 4½ - 2	40	31	8
	6½ - 5 - 1	21	18	3
	6 - 4½ - 1	20	16	3
Station 52 22/8/60	7½ - 6½ - 2	60	44	10
	9½ - 7 - 2	106	85	13
	7½ - 6½ - 2	64	54	9
	7½ - 5½ - 2	55	44	10
	7½ - 5 - 1	43	34	8
	5½ - 4 - 1	19	14	3
	5½ - 5 - 1	23	16	4
	5½ - 4½ - 1	15	11	2
	5 - 3 - 1	13	10	2
	5½ - 5 - 1	23	17	3
Station 393 24/1/61	9 - 8 - 1½	105	85	20
	9 - 6 - 1½	102	90	12
	8 - 5½ - 1½	72	62	10
	7 - 6 - 1	60	51	9
	7 - 6 - 1	58	50	8
	6½ - 5 - 1	24	20	4
	6 - 4½ - ½	18	16	2
	5 - 4 - ½	16	14	2
	5 - 3½ - ½	15	13	2
Station 119 19/9/60	8½ - 7 - 2	71	57	13
	7 - 5½ - 2½	71	62	9
	7½ - 5½ - 2½	73	58	8
	7½ - 5 - 2	52	44	6
	7 - 5 - 2	61	48	12

AREA F

Appendix 2 cont.

	Shell Dimensions (in cm.) Length x Width x Depth	Weight (in cm.) Whole	Shell	Flesh
Station 245 31/10/60	7½ - 6 - 2	75	61	11
	8½ - 6 - 2	52	40	10
	7½ - 6 - 1½	57	40	14
	7½ - 6½ - 1	47	38	8
	8 - 6½ - 2	70	60	8
	6½ - 6 - 1	38	32	5
	6½ - 5 - 1	25	21	4
	6½ - 5½ - 1	33	27	5
	5½ - 5½ - 1	36	30	5
Station 292 21/11/60	8½ - 6½ - 1½	95	70	12
	8½ - 7 - 2	73	58	15
	7 - 6 - 1½	42	33	9
	7½ - 6 - 1	35	28	7
	7 - 6 - 1	32	25	5
	6 - 4½ - 1	20	15	5
	4½ - 4½ - 1	11	9	2

AREA G Appendix 2 cont.

	Shell Dimensions (in cm.) Length x Width x Depth	Weight (in gm.) Whole	Shell	Flesh
Station 261 9/11/60	8½ - 7 - 1½	43	35	5
	8 - 6 - 1½	42	35	5
	6 - 4½ - 1	21	17	3
	6½ - 5½ - 1	22	18	3
	6 - 4½ - 1	27	21	4
	6 - 4 - 1	17	12	3
Station 311 24/11/60	9 - 7½ - 1½	130	110	17
	9 - 8 - 1½	75	65	10
	7½ - 7 - 1½	75	59	10
	8 - 6½ - 1½	65	52	13
	8 - 6 - 1	52	43	9
	7 - 5½ - 1	38	31	7
	6½ - 5½ - 1	28	22	6
	5 - 4½ - ½	13	10	3
Station 258 7/11/60	10 - 8 - 2	125	100	23
	8½ - 7 - 1½	66	52	11
	7 - 6½ - 1	40	34	6
	7½ - 5½ - 1½	59	51	7
	7½ - 7 - 1	37	32	5
	6½ - 6 - 1	37	32	5
	5½ - 5½ - 1	27	24	3
	7½ - 5½ - 1½	26	22	4
Station 368 17/1/61	9 - 7½ - 1	55	44	11
	7 - 5 - ½	26	21	5
	8 - 6½ - 1½	43	35	8
	7½ - 7 - 1½	54	43	11
	7 - 5 - ½	25	22	3
	9½ - 7 - 1½	84	69	15
	6½ - 4½ - 1	14	10	4

AREA G

	Shell Dimensions (in cm.) Length x Width x Depth	Weight (in gm.) Whole	Shell	Flesh
Station 325 28/11/60	9 - 7 - 1½	90	65	17
	8 - 6½ - 1½	90	67	18
	7½ - 6 - 1	47	35	10
	9 - 7 - 1	88	68	19
	7½ - 6½ - 1	36	29	7
	7 - 5 - 2	51	40	7
	7½ - 6 - 1	45	34	10
	7 - 5½ - 1½	50	40	8
	5 - 4½ - 1	18	15	3
	5½ - 4½ - 1	22	19	3
Station 328 30/11/60	7½ - 6 - 1½	57	47	6
	7 - 5½ - 1	33	26	6
	6 - 5 - 1	29	22	6
	6 - 5½ - 1	31	24	6
	7 - 5½ - ½	41	33	6
	5 - 4½ - 1	17	14	3
	5 - 3½ - 1½	17	13	4

AREA H

	Shell Dimensions (in cm.) Length x Width x Depth	Weight (in gm.) Whole	Shell	Flesh
Station 366 16/12/60	8 - 6 - 1½	56	42	11
	8 - 6½ - 1½	57	41	10
	8 - 6 - 1½	53	39	9
	6½ - 6 - 1	25	20	5
	4 - 3 - ½	7	5	2

AREA I

	Shell Dimensions (in cm.) Length x Width x Depth	Weight (in gm.) Whole	Shell	Flesh
Station 113 16/9/60	7½ - 7 - 2½	85	72	13
	9 - 7 - 3	139	118	21
	6½ - 5 - 2	41	37	4

AREA J

	Shell Dimensions (in cm.) Length x Width x Depth	Weight (in gm.) Whole	Shell	Flesh
Station 333 1/12/60	8 - 6 - 2	62	50	12
	8 - 6½ - 1	64	53	11
	8½ - 7½ - 1	85	65	19
	6 - 5 - 1	23	19	4
	6½ - 5½ - 1	33	27	6

APPENDIX 3

DREDGE CALIBRATION DATA

STATION	Number of Takeable Size Oysters				Commercial Evaluation of Ground
	Survey Dredge		Commercial Dredge		
	5 Min	10 Min	5 Min	10 Min	
1	24	15	451	798	Average - good
2	15	27	36	160	Low dredge efficiency poor *Pyura*
3	3	1	208	117	Poor
4	9	20	479	1214	Good
5	3	7	821	790	Average - good
6	8	10	669	879	Average - good
7	39	11	591	1022	Very good
8	4	0	145	108	Poor
9	0	1	4	4	Very poor
10	25	14	536	718	Average - good
11	26	34	743	1178	Very good
12	20	7	276	364	Average
13	29	17	76	42	Poor
14	1	3	70	98	Poor
15	3	7	17	46	Poor
16	32	53	383	525	Average - good
17	11	10	200	110	Poor - average
18	20	24	64	501	Average -good, *Pyura*
19	10	26	625	671	Average - good
20	17	7	79	14	Poor
21	14	24	13	23	Poor-low dredge efficiency dense fauna.
22	67	30	574	167	Average - good
23	61	30	1112	1120	Very good
24	0	1	33	30	Poor
25	17	0	353	539	Average - good
26	13	7	45	82	Poor
27	2	6	140	90	Poor -dense fauna
28	29	46	132	82	Poor -dense fauna
29	21	2	88	94	Poor
30	1	-	350	-	Average.

DREDGE CALIBRATION DATA

STATION	Number of Takeable Size Oysters: Survey Dredge 5 Min	Survey Dredge 10 Min	Commercial Dredge 5 Min	Commercial Dredge 10 Min	Commercial Evaluation of Ground
31	63	69	1098	187	Very good in patches
32	2	2	78	49	Poor
33	10	100	605	768	Good
34	2	3	33	98	Poor
35	79	2	137	114	Dense fauna-close to good ground
36	24	100	778	1820	Very good-many attached oysters
37	0	1	41	42	Poor -many *Pyura*
38	0	0	1	0	Poor
39	5	-	0	-	Poor
40	12	3	30	160	Poor -average, dense fauna

STATION	Number of Takeable Size Oysters: Survey Dredge 5 Min.	5 Min.	5 Min.	Commercial Dredge 5 Min.	5 Min.	5 Min.	Commercial Evaluation of Ground
41	21	15	0	327	297	123	Poor to average many attached oysters.
42	16	10	16	655	607	206	Good-some Pyura Tow "C"
43	19	14	16	460	378	342	Average-good
44	14	18	11	482	442	346	Average-good
45	3	19	15	50	371	412	Average-good
46	20	16	17	253	160	270	Average-large oysters
47	34	23	147	335	389	417	Good in patches
48	37	8	37	228	281	358	Average -good

STATION	Number of Takeable Size Oysters						Commercial Evaluation of Ground
	Survey Dredge		Commercial Dredge				
	5 Min.	5 Min.	5 Min.	5 Min.	5 Min.	5 Min	
49	27	131	53	120	394	374	Good in patches dense fauna
50	2	3	80	1	0	1040	A & B -dense fauna. C-V.G.
51	1	0	0	24	19	71	Poor-Many dead oysters
52	12	31	22	153	717	275	Average -good
53	22	20	7	396	306	264	Average -good for this area
54	4	0	2	78	40	92	Poor
55	6	2	1	127	137	77	Average. Well worked ground.
56	18	9	16	534	190	330	Average
57	16	12	9	63	199	83	Low dredge efficiency many *Pyura*.
58	41	64	37	684	540	463	Good
59	42	53	44	383	549	382	Average - good
60	63	43	39	130	698	920	Good
61	69	67	14	333	775	542	Good
62	6	68	68	5	264	802	A dense fauna C good ground
63	144	144	64	207	775	687	Good ground dense fauna patches
64	60	14	72	510	206	936	Good
65	33	4	3	235	174	33	Poor average dense fauna
66	0	34	0	0	467	0	A & C dense fauna B good
67	3	18	30	311	158	462	Dense fauna, good in patches.
68	106	17	11	249	412	332	Dense fauna good in patches
69	66	31	75	397	84	671	Dense fauna good in patches

STATION	Number of Takeable Size Oysters: Survey Dredge 5 Min.	5 Min.	5 Min.	Commercial Dredge 5 Min.	5 Min	5 Min.	Commercial Evaluation of Ground.
70	18	28	13	506	619	114	Good previously uncxploited.
71	1	11	0	31	182	5	Poor
72	7	58	8	80	365	258	Average dense fauna
73	21	7	12	378	66	155	Average small oysters
74	32	298	53	394	782	454	Good in patches Dense Fauna
75	10	90	40	289	883	472	Good
76	3	12	3	5	277	11	Poor
77	25	54	9	374	708	114	Good in patches Dense fauna.
78	2	0	5	156	2	11	Poor Dense fauna
79	28	38	38	489	649	645	Good Some dense fauna
80	12	21	24	446	510	74	Good dense fauna patches
81	10	8	10	167	12	137	Poor dense fauna
82	3	7	9	44	436	353	A poor B & C average.
83	50	0	11	956	30	289	A good B poor C average
84	57	24	54	86	752	1056	C very good near dense fauna
85	3	3	28	24	13	571	A & B poor C good
86	5	27	7	47	245	45	A & C poor, B-average old shells
87	0	0	0	0	20	11	Poor-mainly old shells
88	7	2	12	196	21	24	Poor shels and dense fauna
89	3	0	1	11	6	5	Poor sparse fauna
90	4	6	2	17	33	14	Poor little in dredge.

STATION	Number of Takeable Size Oysters: Survey Dredge 5 Min.	5 Min.	5 Min.	Commercial Dredge 5 Min.	5 Min	5 Min.	Commercial Evaluation of Ground
91	0	0	0	18	0	0	Poor shell pebbles
92	0	1	1	0	9	33	Few oysters mainly shell
93	1	4	71	8	71	674	C-good Dense fauna
94	89	115	10	726	778	573	Good
95	89	85	129	463	579	501	Good, but many Limit size oysters
96	42	26	22	569	526	366	Good Well worked ground
97	12	14	18	689	316	389	Average good Well worked
98	28	71	38	314	367	203	Average good Well worked
99	4	1	5	47	2	41	Very dense fauna few good oysters
100	0	4	1	4	31	2	Poor mainly old shell
101	5	0	10	28	36	43	Poor dense fauna patches
102	4	6	14	2	57	10	Poor dense fauna
103	6	26	0	648	17	56	A good dense fauna
104	37	35	20	574	542	512	Good
105	11	2	0	17	25	209	Poor many old shells
106	14	0	5	149	0	156	Poor
107	1	0	38	0	0	169	C-average dense fauna area
108	8	2	10	33	3	54	Poor
109	4	1	11	109	14	461	A & B poor C Average.

STATION	Number of Takeable Size Oysters Survey Dredge 5 Min.	5 Min.	5 Min.	Commercial Dredge 5 Min.	5 Min.	5 Min.	Commercial Evaluation of Ground
110.	113	147	6	884	824	155	A & B Good. C- dense fauna area
111	0	0	0	46	0	0	Poor A few old oysters.
112	23	5	1	150	102	19	Average -dense fauna
113	72	37	7	705	417	204	A good B Average C dense fauna
114	0	5	62	7	52	142	Poor average
115	6	77	70	385	1067	684	A -average B & C very good
116	1	1	16	62	25	1	Poor dense fauna
117	1	17	0	31	186	12	Poor average
118	7	1	9	60	191	62	Poor average some good oysters
119	29	43	31	517	404	415	Good
120	40	47	90	318	447	628	Good
121	10	13	25	22	32	65	Many *Pyura* oysters beneath
122	0	0	0	22	5	7	Poor few good oysters
123	0	0	0	0	0	0	No oysters many large *Pyura*

APPENDIX 4

Underwater Photography with automatic camera. No of oysters per exposure.

In view of the difficulties in distinguishing live and dead oysters on some of the photographs, the data in Table 5 gives only an approximate estimate of the surface density of oysters. Question marks indicate poor definition. Each exposure covered an area of almost one square yard.

Area	Station Map 5	Number of Oysters on Photograph Total	Takeable Size	Bottom
A	1	6	3	Pebble-shell
		5	2	"
		8	3	"
		2	1	"
		6	3	"
A	10	5	2	Pebble-shell
		5	1	"
		7	2	"
		3	2	"
		1	1	"
A	11	8	1	Sand Shell pebble
		7	3	"
		8	3	"
		7	5	"
		3	0	"
A	12	7	3	Pebble-shell
		?	?	*Pyura*
		?	?	"
A-B	3	11	5	Pebble-shell
		?	?	*Pyura*
A-B	13	20	12	Sand-shell
		15	11	"
		25	15	"
		27	13	"
		20	12	"

Area	Station Map 5	Number of Oysters on Photograph Total	Takeable Size	Bottom
B	4	9	6	Pebble-shell
		?	?	Pyura
B	14	0	0	Pebble-shell
		0	0	"
		1	0	"
		1	1	"
		0	0	"
		0	0	"
B	15	3	1	Pebble-shell
		4	1	"
		7	5	"
		8	4	"
		8	5	"
El	7	?	?	Sand-shell
		10	4	"
El	8	3	0	Sand-shell
		?	?	"
		2	0	"
		2	1	"
		3	0	"
El	9	5	3	Pebble-shell
		2	0	"
		2	1	"
		15	8	"
		10	5	"
		5	3	"

Area	Station Map 5	Number of Oysters on Photograph Total	Takeable Size	Bottom
F-H	5	?	?	Pebble-shell
		0	0	"
		6	2	Sand-shell
		0	0	Clean sand
G	2	5	3	Sand-shell
		8	4	"
		7	4	"
		15	8	"
G	6	30	12	Sand-shell
G	16	11	5	Sand-shell-pebble
		22	7	"
G	17	?	?	Dense fauna
		?	?	"
		?	?	"
		?	?	"
		?	?	"
G	18	50	10	Sand-shell-pebble
		100	20	"
		40	15	"
		20	10	"
		25	15	"
		20	10	"
G	19	5	2	Sand-shell-pebble
		15	7	"
		60	25	"
		50	15	"

DIVING AND DREDGE RESULTS 1960-1964

APPENDIX 5

Area	Station	Date	Diving: Total takeable No. oysters sq/yd Total	Takeable	Depth in sediments	Bottom	Dredging: Takeable oysters in dredge 5 min survey	10 min commercial	Evaluation	Ref. sheet
A	4	28.9.60	18	12	To 4"	Loose sand-shell-pebble several small individual oysters	181	-	Good, well worked ground	D
	5*	28.9.60	68	24	To 5"	Loose sand-shell-pebble-stone. Individual oysters	-	-	Good	E
	7	16.8.62	7	3	Surface	Loose-shell-pebble Random oyster distribution	24	438	Well worked oyster ground	G
	11	29.11.62	21	9	To 2"	Sand-shell-pebble several attached 'wing' oysters	76	157	Good, but patchy dense fauna in places	D1
	20	10.12.62	1	1	Surface	Firm sand-shell pebble. Sparse fauna	3	684	Only average, well worked in the past	D10
	22	5.2.63	6	2	Surface	Firm pebble sand, some shell, several 'wing' oysters	-	194	Poor-average, well worked in the past	Test Tow 24

APPENDIX 5 (Cont'd)

Area	Station	Date	Diving: Total takeable No. oysters sq/yd Total	Diving: Total takeable No. oysters sq/yd Takeable	Depth in sediments	Bottom	Dredging: Takeable oysters in dredge 5 min survey	Dredging: Takeable oysters in dredge 10 min commercial	Evaluation	Ref. sheet
	33	11.2.64	1	1	Surface	Pebble over sand sparse fauna	-	420	Not commercial grade - well worked in the past	D23
	36	13.5.64	1	1	Surface	Pebble-stone sand, undulating bottom-ridges 1" high, 10' apart	-	320	Not commercial grade	D26
B	6	29.9.60	15	8	Surface	Loose sand-shell-pebble. Individual oysters	-	-	Good	F
B	8	17.8.62	8	5	To 3"	Loose sand-shell-pebble. Random oyster distribution	78	-	Good, well-worked oyster ground.	H
B	10	22.8.62	5	3	Surface	Loose shell-pebble. Random oyster distribution.	12	318	Not commercial grade	J
B	12	30.11.62	24	7	Surface	Sand-shell-pebbles many "wing" clusters	42	677	Good, well worked ground.	D2
B	13	30.11.62	24	6	Surface	Sand-shell-pebble, several "wing" clusters	26	917	Good, well-worked ground	D3

APPENDIX 5 (Cont'd)

Area	Station	Date	Diving: Total takeable No.oysters sq/yd Total	Takeable	Depth in sediments	Bottom	Dredging: Takeable oysters in dredge 5 min survey	10 min commercial	Evaluation	Ref. sheet
B	18	7.12.62	8	6	To 2"	Sand-shell-pebble. Random oyster distribution - several "wing" oysters.	30	692	Well worked ground. Has maintained productivity.	D8
B	24	8.2.63	28	9	To 1"	Sand-shell, few pebbles, several "wing" oysters.	-	960	Well worked good ground.	Test Tow D.14
B	30	3.7.63	5	2	Surface	Sand-shell-pebble. Random oyster distribution.	-	300	Not commercial grade.	D20
C	1	28.8.60	-	-	-	Clean firm sand	-	-	-	A
C	2	23.8.60	-	-	-	Foul ground	-	-	-	B
C	3	23.8.60	17	10	Surface	Sand-shell-pebble groups of oysters.	-	-	Good	C
C	9	21.8.62	2	1	To 2"	Loose shell-pebble. Random oyster distribution.	13	231	Not commercial grade.	I

APPENDIX 5 (Cont'd)

Area	Station	Date	Diving: Total takeable — No. oysters sq/yd Total	Takeable	Depth in sediments	Bottom	Dredging: Takeable oysters in dredge — 5 min survey	10 min commercial	Evaluation	Ref. sheet
C	29	2.7.63	7	2	To 1"	Pebble overlying sand. Sparse fauna. Random oyster distribution.	-	310	Not commercial grade.	D19
C	31	31.11.63	4	1	Surface	Pebble-stone over sand. Oyster patchy.	-	970	Average well worked ground.	D21
C	34	13.2.64	17	9	Surface	Pebble-stone over sand. Oysters well distributed.	-	1,210		
D1-D2	16	6.12.62	59	10	To 2"	Sand-shell-pebble many oysters in depressions, many "wing" oysters.	41	1,061	Very good dredges miss oysters in depressions.	D6
D2	17	6.12.62	9	3	To 2"	Sand-shell-few pebbles. Random oyster distribution, several "wings".	16	895	Well worked ground average.	D7

APPENDIX 5 (Cont'd)

Area	Station	Date	Diving: Total takeable – No. oysters sq/yd Total	Takeable	Depth in sediments	Bottom	Dredging: Takeable oysters in dredge – 5 min survey	10 min commercial	Evaluation	Ref. sheet
D2	27	28.6.63	10	3	To 1"	Sand-shell-pebble. Few "wing" oysters.	-	500	Average well worked in the past.	D17
E1	15	3.12.62	16	11	Surface	Sand-shell-pebble. Heavy fauna masses. Groups of oysters mainly individuals.	124	371	Good ground in patches, dense fauna impairs dredge efficiency.	D5
E2	19	7.12.62	8	7	To 3"	Sand-shell-pebble. Random oyster distribution.	47	992	Good ground, rarely worked prior to 1961.	D9
E1	23	7.2.63	1	1	Surface	Firm clean sand, patches of dense fauna.	-	232	Not commercial grade.	
E	26	17.6.63	3	2	To 1"	Sand-shell. Random oyster distribution.	-	600	Average - patchy ground.	D16

APPENDIX 5 (Cont'd)

Area	Station	Date	Diving: Total takeable No.oysters sq/yd Total	Takeable	Depth in sediments	Bottom	Dredging: Takeable oysters in dredge 5 min survey	10 min commercial	Evaluation	Ref. sheet
F	32	10.2.64	15	8	Surface	Pebble-stone over sand. Several "wing" oysters dense fauna patches.	-	1,014	New ground good catches since 1964.	D22
G	14	3.12.62	5	3	To 1"	Sand-shell-pebble. Several "wing" oysters.	96	923	Rarely worked prior to 1961, since proved to be good. Some dense fauna.	D4
G	21	12.12.62	4	2	Surface	Firm sand-much dead shell - patches of dense fauna.	-	909	Average - rarely worked prior to 1964.	D11
G	25	26.6.63	2	2	To 1"	Firm sand-shell dense fauna patches.	-	300	Not commercial grade.	D15
G	35	14.2.64	35	14	Surface	Many oysters in depressions and against sand-banks dense fauna in places.	-	1,730	Unworked ground good catches since.	D25

APPENDIX 5 (Cont'd)

Area	Station	Date	Diving: Total takeable No.oysters sq/yd Total	Takeable	Depth in sediments	Bottom	Dredging: Takeable oysters in dredge 5 min survey	10 min commercial	Evaluation	Ref. sheet
H	28	1.7.63	17	6	To 1"	Pebble shell over-lying sand. Random oyster distribution.	-	480	Previously un-worked. Very good catches since.	D18

COMMERCIAL DREDGING

Data obtained during observations on commercial oyster boats during the surveys. At stations 1-79, the number of takeable size oysters for a one dredge 10 minute tow is shown, and at other stations the daily tally in sacks is shown. Map 6 shows commercial station positions. Field sheet references are:

Sta 1-46 = Spawn St 1-46
Sta 47-79 = Test Tow 1-37

Station	Date	Takeable Oysters in Dredge	Remark
1	15.10.62	489	
2	"	488	
3	"	346	
4	16.10.62	83	
5	"	1,142	
6	"	136	
7	"	2,088	
8	"	70	
9	"	467	
10	17.10.62	80	Dense fauna
11	"	126	
12	"	988	
13	"	0	
14	18.10.62	944	
15	"	0	
16	"	400	
17	"	14	Dense fauna
18	"	749	
19	24.10.62	17	
20	"	21	Dense fauna
21	"	1,874	
22	"	24	
23	"	0	
24	"	0	
25	"	942	
26	26.10.62	163	
27	"	154	

Station	Date	Takeable Oysters in Dredge	Remark
64	5.2.63	594	
65	"	508	
66	"	50	
67	"	194	
68	"	1,422	
69	6.2.63	165	
70	"	732	
71	"	75	
72	7.2.63	20	
73	"	13	
74	"	6	
75	"	25	
76	"	0	
77	"	431	
78	"	232	
79	8.2.63	960	
		Sacks/day 2 dredges	
80	5.9.61	85	
81	29.3.62	131	
82	5.4.62	62	
83 (A & B)	26.4.62	15 + 45 = 60	
84	16.5.62	74	
85 (A & B)	25.5.62	7 + 46 = 53	
86	30.5.62	60	
87 (A & B)	18 7.62	34 + 17 = 51	
88	26.7.62	66	
89 (A & B)	5.6.63	28 + 31 = 59	
90	11.6.63	43	
A-R	13.5.63	Small catches	
S-Y	14.5.63	Poor ground 5 sacks for 2 day trials.	

Station	Date	Takeable Oysters in Dredge	Remark
28	30.10.62	215	
29	"	409	
30	"	364	
31	"	384	
32	"	513	
33	"	988	
34	31.10.62	2	
35	"	111	
36	"	292	
37	"	251	
38	"	278	
39	"	222	
40	"	346	
41	"	0	Dense fauna
42	"	192	
43	"	331	
44	1.11.62	51	Dense fauna
45	"	116	
46	"	30	
47	18.12.62	47	
48	"	81	
49	19.12.62	82	
50	"	13	
51	29.1.63	218	
52	"	254	
53	30.1.63	369	
54	"	129	
55	"	550	
56	"	349	
57	"	137	
58	"	1,170	
59	"	166	
60	"	1,564	
61	31.1.63	318	
62	"	451	
63	"	515	