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NEW ZEALAND MARINE DEPARTMENT

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MOLLUSCAN SURVEY OF THE TAMAKI RIVER, WAITEMATA HARBOUR, AUCKLAND, AUGUST, 1968, AT THE SITE OF THE OTARA GAS-TURBINE POWER STATION

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<u>CONTENTS</u>

I. SUMMARY

The Otara Gas-Turbine Power Station scheme was promoted in 1966. Initial construction is progressing rapidly and the tidal weir and facilities on the shore are nearly complete.

This report summarises information collected during the period up to the time that the power station will commence continuous operation, and to set out in particular the biological data obtained.

During May 1967, preliminary observations were made to ascertain the likely effect of effluent cooling water from the station on any fisheries and marine aquatic organisms in the Tamaki River.

A more recent survey in August, 1968, together with a repeat of laboratory experiments to determine the water temperature tolerance of *Chione stutchburyi*, confirmed the previous observations. It now appears that little interference is to be expected to the present balance.

II. INTRODUCTION

A brief survey of the Tamaki River and Eastern Beaches has disclosed extensive beds of two commercially valuable molluscan species, the common New Zealand cockle *Chione stutchburyi* (Gray), and the pipi *Amphidesma australe* (Gmelin).

The other mollusc present and noteworthy is the Auckland Rock Oyster, *Crassostrea glomerata*. These rock oysters are not harvested due to adverse counts of coliform organisms and their general condition, which is poor. *Chione stutchburyi* is confined to a narrow band in the estuarine waters, with beds up to 100 ft in length and often severed by diverging subsidiary channels. They inhabit the mud-banks and fringes of channels on both sides to a depth of 8 cm - 12 cm. Beds extend from the lower reaches of the Tamaki River (Otara Creek) to the mouth of the river and Eastern Beaches (Cockle Bay). Extensive beds are located on the mud-flats and adjacent sandy mud-banks. *Amphidesma australe* is dispersed throughout the entire length of the Tamaki estuary, but restricted to relatively small 'pockets' and numbers. In comparison with Eastern Beach (Cockle Bay) *A. australe* shares predominance with *C. stutchburyi* in large numbers.

III. TOPOGRAPHY

The general configuration of the Tamaki estuary is shown in Fig. 1 and the locality in Fig. 2.

The Tamaki River is an arm of the sea running more or less westward into an area of low-lying land. At its mouth there is a 1¼ mile expanse of sea water between West Tamaki Head and Musick Pt. at high tide. Between these points the mid-channel length of the estuary is some 10 miles to the Otara Creek. At high-tide the lower 4½ miles are little more than ¼ mile wide. During low-water the estuary is much narrower, being only several hundred yards wide opposite the power station.

The river is shallow and for quite a short distance only the deepest part of the channel, off Pt. England, exceeds 3 fathoms at high tide.

Just west of Panmure Bridge there are two more distinct creeks all running 2-3 miles inland, but emptying together by one main channel almost in the vicinity of the proposed site. The site is situated on the south-west shores of the Otara Creek. This creek penetrates the hinterland of Otara and East Tamaki for approximately two miles. The area is typically estuarine and showing all the characteristics of East Coast configuration (Northland and South Auckland) with many long penetrating finger-like intertidal inlets, mudflats and mangrove-strewn swamp conditions. It is interspersed with ribbon-gutters that trickle from mud-bank mounds into, and link with, a main channel which takes precedence at low-tide when about 80% of the original water is left exposed solely as mud-flats. This is an extremely sheltered bay of water with few disruptive outcrops.

The power station is situated adjacent to a residential area, (Otara), and bounded to the west by the Southern Motorway.

IV. BOTTOM SEDIMENTS

For the main part the substratum appears to be composed of gritty-mud and sand. In some areas, especially along the fringes of mud-banks and creeks, the composition consists of thick soft mud, sepia coloured, and silty in appearance.

The estuarine water contains appreciable quantities of silt at all times.

There is some evidence of erosion and deposition processes progressively changing the character of the shores of the Tamaki River, with a tendency for mud and clay to cover shell and gritty-mud. Such changes will eventually have a strong bearing on the fauna. Soft mud deposited from suspension is derived mainly from the erosion of local muddy shores or from the tidal mud-banks at the mouth and outside the estuary. Soft mud accumulates in the creeks and especially in depressions on the bottom (Panmure Basin).

Considerable excavation and levelling of the terrain in the vicinity of the site has taken place. Heavy silting has been evident recently, causing a thick blanket of colloidal clay to be deposited on the shores in front of the power station. This substance has settled on the mud and formed a layer 1 ft. deep in places. However, it does not appear to have covered the foreshore to any great extent and should not

Tidal waters are generally opaque due to large amounts of suspended particles and sediments that carry out into the estuary from the surrounding mud-flats. A screen of detritus continually drifts to the bottom.

V. THE GAS-TURBINE STATION

It has been proposed to earth-dam the Otara Creek and install a 1.5' (above M.S.L.) tidal weir (Fig. 3), with three flood gates as by-pass valves. The ponding area so created will effectively seal off the creek to navigation and, ultimately, to natural tidal flows. This pond will be filled at each run of the tide, so cooling water for the turbines can be drawn at all times regardless of tidal conditions. The cooling water pumphouse is to be fitted with three inlet pipes and will draw between 11-15 cusecs of water for each machine.

(a) Normal Discharge:

Initial installation is four machines, producing 180,000 K.W. The cooling water cycle involves heated water to be piped to a cooling pond for circulation, and eventually returned to the ponding area for further use.

(b) Peak Discharge:

Eventually when six machines are in operation the cooling water will be heated to 120°F + and piped to the cooling pond and retained until favourable tidal conditions occur, this warm effluent being then discharged directly into the Tamaki River ½ hour before high tide and for approximately 3 hours on an ebb tide (time switch). The float switch control monitors the low tide cycle and keeps the gates closed. Some cooling will take place in both cases within a radius of 400'-900' from the outfall, and once dispersed should not exceed 80°F which is 3°F above the water ambient as measured at a maximum of 77°F. Due to rapid initial mixing this rise in temperature may be quickly lost.

Float tests on an ebb tide have reached as far as the Panmure Bridge, a distance of 3½ miles. With this flow pattern sufficient mixing area should be available to compensate any draw-back of warm water, and ensure that the cooling water intakes are not affected.

The main discharge outlet consists of a 72" diameter concrete pipe some 550 feet in length and driven beneath the bed of the river. This branches out into six smaller vertical shafts, which just protrude above the bottom. The pipes each having sixty 6" diameter holes to facilitate a wider coverage of discharge and mixing. Large grills will be inserted over the exposed openings to prevent silting and clogging debris from entering.

VI. PROCEDURE AND METHOD

Because of the extent of the estuary, (estimated at five and a half square miles), and the time available for low tide sampling periods being restricted, more time was spent in briefly examining as much of the estuary as possible, rather than specifically studying any particular area in detail.

However, sampling stations were sited on most of the main mollusc beds, according to accessibility, and on localised defined gathering grounds of shellfish used by the general public.

Littoral sampling points were selected along the estuary (Fig. 1). At each station two quadrats were dug. Transects were sampled using quadrats marked out with a device constructed of steel angle leaving an impression one foot square. This frame was trodden into the mud and the impression carefully scooped out with a trowel, then sieved through a standard series of mesh apertures. All the molluscs retained were counted and the substrate type, with any notable features encountered, recorded and summarised. (See Table 1).

The common cockle is the most important animal encountered in the littoral fauna, being widely distributed and exceedingly abundant. It is therefore a useful animal for population studies. For these reasons it was selected for detailed investigations to assess the conditions in the estuary, both prior to and after the commissioning of the power station

At each transect line samples were taken and the living animals measured for shell length frequencies. The length measurements taken were smoothed into 5 mm size groupings. (Fig. 4).

VII THE MOLLUSC BEDS

Extensive beds of the common New Zealand cockle *Chione stutchburyi*, and the pipi *Amphidesma australe*, occur throughout the entire area surveyed (Tamaki River, Panmure Basin, and Eastern Beaches).

In May, 1964, what appeared to be widespread natural mortalities in cockle beds occurred during the summer months off Cheltenham and especially Eastern Beaches. The specific cause was not found, but was more prevalent in cockles at Eastern Beach. The widespread decomposition in the beds gave rise to much local comment and lasted over a period of weeks before equilibrium was reached. During the present survey no quantity of cockles could be found on this beach, and there were no signs of any recovery among younger stock. Satisfactory stocks for sampling purposes were obtained, however, in Cockle Bay, approximately two miles from Eastern Beach, southeast of Howick Point.

(a) *Chione stutchburyi*

This cockle is the most abundant mollusc in the estuary and Eastern Beaches. The distribution and abundance of *C. stutchburyi* in the survey area, as recorded from the general survey of the littoral zone in 1967, is shown in Fig. 1. It will be seen that the main concentration occurs along the south shore above and below low water in several areas.

The density in the beds examined varies, but each bed tends to have a relatively uniform density, and to contain animals of similar size, which perhaps in this case denotes a dominant year class. Within some beds, however, dense areas of juvenile cockles 2 mm to 12 mm in length are aggregated especially in sample station 1, positions A and B.

The substrate of the cockle beds varies from relatively firm coarse sandy-mud to soft gritty mud. The smallest cockles tend usually to keep in the soft gritty-mud; the larger cockles usually occurred in the packed coarse sandy-mud. In the latter case this is notable on the Eastern Beaches (Cockle Bay).

It seems significant that the molluscs down-stream, and more especially within the confines of the lower reaches of estuaries and inlets, are small. They appear to be of a stunted and undernourished nature, meats being pallid and body condition overall repugnant to the palate. This is attributed to natural adverse environmental conditions. Incrustation by the small white barnacle, Eliminus modestus and the small browsing mussel Modiolus neozelanicus occurs, with sometimes eight or more barnacles attached to the vertically projecting end of each animal. These two fouling organisms are abundant on station 1 and station 2, positions A and B. Station 3 on the other hand is relatively free from incrustation by them. In contrast with the other areas their meats are firm and the gonads creamy-yellow in appearance.

(b) Amphidesma australe

Several large beds occur near the estuary mouth, and extensive beds on the East Coast where the substrate is composed of clean firm sand and mud.

The small carnivorous gastropod Cominella glandiformis is abundant at the extremities of the Tamaki River, especially in the creeks, with large numbers of the horn shell Zeacumantus lutulentus and scattered Macomona liliana.

VIII. DISCUSSION

Within the estuary there are two main ecological zones in which C. stutchburyi and A. australe occur, the abundance and distribution of these dominant species being determined by the type of sediment sampled rather than by the level of shore.

1. In the lower reaches of the Tamaki River the bottom sediment is often very soft. Foraging mud snails are common, especially Amphibola crenata. Scattered beds of C. stutchburyi occur, although not commercially worthwhile.

They are not considered to be of such good size and quality as those from the East Coast (Cockle Bay), which can be rather heavily covered by barnacles. The majority are hand gathered over the mud flats around Panmure Basin.

2. Over most of the remainder of the area surveyed, the upper reaches of the estuary and Eastern Beaches, the substrate is relatively firm mud and coarse sand. The main C. stutchburyi and A. australe beds occur in this locality, the latter adjacent to the main channel at the mouth of the estuary and nearer the entrance. The strong water currents prevent any deposition and accumulation of mud. These beds are mainly exploited by individuals for local consumption in substantial quantities. This expanse of mud flats might be developed for small scale cultivation of cockles.

Similar observations are foreseen to those given in the Bradwell Report of 1959-1965, where animals may vary with changes in the environment. "It appears reasonable to assume that a heated discharge could be advantageous to some species and detrimental to others. This might result in the decline of a normally dominant species and the expansion of some newly introduced or normally scarce one."

It is hoped that the comparison of results from similar studies after commissioning will indicate any changes which might be attributable to the station discharge.

If the effluent continued to be piped into the estuary on a wider scale (increased volume and velocity), with greater area coverage it could have an adverse effect and serious repercussions on the fauna in the area. This could be accentuated, especially during extreme day temperatures in the summer months. When the mud flats have been uncovered for a number of hours, the incoming tidal flows will be pre-heated and subjected to an increase in temperature before arrival at the discharge point.

In agreement with Spencer 1967, (Bradwell Report 1959-1965), the temperature of mudflats uncovered by the tide was found to be related to the weather conditions, especially air temperature. The water temperature of the estuary under normal conditions ranges from 14°C or less in winter to 20°C or more in summer. There appears to be a significant amount of heat energy lost or gained when a flood tide recovers the mud flats.

Therefore the intertidal zone experiences, without additional causes, a great many changes in terrestrial climate. The estuary may reach 25°C in the heat of the summer, and littoral animals of a eurythermal nature must be so in order to survive. This is illustrated in investigations by J.A. Colin Nicol (1967) in dealing with the heat tolerance of littoral gastropods, Broekhuysen, (1952), determined the lethal temperatures and the survival times at high temperatures at False Bay, South Africa, and he discovered that these factors were graded according to the zonal sequence of the species on the shore. Evans, (1948), has investigated the thermal death-points of littoral gastropods in Cardigan Bay, Great Britain, where mean lethal temperatures varied from 46.3°C for *Littorina neritoides*, which lives above mean high water neaps, to 36.2°C for *Gibbula cineraria* which occurs in damp shaded positions below mean low water neaps. The highest temperatures recorded on the shore were 40.5°C for sunbaked rocks and 30°C in tidal pools. In conclusion the degree of heat tolerance shown by these various gastropods is related to the temperature range which they encounter in nature, and the safety factor is sufficiently high so that they are rarely, if ever, exposed on the shore to temperatures which are lethal.

It appears reasonable to assume that *Chione stutchburyi* and *Amphidesma australe* would tolerate intermittent tidal immersion at 26.6°C with some upward latitude. The heat tolerance of the animals in the estuary could therefore depend solely on the time they are exposed and separated from tidal flows.

At the point of the proposed discharge there is a typical estuarine bed of cockles. Its disappearance would not affect anyone's livelihood. However, the warm water resulting from the cooling of the turbines might upset normal feeding and processing activities of the animals. Once accustomed, however, in their natural habitat to this rise in temperature it should not unduly worry the cockles in this particular locality.

Their disappearance and decomposition, however, might cause local comment because organic matter could possibly cause ground pollution, e.g. products of decomposition might affect the filter feeding molluscs as there is only a moderate current to remove them. At the present time only negligible effects are anticipated since the organic matter would be quickly removed by normal populations of gastropods and isopods and equilibrium restored before the inevitable putrefaction and decomposition reached its climax. Any large concentration of organic matter may attract isopods and gastropods from other areas. Such a shift in the population and abundance of predators could have a detrimental effect on the cockles in the area over a period of time.

The Tamaki estuary at the moment has no commercial or recreational value from a fisheries viewpoint, although it empties into a body of water, the Tamaki Strait, which is valuable to both the commercial and sports fishery. Sailing and boating are very popular at the mouth of the Tamaki estuary and centres for launching boats and moorings are to be found at Panmure Basin, Buckland's Beach, and other points on the upper Tamaki. Any detrimental changes to these recreational amenities would be serious, in regard to accelerated marine fouling on hulls.

IX. CONCLUSION

Environmental temperature affects most body activities in poikilotherms. Upper and lower limiting temperatures for activity have been established for many species, and the effect determined by temperatures on various processes. Extremes of temperatures have a general stimulatory action on behaviour; very low temperatures produce anaesthesia; and high temperatures abnormal muscular contractions. Sudden thermal changes bring about either shock reactions or modify the rate of movement.

A crude experiment on temperature acclimatisation has been carried out on diverse functions; survival at extreme temperatures, rates of several activities, e.g. ciliary motility and body metabolism. An instance of the latter functions is provided from experiments on the common cockle *Chione stutchburyi*, which eventually shows reduced rates of metabolism when exposed for several minutes to high artificial temperatures. Cooling water could exert a direct action upon lower invertebrates causing an upset in their natural feeding cycle.

Laboratory studies

Most of the cockles at 26.6°C were moving their shells and pumping small quantities of water. They resumed normal pumping soon after immersion, with a water current containing suspended particles observed to enter the enclosed animal. After 19 hours immersion at 26.6°C, the maximum sustained rate of pumping showed no marked fluctuations. If anything this proved to be an optimum temperature for the animal. This increase in temperature accelerated vital processes and pumping speeded up rapidly.

An aerator was not used during these experiments to compensate oxygen drawn off by the animals or the electrothermal crucible. It is interesting to note that for brief periods up to 5 hours they survived and tolerated a temperature of 32°C. These observations indicate that the response of cockles to change in the environment and adjustment to such changes is extremely rapid.

Between 32.1°C and 35°C the rate of pumping was spasmodic and retarded. This retardation was probably caused by an oxygen deficiency, and primarily pumping and filtering processes were hampered. Beyond 35°C the cockles began to show immediate distress resulting in a marked decrease in the rate of pumping, and in abnormal shell movements.

It was ascertained that these artificial conditions imposed a more severe strain on the animals than would normally occur in their natural environment. Even when influenced by cooling water discharge on estuarine temperatures, they should be able to adapt to the rise in temperature.

As a precaution it might be worthwhile following the effect, if any, of future discharge over these cockles in close proximity to the intake and discharge openings. Flow patterns have been worked out and sufficient mixing area is available to ensure the warm water is not drawn back into the Otara Creek and affect the cooling water intakes. This warm water should be dissipated and well mixed by the time it reaches the mouth of the estuary (5 miles away from Panmure Bridge), where the main mollusc beds are located. Water temperatures (surface - bottom) and air temperatures at various stations within the estuary should be taken regularly throughout the year.

Growth and condition studies on cockles after commissioning of the power station may be undertaken. Four stations could be selected and established within the estuary, with a control at Eastern Beach (Cockle Bay). Several hundred cockles of all sizes may be marked, shell length measured and placed in concrete troughs at each site.

Objectives

(a) To determine if the warm effluent accelerates or retards shell growth.

(b) Compare quality and mortalities.

(c) To survey the main cockle beds; for population densities and assess distribution of age groups.

(d) Follow fluctuations in population numbers.

There are no significant commercial fisheries within this area surveyed although a number of persons (estimated at less than fifty) may engage in netting for flounder R. leporina, yellow-eyed mullet Agnostomus forsteri and red gurnard Chelidonichthys kumu nearer the Tamaki River mouth.

During the warmer months off Buckland's Beach resort large shoals of sprats have been regularly reported in recent years, being harassed and driven inshore by predaceous fish. They can be netted on this beach in great quantities.

Private collecting of cockles from the numerous beds along the estuary probably takes place, although it would appear not as frequently as on Eastern Beaches. Estimating total amounts removed would be sheer guesswork.

It may be of interest to note that the tidal weir seals off the Otara Creek to navigation and it is proposed to erect a pipeline fence along its top, which will be visible at all states of the tide. It is thought that this will make an attractive small boating lake of the creek. Alternative access to a launching ramp in the main estuary near the motorway bridge could be made if the need arises.

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Fig. 1 — Sketch map of Tamaki River, showing positions of the main mollusc beds, littoral sampling stations, and low tide channels. August 1968.

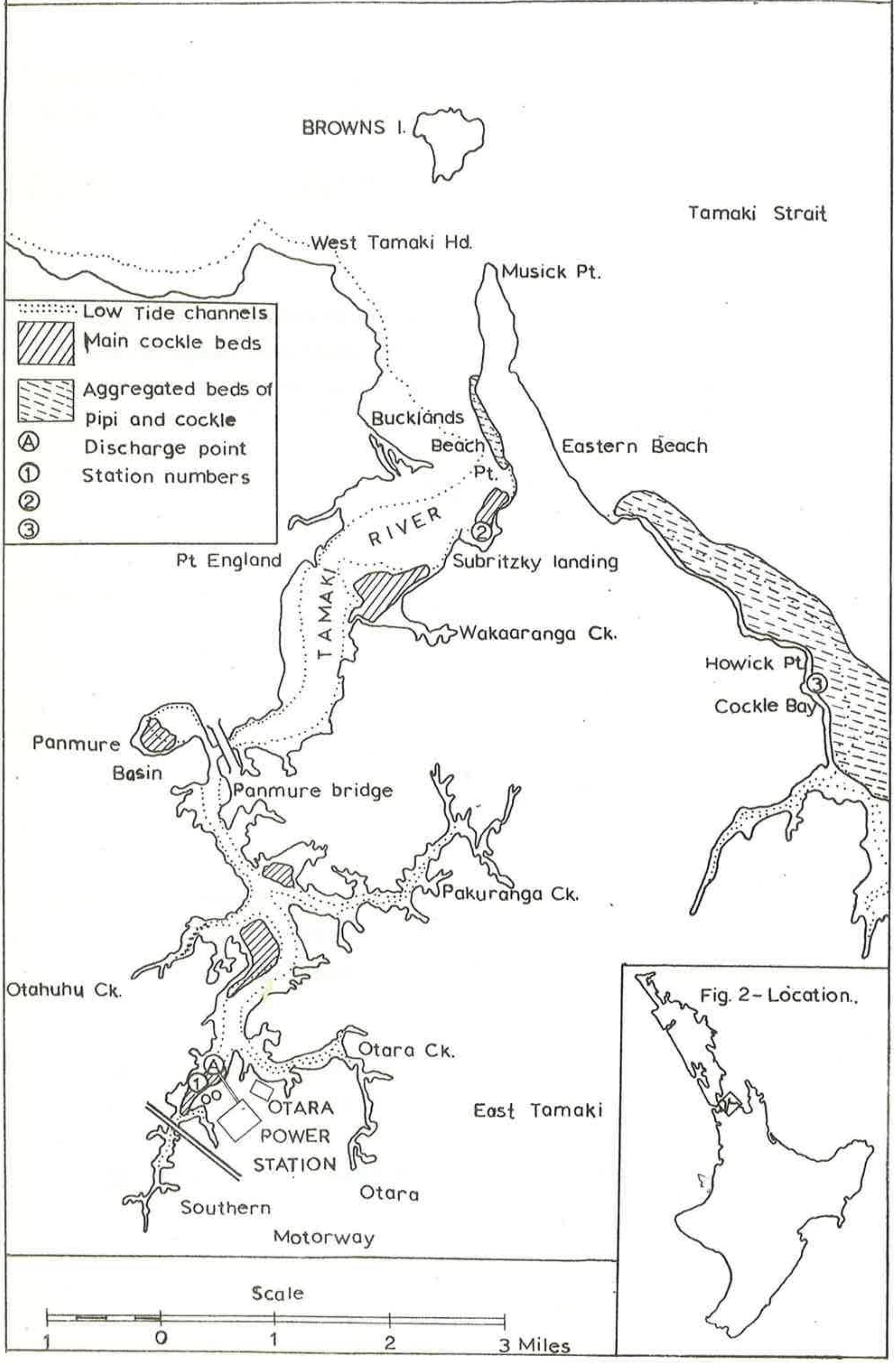

Fig. 3 - Diagram showing layout of the Otara Generating Station and cooling water arrangement. (not to scale)

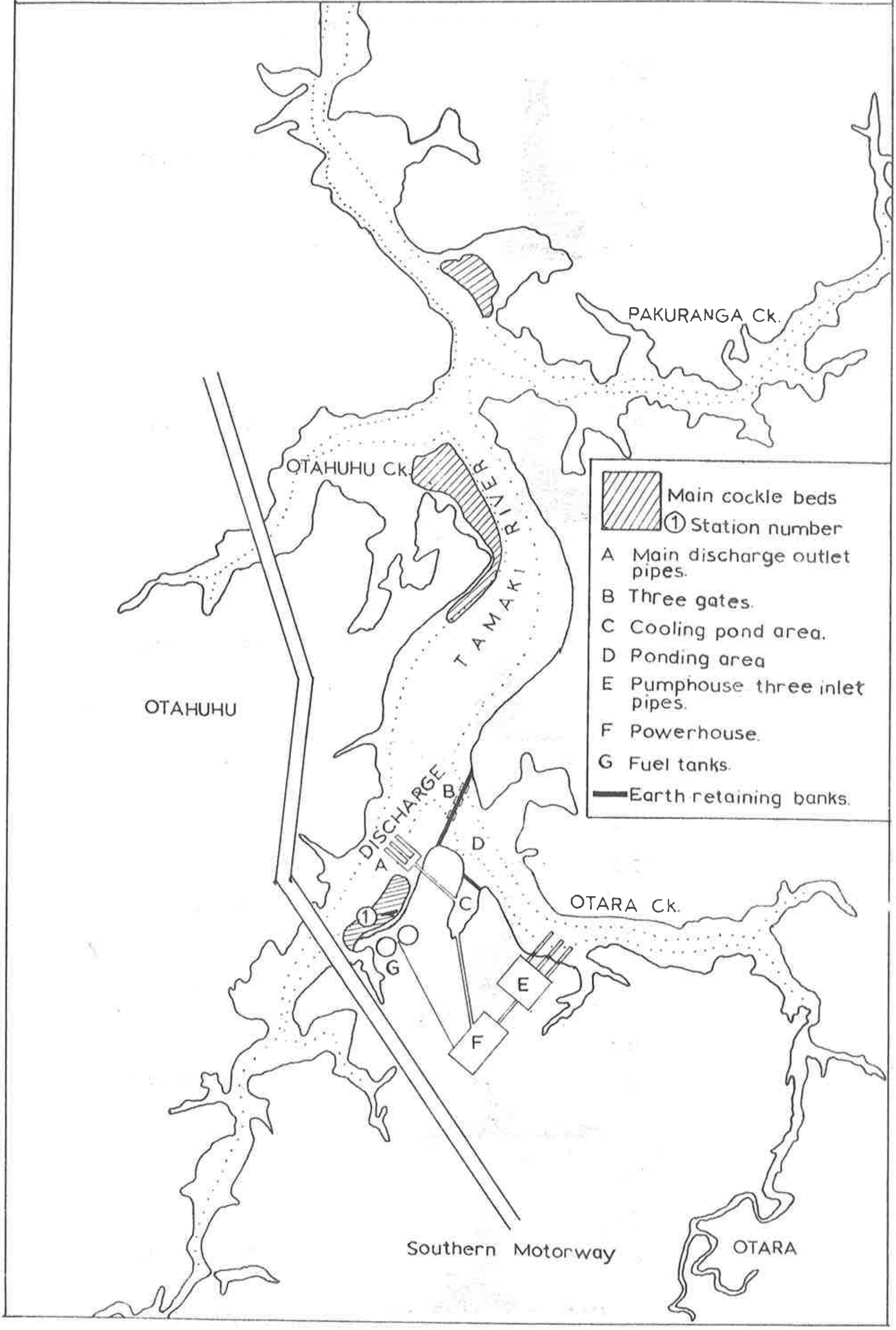

Fig. 4 — Length frequency distribution of Chione stutchburyi at three sampling stations, August 1968. Station postions and number of animals in each sample are shown as in Fig. 1.

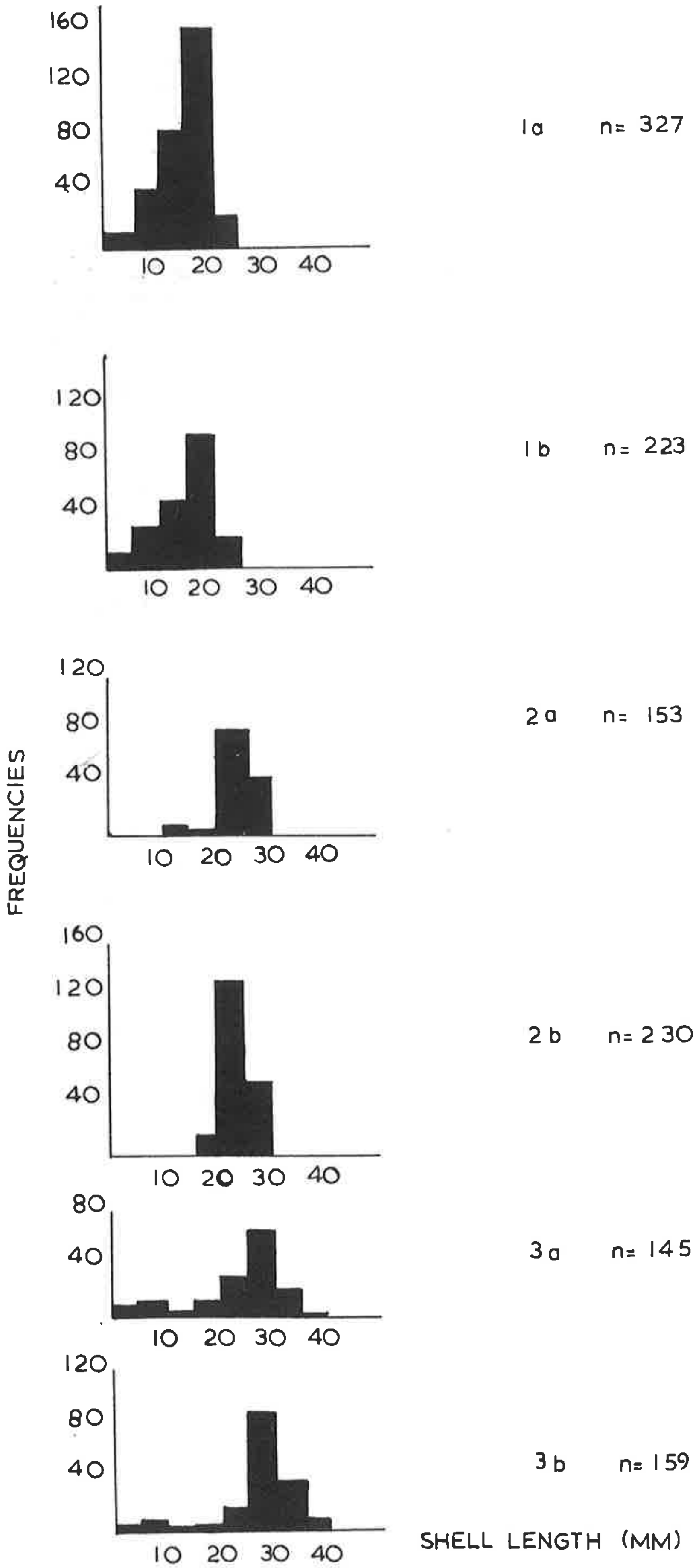

TABLE 1. Numbers of Molluscs present at each sampling station. Tamaki River, Eastern Beach (Cockle Bay) August 1968.

Station		Species	Sample Size	Substrate	Remarks
1.	A	Chione stutchburyi	327	Soft-gritty mud and sand.	Shells encrusted with barnacles.
		Zediloma subrostrata	4	"	-
		Zeacumantus lutulentus	49	"	-
		Cominella glandiformis	15	"	-
		Nucula hartvigiana	16	"	-
		Amphibola crenata	2	"	-
		Modiolus neozelanicus	1	"	-
		Macomona liliana	7	"	-
	B	Chione stutchburyi	223	Soft-gritty mud and sand.	Shells encrusted with barnacles.
		Zediloma subrostrata	16	"	-
		Zeacumantus lutulentus	52	"	-
		Cominella glandiformis	15	"	-
		Nucula hartvigiana	56	"	-
		Amphibola crenata	3	"	-
		Modiolus neozelanicus	3	"	-
2.	A	Chione stutchburyi	153	Gritty-mud and sand with small deposits of small broken dead shell.	Shells encrusted with barnacles.
		Amphidesma australe	14	"	Small areas of A. australe present in the C. stutchburyi bed.
		Zediloma subrostrata	1	"	-
		Zeacumantus lutulentus	7	"	-
		Cominella glandiformis	1	"	-
		Nucula hartvigiana	1	"	-
	B	Chione stutchburyi	230	Gritty-mud and sand with small deposits of small broken dead shell	Shell encrusted with barnacles
		Amphidesma australe	8	"	Small areas of A. australe present in the C. stutchburyi bed.
		Zediloma subrostrata	1	"	-
		Zeacumantus lutulentus	28	"	-
		Cominella glandiformis	9	"	-
		Nucula hartvigiana	28	"	-
		Macomona liliana	3	"	-
		Cominella adspersa	5	"	-
		Pervicacia tristis	2	"	-

Station		Species	Sample Size	Substrate	Remarks
3.	A	Chione stutchburyi	145	Gritty-mud and coarse sand with large deposit of dead shells	Shells relatively free of encrusting barnacles, mussels etc.
		Amphidesma australe	21	"	Large area A. australe present C. stutchburyi bed
		Zediloma subrostrata	4	"	-
		Zeacumantus lutulentus	4	"	-
		Cominella glandiformis	9	"	-
		Nucula hartvigiana	17	"	-
		Macomona liliana	2	"	-
		Pervicacia tristis	1	"	-
		Dosina subrosea	1	"	-
	B	Chione stutchburyi	159	Gritty-mud and coarse sand with large deposit of dead shells	Shells relatively free of encrusting barnacles, mussels etc.
		Zeacumantus lutulentus	15	"	-
		Amphidesma australe	16	"	Large areas of A. australe present in C. stutchburyi bed.
		Cominella glandiformis	5	"	-
		Nucula hartvigiana	9	"	-

XI. APPENDIX

A series of experiments was performed to determine the effects of temperature upon certain activities of cockles, shell movements and rate of pumping receiving most attention. Particular attention was directed to testing the effect of seawater at 80°F (26.6°C) on samples of cockles, *Chione stutchburyi* taken near to the Otara Gas Turbine Power Station site position (1).

Test 1

Temperature of seawater held constant for 1 hour at 26.6°C. This allowed the undulating fluctuations of the thermometer to remain steady due to temperature of atmosphere in the laboratory 14°C.

The size and shape of the electrothermal crucible permitted only three specimens to be placed in the pot at one time.

The input - output regulator was set at 1/2,000 (26.6°C) and the internal thermostat kept the coiled fibre-glassed asbestos element at the predetermined temperature.

Two thermometers (F and C) were inserted into the pyrex crucible for comparison and remained so throughout the first and second stages of the experiment.

The apparatus was left overnight to find if temperature increase would alter the appearance of the cockles.

Test 2

Followed the same procedure as Test 1, excepting that seawater was heated to 90°F (32°C), and confirmed that this rise in temperature over the same period affected the appearance and pumping manner of the cockles. If this increase in temperature curtails vital processes within the body of the animal we can determine the endurance of the cockles and the temperature they would tolerate and still function normally.

Test 3

Finally the temperature of the seawater was raised in 5°F graduations (5 minute duration) to find the maximum temperature they could withstand, the experiment terminating when the adductor muscles relaxed causing them to "gape" spontaneously.

RESULTS TEST 1: 80°F (26.6°C)

TIME	LIQUID	LENGTH OF PERIOD	APPEARANCE OF COCKLES	REMARKS
1300	Seawater Preheated	1 hour		Steady temp. 26.6°C.
1415-1430	"	15 minutes	1.L.P. 10x. Under the microscope most of the cockles were moving their shells and pumping small quantities of water. They resumed normal pumping soon after immersion, with a water current containing suspended particles observed to enter the enclosed animal. True faeces were formed. Normal appearance and no visible signs of adductor muscles relaxing, which would cause them to separate or "gape".	
1430-1445	"	"	"	"
1445-1500	"	"	"	"
1500-1515	"	"	"	"
1515-1530	"	"	"	"
1530-1545	"	"	"	"
1545-1600	"	"	2.L.P. 10x. Under the microscope the rate of pumping steadily increased. However from this point the rate of pumping showed no marked fluctuations. Similar observations as in 1. Normal appearance.	
1600-1615	"	"	"	"
1615-1630	"	"	"	"
1630-1645	"	"	"	"
1645-1700	"	"	"	"
1700-0900	"	16 hours	3.L.P. 10x. Similar observations as in 1. Shells tightly closed. Normal appearance.	Temperature dropped slightly overnight 78.5°F (25.1°C).
Direct Observations	"	3 hours		
Overnight	"	16 hours		
Total hours subjected to immersion		19 hours		

RESULTS TEST 2 (A) 90°F (32°C)

TIME	LIQUID	LENGTH OF PERIOD	APPEARANCE OF COCKLES	REMARKS
1300	Seawater preheated	1 hour	-	Steady temp at 32°C.
1400-1415	"	15 minutes	1.L.P. 10x. Under the microscope they resumed pumping. A further increase was again noticed within the range extending between 26.6°C and 32°C. It is within this range that the maximum rate of pumping occurs. Normal appearance, and no visible signs of adductor muscles relaxing.	
1415-1430	"	"	"	"
1430-1445	"	"	"	"
1445-1500	"	"	"	"
1500-1515	"	"	"	"
1515-1530	"	"	"	"
1530-1545	"	"	"	"
1545-1600	"	"	"	"
1600-1615	"	"	"	"
1615-1630	"	"	"	"
1630-1645	"	"	"	"
1645-1700	"	"	"	"
1700-1715	"	"	"	"
1715-1730	"	"	"	"
1730-1745	"	"	"	"
1745-1800	"	"	"	"
1800-1815	"	"	"	"
1815-1830	"	"	"	"
1830-1845	"	"	"	"
1845-1900	"	"	"	"
1900-1915	"	"	"	"
1915-1930	"	"	2.L.P. 10x. The rate of pumping remained steady. Similar observations as in 1.	"

RESULTS TEST 2 (A) 90°F (32°C) - Continued

TIME	LIQUID	LENGTH OF PERIOD	APPEARANCE OF COCKLES	REMARKS
1930-0900	Seawater preheated	13½ hours	3.L.P. 10x. Examined under the microscope, the shells "gaped" slightly. The cockles began to show distress, resulting in a marked decrease in the rate of pumping. No visible signs of a water current observed. Adductors relaxed and meats appeared dehydrated and compressed. Several of the cockles were exposed due to overnight evaporation from crucible.	
Direct Observations		5½ hours		
Overnight		13½ hours		
Total hours subjected to immersion		19 hours		

To substantiate the above results we selected samples from the same station, and heated them for 5½ hours at 32°C.

RESULTS TEST 2 (B), 90°F (32°C)

TIME	LIQUID	LENGTH OF PERIOD	APPEARANCE OF COCKLES	REMARKS
0900	Seawater preheated	1 hour		Steady temp. 32°C.
1000-1015	"	15 minutes	1.L.P. 10x. Examined under the microscope; similar observations as in Test 2(A)1. However filtering is not rapidly performed and pumping erratic, probably as cockles were not fresh samples as those in Test 2. (a) 20 hrs had elapsed between Test (a) and (b). This retardation was probably caused by an oxygen deficiency, and ultimately pumping and filtering processes were hampered.	
1015-1030	"	"	"	"
1030-1045	"	"	"	"
1045-1100	"	"	"	"
1100-1115	"	"	"	"
1115-1130	"	"	"	"
1130-1145	"	"	"	"
1145-1200	"	"	"	"
1200-1215	"	"	"	"
1215-1230	"	"	"	"
1230-1245	"	"	"	"
1245-1300	"	"	2.L.P. 10x. Similar observations as 1. The cockles began to show distress, resulting in a marked decrease in the rate of pumping.	
1300-1315	"	"	"	"
1315-1330	"	"	"	"
1330-1345	"	"	"	"
1345-1400	"	"	"	"
1400-1415	"	"	"	"
1415-1430	"	"	"	"
1430-1445	"	"	"	"
1445-1500	"	"	"	"
1500-1515	"	"	"	"
1515-1530	"	"	3.L.P. 10x. Similar observations as 2.	"

RESULTS TEST 3

TIME	LIQUID	LENGTH OF PERIOD:	APPEARANCE OF COCKLES	TEMPERATURE OF SEAWATER
0900-0915	Seawater preheated	15 minutes	1.L.P.10x: Under the microscope the cockles resumed normal pumping for approximately 5 mins. Between 32.3°C and 34.0°C. the cockles began to show immediate distress resulting in a marked decrease in the rate of pumping and in abnormal shell movements. Irregularities followed; cilia functioning although not rapid. Filtering extremely slow and practically non-existent (A) Possibly due to increase in temperature, (B) an oxygen deficiency, the adductors showed no signs of relaxing.	95°F (35°C)
0915-0930	"	5 minutes	2.L.P.10X. Under the microscope similar observations as in 1. The adductors showed signs of relaxing and would be just a matter of time before doing so. Air bubbles escaping from "lips" of cockles.	100°F (38°C)
0930-0945	"	3½ minutes	3.L.P.10X: Under the microscope the shells showed immediate distress, abnormal shell movements. The shell could be prised open by inserting finger nail. Filtering and pumping non-existent. Continual air bubbles escaping from "lips" of cockles.	110°F (43.2°C)
0945-1000	"	3 minutes	4. H.P. Under the microscope no motive power from either cilia or labial fringes was detected. Similar observations as in 3. The shells "gaped" widely soon after immersion. Adductors relaxed, meats appeared dehydrated and constricted.	120°F (49°C)

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