NZOI OCEANOGRAPHIC SUMMARY

No 7 May 1975

SETTLEMENT SEASONS OF ACTUAL AND POTENTIAL FOULING ORGANISMS AT THE NEW PLYMOUTH POWER STATION

by P.A. LUCKENS

NEW ZEALAND OCEANOGRAPHIC INSTITUTE
D.S.I.R.

Publications in this series result from specific enquiries for information. They record and comment on relevant available data.

The present summary was prepared to assist in the development of control measures against fouling organisms at New Plymouth.

Distributed on exchange

New Zealand Oceanographic Institute, P.O. Box 8009, Wellington, New Zealand.

SETTLEMENT SEASONS OF ACTUAL AND POTENTIAL FOULING ORGANISMS AT THE NEW PLYMOUTH POWER STATION

Penelope A. Luckens

INTRODUCTION

When the thermal power station at New Plymouth comes into full operation an average of 165,000 gallons of cooling water per minute will pass through the system. One of the main problems to be overcome at the seawater cooled thermal power station is the settlement and growth of sessile organisms in the ducts and pipes. To combat this, the incoming water is dosed with chlorine. The rate and timing of chlorine application must be planned so that the smallest possible amount of chlorine is used for the least growth of organisms in the pipes. The main reasons for limiting the amount of chlorine are:

1. *Ecological.* Chlorine is capable of killing not only the undesirable fouling species, but will also kill or damage other organisms present as larvae or adults. Phytoplankton, the minute floating plants of the sea on which all other species ultimately depend, have been shown to be particularly vulnerable to chlorine damage, but most larval forms show some degree of damage (Morgan and Stross 1969; Brook and Baker 1972).

2. *Economic.* Chlorine injected into the system in excess of that required to discourage or kill settling organisms is chlorine and money wasted. Thus information on the settlement times and intensities of potential fouling species, together with their vulnerability to chlorination is needed so that a suitable chlorination schedule can be worked out.

The number and kind of settling organisms varies both seasonally, and from one place to another. Where the peculiar conditions obtaining within the power station pipes differ considerably from other local conditions, so will the fouling species which are important within the power station differ considerably from the species found nearby. Several important fouling species have been widely distributed by shipping and now occur wherever water temperatures are suitable.

LOCAL GEOGRAPHY AND HYDROLOGY

The location of the power station in relation to Port Taranaki and the nearby reefs and islands offshore is shown in Fig. 1. Offshore from the power station the bottom is largely composed of shifting sand, and bottom topography can change markedly over a relatively short period of time. Much of the power station is on land reclaimed from the sea and bounded by breakwaters built of boulders and concrete akmons. Natural rock outcrops occur immediately west of both the inlet and the outlet. The breakwater to the east of the outlet is continuous with the main Port Taranaki breakwater.

Although the general water movement offshore is thought to be in a north-easterly direction (Heath 1973, 1974), currents immediately offshore are mainly wind dependent, and can flow generally north-east or south-west (*see* Ridgway 1973). The shallow water and the presence of the offshore reefs and islands also complicate local water currents.

ORGANISMS CAUSING FOULING PROBLEMS

The conditions prevailing in the pipes and ducts of a seawater cooling system are somewhat different from those found on the intertidal and shallow subtidal areas. Water flow is usually continuous and in a constant direction, light is absent and the presence of intake screens restricts the size of organisms entering the system. Organisms which can take advantage of such a situation must have larvae which can enter the system from outside (at least initially), settle, and live in the dark and obtain their food from the passing water, i.e., filter feeding species of sessile animals with planktonic larvae. Many of these will be species found locally on hard shores, particularly those occurring in caverns and beneath ledges, although by no means confined to such species. Of increasing importance are those species causing fouling problems on ships, and transported by ships to all parts of the world where sea temperatures are suitable. Harbours served by overseas shipping, particularly where ships are likely to remain in port for several days, serve as the introduction points for such species, and where conditions are suitable the species can then spread along the coast. The bryozoan *Watersipora cucullata*, already present in Port Taranaki is a good example of this (*see* Skerman 1960a and below).

The main groups of fouling organisms include the following: sponges, tubeworms, bryozoans, barnacles, bivalve molluscs and ascidians. The three volumes of the Catalogue of Main Marine Fouling Organisms (Organisation for Economic Co-operation and Development 1963, 1965, 1967), together with the older "Marine Fouling and its Prevention" (Woods Hole

Oceanographic Institution 1952) provide much useful information on the life history and identification of fouling species.

PREVIOUS WORK

Initially no information on the settlement seasons of likely fouling species was available for New Plymouth. A table of information on their settlement at other places was assembled as a general guide (Table 1). Several of these species, including *Watersipora cucullata*, *Bugula neritina* and *Hydroides norvegica*, are widespread fouling species which have been brought to New Zealand by ship from warmer waters. It is interesting to note that while all three breed and settle throughout the year at Sydney they have more restricted settlement seasons in New Zealand, probably as a result of the lower temperatures prevailing here. Published work on settlement seasons of fouling species in New Zealand is restricted to results from Auckland (Skerman 1959), Wellington (Ralph and Hurley 1952) and Lyttelton Harbours (Skerman 1958), although unpublished results are available for further work both in the Auckland Harbour (Luckens 1964; Harger 1964), and for Piha, an exposed west coast beach near Auckland (Luckens 1964). All authors note that the general pattern is similar from year to year, but that a certain amount of variation occurs.

SETTLEMENT AT NEW PLYMOUTH

In March 1973 two series of settlement plates were set up within the sand trap at the power station (*see* locations A and B, Fig. 2). The settlement surfaces were 6 in. (150 mm) squares of 3/8 in. (9.5 mm) fibrolite. These were attached at 2 ft (0.6 m) intervals between two continuous ropes extending from the bottom of the sand trap to the level of high water of spring tides. Initially each series consisted of 17 plates, but later, further plates were added into each series. Experience has shown that the system has several drawbacks, particularly a high sensitivity to silting (which prevents inspection of the plates), and accessibility of the plates to fish predators (there is no screening between the open sea and the sand trap, and fish, octopus and penguins have all been seen there).

The plates were examined at two-monthly intervals (and photographed where possible). Notes were made of the species found on them. Although one side of each plate was carefully cleaned of adhering silt at each examination it seemed likely that a silt coating was inhibiting settlement of at least some of the fouling species.

Results of settlement on the sand trap plates have been incorporated into the species-by-species discussion below.

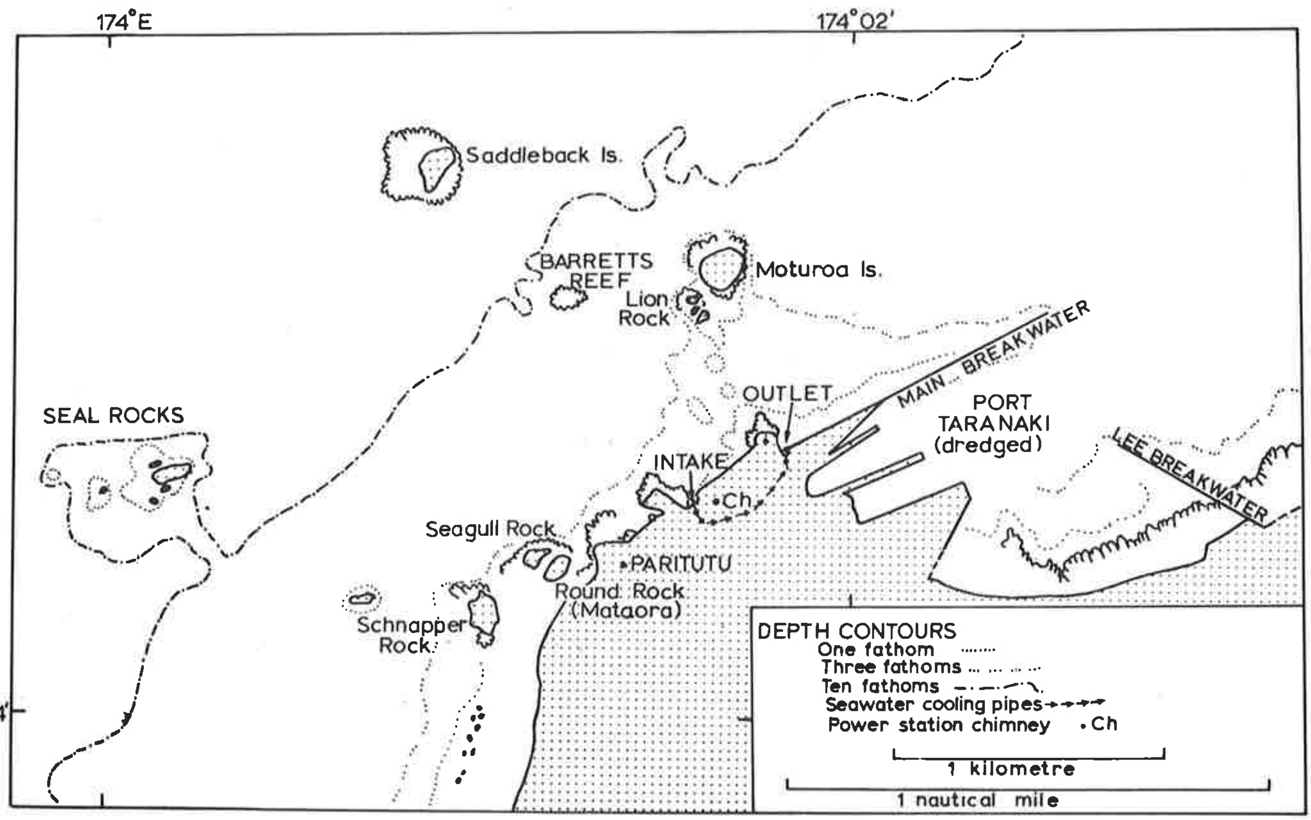

Fig. 1. Location of the New Plymouth Thermal Power Station intake and outlet in relation to inshore bathymetry, offshore islands and reefs, and to Port Taranaki.

Table 1. The settlement seasons of some fouling species likely to be found at the New Plymouth Thermal Power Station.

Species	Settlement Season J	F	M	A	M	J	J	A	S	O	N	D	Location	Author and Date
BRYOZOA														
Watersipora cucullata	–	–	–	–		–							Auckland Harbour	Luckens 1964
	summer												Auckland Harbour	Skerman 1960a
	–	–	–	–	–	–	–	–	–	–	–	–	Sydney Harbour	Wisely 1959
Bugula neritina			–	–	–	–							Auckland Harbour	Luckens 1964
	–	–	–	–	–	–						–	Lyttelton Harbour	Skerman 1960b
	–	–	–	–	–	–			–	–	–	–	Auckland Harbour	Skerman 1959
	–	–	–	–	–	–	–	–	–	–			Auckland Harbour	Harger 1964
	–	–	–	–	–	–	–	–	–	–	–	–	Sydney Harbour	Wisely 1959
Bugula flabellata	–	–	–	–	–	–		–	–	–	–	–	Auckland Harbour	Skerman 1959
SERPULIDAE														
Hydroides norvegica	–	–	–	–								–	Auckland Harbour	Skerman 1959
		–	–	–									Lyttelton Harbour	Skerman 1958
	–	–	–	–	–	–						–	Auckland Harbour	Luckens 1964
	–	–	–	–	–	–	–	–	–	–	–	–	Sydney Harbour	Wisely 1959
Galeolaria hystrix	–	–	–	–	–	–	–	–	–	–	–	–	Port Nicholson	Ralph and Hurley 1952
	–	–	–	–	–	–		–	–	–	–	–	Auckland Harbour	Skerman 1959
Pomatoceros terraenovae			–	–	–	–			–	–	–	–	Lyttelton Harbour	Skerman 1958
BIVALVIA														
Xenostrobus pulex	–	–	–	–	–	–	–	–	–	–	–	–	Piha, Auckland	Luckens 1964
								–	–	–	–	–	Auckland Harbour	Luckens 1964
Perna canaliculus		–		–		–	–	–	–	–	–	–	Piha, Auckland	Luckens 1964
								–	–	–			Auckland Harbour	Luckens 1964
							–	–	–	–	–	–	Auckland Harbour	Harger 1964
Anomia walteri				–	–	–				–			Auckland Harbour	Luckens 1964
		–	–	–							–	–	Auckland Harbour	Skerman 1959
	–	–	–	–								–	Auckland Harbour	Harger 1964
CIRRIPEDIA														
Balanus decorus			–	–	–								Piha, Auckland	Luckens 1964
Elminius modestus	–	–	–	–	–	–	–	–	–	–	–	–	Auckland Harbour	Harger 1964
ASCIDEA														
Ascidians *	–	–	–	–	–	–	–	–	–	–	–	–	Auckland Harbour	Harger 1964

* Includes *Microcosmus, Diplosoma, Aplidium, Botryllus* and *Botrylloides.*

DISCUSSION

Bryozoa

The bryozoan *Watersipora cucullata* was first seen at Auckland in the late 1950's, and it appeared to be spreading slowly out from the Port of Auckland where it had come as a fouling species on boats from overseas. At Auckland, settlement is found over the first half of the year, with colonies larger than 5 mm diameter surviving the winter and enlarging further the following spring. It forms black encrusting colonies of irregular but rounded shape up to or exceeding 15 cm in diameter often with a red or orange edge. It is a common species at Port Taranaki and may be seen along the inner side of the Lee Breakwater from the small boat launching ramp to the harbour entrance, on and under stones of a wide range of sizes. So far it has not been seen outside Port Taranaki, but with suitable surfaces existing almost continuously from Paritutu to well east of New Plymouth it will probably be only a matter of time before it spreads along the coast. Although not a massive species, it tends to grow outwards rapidly, smothering other organisms in its way, and in turn providing a suitable surface for settlement by other species. Since it appears to have come from more tropical shores it is likely to be favoured by any temperature increase.

Both *Bugula neritina* and *B. flabellata* are common fouling species at Auckland, forming much-branched pendant colonies, but neither species has been seen at New Plymouth.

Serpulidae

The three species of tubeworm listed in Table 1 have all been found on the plates in the sand trap, and on the plugs at the sand trap intake pipes. *Hydroides norvegica*, although the smallest species of the three is not only the most numerous, but is also one of the best-known and most widespread fouling species. Identification of recently settled tubeworms is not possible with certainty, but under the somewhat unfavourable circumstances in the sand trap settlement of tubeworms has been seen in March, April, August and November.

Galeolaria hystrix is the largest species of tubeworm found in the sand trap and is easily distinguished by its double keel and its bright orange-red colouration. Specimens on the plates reached a length of over 50 mm within a year, but much larger specimens have been found in the sand trap.

Two species of *Pomatoceros* have been seen in the sand trap. *Pomatoceros caeruleus* is one of the commonest organisms on the rock and concrete breakwaters in the New Plymouth area. Found from about midtide level downwards both on and under rocks, its white or blue tinged tubes may be distinguished by their prominent keel running along the top of the tube and extending as a spine over the opening. The second species, tentatively identified as *P. terraenovae*, is much rarer. One specimen found on the plates in the sand trap had a tube similar in shape to *P. caeruleus* with an undulate keel, but was of pinkish-mauve colour quite distinct from the blue and white of *P. caeruleus*. *Pomatoceros terraenovae* was first described from South Trinidad in the Atlantic Ocean, but has since been reported from Queensland to Tasmania (Dew 1959) and at Lyttelton (Skerman 1958) and is illustrated as a New Zealand species by Morton and Miller (1968).

Besides the above three species, there appear to be specimens of other tubeworms present on the plates, but their settlement times and other behaviour are similar to these three species, and until more positively identified they will not be discussed further. In general, tubeworms settle predominantly during the warmer months, secrete hard tubes which at least initially are firmly attached to the substrate although they may later grow out from the substrate, and provide increasing roughness which can enhance later

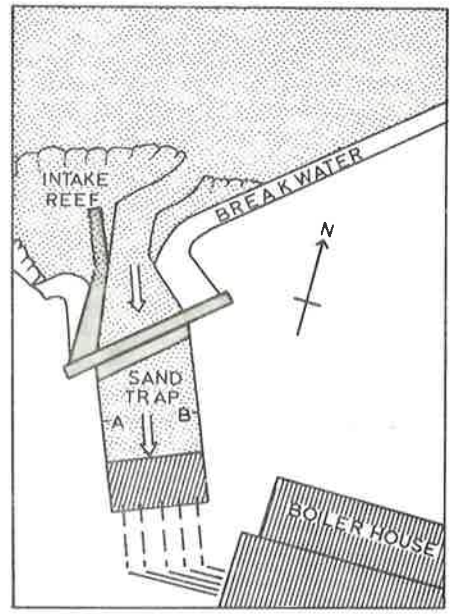

Fig. 2. The New Plymouth Thermal Power Station intake area and sand trap. The direction of cooling water flow is indicated by arrows. The location of the two series of experimental plates in the sand trap is at A and B. The revolving intake screens (1/4 in. (6 mm) mesh), the chlorination plant and the cooling water pumps are housed in the building at the southern end of the sand trap.

settlement of other fouling species such as mussels. Even after the worms die or are killed the tubes remain unless physically removed.

Bivalvia

Like the tubeworms, the bivalve molluscs also have a hard outer covering which they can close firmly when external conditions are unfavourable. *Xenostrobus pulex*, although the smallest of the three species listed in Table 1 is also the most numerous on the plates in the sand trap, and has already been found in large numbers on concrete pipes within the power station. At both Piha and New Plymouth it appears to settle throughout the year. During periods of dense settlement the small black larvae appear like a sprinkling of black sand grains over all suitable surfaces, both intertidal and subtidal. Although attaching to the surface by a series of byssus threads consisting of tanned protein secreted by the animal, it is not incapable of further movement. Throughout its life the mussel is continually secreting fresh byssus threads and attaching them to surrounding surfaces, and is capable of slow but definite movement. Particularly in their younger stages, the mussels can also crawl over solid surfaces using their foot, and if detached either voluntarily or otherwise can be carried along by the current to re-attach in some other place. Once initial settlement has occurred and the shell developed beyond a certain stage the mussels cannot swim, but depending on their size and the strength of the current they can be carried for long distances.

This power of limited movement by crawling and re-attaching byssus threads enables them to form dense mats of individuals joined by their byssus threads, and to avoid being smothered by sand or silt accumulating between and beneath them. Such mats may be attached to the substrate only at the edges. If a break occurs in the mat, the whole sheet may be stripped away by water movement. The byssus thread is anchored within the body of the mussel, and when the mussel dies and decays the shell is detached from the byssus. If the mussel was attached only to the substrate the shell then falls off when the animal dies. If the byssus was attached to surrounding mussels, and these remain alive, then the dead shell will be held among the surrounding shells.

Growth rate is dependent on a variety of factors including temperature and the time available for feeding. One of the most important features of power station pipes in this regard is that they are supplied with a continuously flowing water supply, and in the absence of noxious substances and any inherent feeding rhythm in the organism, then feeding can continue for 24 hours a day, with consequent increases in growth rate compared with intertidal specimens where feeding is interrupted at low tide. Intertidally both growth and settlement rates are increased lower on the shore. *Xenostrobus pulex*, the small black mussel, rarely reaches a size greater than 3 cm long. In contrast, the green mussel *Perna canaliculus* can reach a length of more than 17 cm. The green mussel was noted as present on Round Rock (*see* Fig. 1) by Morton and Miller (1968), but in August 1972 it was not seen either at Round Rock (Mataora) or in the vicinity of the power station. In January 1973 numerous small *P. canaliculus* were seen at Round Rock, particularly on rocks on the southwestern side adjacent to the sand tombolo, on the reef and reef flat adjacent to the power station intake, and at several other points on the coast. By the end of June 1973 the largest *Perna* had reached a length of 3 cm although their numbers had been considerably reduced by an influx of the large predatory gastropod *Neothais scalaris*. In June 1974 one small specimen was seen on one of the sand trap plates. In general mussels tend to settle more readily on fibrous or irregular surfaces, but this is not always so. Several years ago a barge moored in the Bay of Islands was found to have been settled densely on all its immersed surfaces. Not only were the surfaces smooth and tarred, but there was no known source of larvae anywhere near the barge.

At New Plymouth the source of larvae is thought to have been a subtidal bed further along the coast. Local divers state that mussels have been too scarce around the offshore islands and reefs near New Plymouth to be worth diving for in recent years. Mussel beds are known to fluctuate in their abundance over a period of years in any one area. Both species of mussels are likely fouling species, and with substantial numbers of *P. canaliculus* of breeding age present along the coast the number of larvae in the water should increase.

The saddle oyster, *Anomia walteri*, belongs to a different family of bivalves. After a planktonic larval stage the saddle oyster attaches to a solid substrate by a fused mass of byssus threads which pass through the flat, right valve to the solid surface beneath. Once the saddle oyster has settled it is incapable of further movement, but the byssus serves to hold the two valves of the shell close together when external conditions are unfavourable. The convex left valve is often transparent and golden or honey coloured, in contrast to the solid white valves of true oysters. A few oysters - probably *Ostrea lutaria* best known from Foveaux Strait - have been seen at Port Taranaki and could occur at the power station.

Cirripedia

The most numerous barnacle settling on the plates in the sand trap is the small species *Elminius modestus*. Its flatly conical shell is composed of four white, slightly ribbed plates surrounding a diamond-shaped opening. A native of Australasia it has now spread to parts of Europe. The eggs are fertilised and develop inside the shell of the adult before being released to develop through several planktonic stages. When the mature larvae find a suitable site for settlement, they cement themselves to the substrate and, except for subsequent growth, are unable to move for the rest of their lives. Under favourable circumstances breeding can begin about six weeks after settlement and continue throughout the year until the death of the adult. The base of *Elminius modestus* is membranous and the valves of the shell only loosely attached to each other. Once the animal has died the shell plates are readily detached.

In contrast, the larger pink *Balanus decorus* has a calcareous base with the parietal plates fused to it and to each other. Even after the death of the animal the shell remains firmly attached to the substrate. This species has been seen in the sand trap, but not on the experimental plates. It may reach a basal diameter of nearly 4 cm. Other species of *Balanus* are also found as fouling species. They may be distinguished by having six parietal plates, unlike *Elminius* (with four valves) or the common intertidal genus *Chamaesipho* (four valves becoming fused into a ring with age, particularly in the smaller *C. columna*). *Chamaesipho* is an intertidal genus which has not been noted as a fouling species.

Ascidea

The final group noted in Table 1 is ascidians. At least two species have been seen on the sand trap plates - probably species of *Asterocarpa* and *Molgula*. Simple ascidians may be described as having a body enclosed in a sac of leathery or cartilaginous appearance with two external openings (siphons). Water is drawn in through the inhalant siphon, passes through a series of filtering devices where food particles are removed, and then is expelled through the exhalant siphon. The incomplete data suggest these simple ascidians breed throughout the year. Once the larvae have settled further movement is not possible. A related group known as compound ascidians are common fouling organisms, but they have not been seen in the sand trap.

CONCLUSIONS

Two features are common to all the species listed. All are filter feeding animals with planktonic larvae. Not only are the larvae transported by the water current in the first place, but once they have settled, the current also brings an abundant supply of food. Since predators larger than the screen mesh size are excluded from the system unless they too have planktonic larvae, the pipes of a power station form an almost ideal place for most of the above species, and it is for this reason that chlorination or an alternative method of control is used by power station operators. Intermittent chlorination, by removing bacterial and other slimes may improve the suitability of the surface for many larger fouling species. Draining of culverts followed by refilling with hot water and steam will kill fouling organisms with no damage to planktonic organisms.

Most shelled species can avoid contact with chlorinated water for limited periods by closing their shells. Overseas experience has shown that where chlorine applications have been carried out on a regular schedule some shelled species have responded by closing their shells on the same schedule. Fouling species settle throughout the year at New Plymouth although the number of species settling from June to August is much lower than during the rest of the year. However, mussels are among the most difficult of fouling species to control, and settle through this period.

The continuing use of settlement plates should provide valuable information on settlement of fouling species, enabling the most economical system of chlorination to be worked out at New Plymouth.

REFERENCES

BROOK, A.J.; BAKER, A.L. 1972: Chlorination at Power Plants : Impact on phytoplankton productivity. *Science, N.Y. 176* : 1414-15.

DEW, B. 1959: Serpulidae (Polychaeta) from Australia. *Rec. Aust. Mus. 25(2)* : 19-56.

HARGER, J.R.E. 1964: Marine Fouling. Unpubl. M.Sc. Thesis, Zoology Department, University of Auckland. 99 pp plus appendices.

HEATH, R.A. 1973: Present knowledge of the oceanic circulation and hydrology around New Zealand - 1971. *Tuatara 20(3)* : 125-40.

LUCKENS, P.A. 1964: Settlement and Succession on Rocky Shores at Auckland. Unpubl. M.Sc. Thesis, Zoology Department, University of Auckland. 285 pp.

MORTON, J.E.; MILLER, M. 1968: "The New Zealand Sea Shore". Collins, Auckland. 638 pp.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT, 1963: "Catalogue of Main Marine Fouling Organisms. Volume 1. Barnacles". O.E.C.D. Publications, Paris. 46 pp.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT, 1965: "Catalogue of Main Marine Fouling Organisms. Volume 2. Polyzoa". O.E.C.D. Publications, Paris. 83 pp.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT, 1967: "Catalogue of Main Marine Fouling Organisms. Volume 3. Serpulids". O.E.C.D. Publications, Paris. 79 pp.

RALPH, P.M.; HURLEY, D.E. 1952: The settling and growth of wharf pile fauna in Port Nicholson, Wellington, New Zealand. *Zool. Publs Vict. Univ. Coll. 19* : 22 pp.

RIDGWAY, N.M. 1973: Some oceanographic observations in the vicinity of proposed thermal power stations. II. New Plymouth. *Proc. Pollut. Res. Conf., Wairakei, N.Z.* : 505-18.

SKERMAN, T.M. 1958: Marine fouling at the Port of Lyttelton. *N.Z. Jl Sci. 1(2)* : 224-57.

SKERMAN, T.M. 1959: Marine fouling at the Port of Auckland. *N.Z. Jl Sci. 2(1)* : 57-94.

SKERMAN, T.M. 1960a: The recent establishment of the Polyzoan *Watersipora cucullata* (Busk), in Auckland Harbour. *N.Z. Jl Sci. 3(4)* : 615-19.

SKERMAN, T.M. 1960b: Ship-fouling in New Zealand waters : a survey of marine fouling organisms from vessels of the coastal and overseas trades. *N.Z. Jl Sci. 3(4)* : 620-48.

WISELY, B. 1959: Factors influencing the settling of the principal marine fouling organisms in Sydney Harbour. *Aust. J. mar. Freshwat. Res. 10(1)* : 30-44.

WOODS HOLE OCEANOGRAPHIC INSTITUTION, 1952: "Marine Fouling and its Prevention". U.S. Naval Institute, Annapolis, Maryland. 388 pp.

(Received for Publication - 6 September 1974)