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Distribution of shipworms (Bivalvia: Teredinidae) in the New Zealand region

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Bankia neztalia was found in temperate waters around New Zealand, mainly south of New Plymouth and Tauranga. *Bankia australis* was found in warm-temperate waters north of Nelson; it requires water temperatures above 19–20 °C for successful breeding and is euryhaline. *Lyrodus pedicellatus* also occurred in warm-temperate waters north of Nelson and had a lower water temperature limit for survival of about 10 °C. *Lyrodus medilobatus* occurred in warm-temperate waters on the north-east coast of the North Island north of Tauranga. *Nototeredo edax* is uncommon and occurred over the same range as *B. australis*.

The presence of shipworms in wood collected from depths of greater than 50 m around New Zealand is reported. *Teredora princesae* is recorded from driftwood around New Zealand.

Keywords: Teredinidae; shipworms; distribution; dispersal.

INTRODUCTION

A number of species of the wood-boring molluscan family Teredinidae have been reported from ports and harbours around New Zealand, but no pattern of distribution for each species can be discerned from these records as the identity of most of the specimens is uncertain.

No comprehensive survey of the distribution of shipworms around the New Zealand coast was undertaken until 1962 when McQuire (1964) collected specimens from wooden test panels set up in 20 ports around the country. His survey demonstrated the widespread occurrence of three genera and five species; *Bankia australis* Calman, *Bankia brevis* Deshayes (subsequently identified as *B. neztalia* Turner & McKoy), *Lyrodus pedicellatus* (Quatrefages), *Lyrodus medilobatus* Edmondson, and *Nototeredo edax* (Hedley), none of which is endemic to New Zealand. *Bankia australis* and *B. neztalia* occur in temperate to subtropical waters in Australia and New Zealand, *Lyrodus pedicellatus* is found in tropical to temperate waters throughout the world, *L. medilobatus* in tropical to warm-temperate seas in the central and south Pacific Ocean, and *Nototeredo edax* in tropical and warm-temperate waters in the Indian and western Pacific Oceans (Turner 1966, 1971a, b, Turner & McKoy 1979).

Factors important in limiting the geographic distribution of shipworms are temperature, salinity, availability of wood, and a suitable mechanism for dispersal (Turner 1966, Nair & Saraswathy 1971, Scheltema 1971). Wood, the natural habitat of shipworms, is widely dispersed through the world's oceans, and the adults of many species are capable of withstanding wide variations in hydrographic conditions (Turner 1966). Thus normally recognised zoogeographic boundaries tend to be of less importance for shipworms (particularly larviparous species) than for many other marine organisms.

The criteria for a valid record of an established member of a shipworm fauna in a particular locality have been defined by Edmondson (1942) and Turner (1966) as successful spawning, larval survival, and subsequent penetration of the wood, since the prevailing conditions are probably most important in the earlier stages of the life cycle. All wood containing shipworms collected during this study was divided into two groups as follows.

Fixed wood—attached wood on which the shipworms must have settled at the site of collection.

Driftwood—the place at which settlement took place could not be determined.

This study aimed to complement and extend the survey of McQuire (1964), and, where possible, to more precisely define the limits of distribution of each species around New Zealand, particularly with regard to thermal and haline limits.

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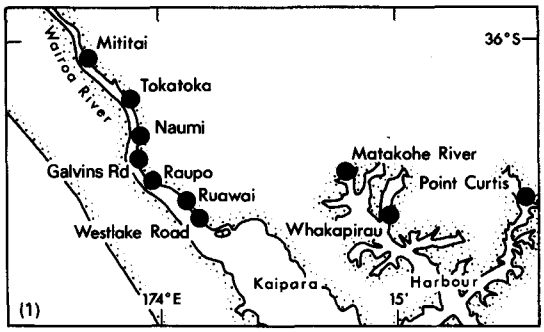
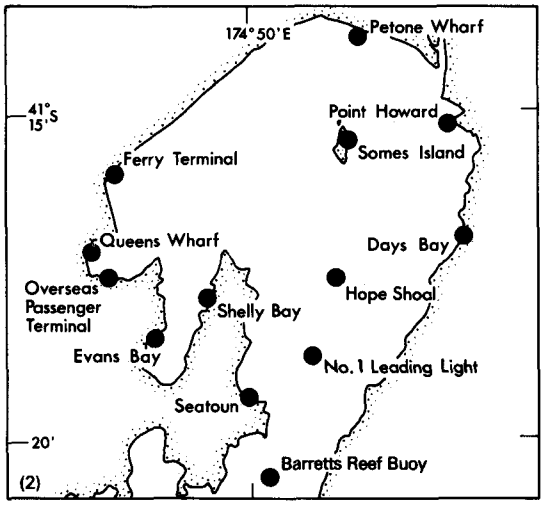
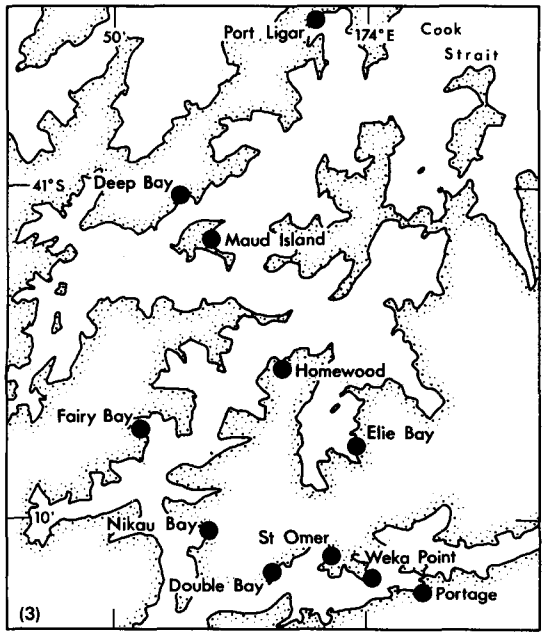






MATERIALS AND METHODS

COLLECTION OF SHIPWORMS

During 1970–74 a sampling programme was undertaken using sets of four *Pinus radiata* panels (each about 20 × 7 × 2 cm). Two of the panels in each set were rough-sawn and two were planed smooth to offer a variety of surface textures for settlement of the larvae. At 45 localities around the coast sets of test panels were wired or bolted 1—2 m on wharf piles above the mud line. They were immersed at various times of the year, removed after 3–12 months' exposure, were cleaned, radiographed, and then dissected to remove any shipworms.

In general it was possible to install only one set of test panels at any one harbour or locality. However, because of the variations of temperature, salinity, and other hydrological factors within most harbours, it is unlikely that one set of panels, installed for only part of a year at one depth, will collect all the species of shipworms present in that harbour. Thus the absence of a species from any one set of panels cannot be regarded as particularly significant.

Studies of the local distribution of shipworms were made in Kaipara Harbour (Fig. 1), Wellington Harbour (Fig. 2), Tauranga Harbour, and Pelorus and Kenepuru Sounds (Fig. 3) to delineate some thermal and haline limits. Collections in Kaipara Harbour were made from mangrove wood only, but in other harbours sets of test panels were placed at a number of sites for periods of up to 1 year. Much additional material was obtained from other fixed wood such as wharf piles, oyster racks, and from mangrove wood in areas north of Tauranga where mangroves are abundant.

Many specimens were obtained from driftwood collected from beaches and by diving around the coast, and from off-shore islands including the Kermadec, Chatham, and Auckland Islands. Shipworms from driftwood from deep water (>50 m) were obtained from the collections of the New Zealand Oceanographic Institute (NZOI) and the Ministry of Agriculture and Fisheries.

Confirmed distribution records from Ralph & Hurley (1952), Hurley (1959, 1961), and McQuire (1964) are also included. Material collected or radiographs made by these authors were re-examined if available. Some specimens from museum collections were also examined and are recorded here.

Details of collections from test panels, other fixed wood, museum collections, and records from

Figs 1–3 Collecting sites and test block sites in: **1** northern Kaipara Harbour; **2** Wellington Harbour; **3** Pelorus and Kenepuru Sounds.

previously published works are available from the author. Details of records from deep water are given in Table 1.

Collection of Hydrological Data

Records of seasonal temperature and salinity ranges in New Zealand harbours are not extensive. Skerman (1958) reviewed seasonal temperature variations in a number of harbours, and discussed the significance of these variations and of the differences between harbour and off-shore temperature measurements. Other temperature and/or salinity records for inshore localities have been published by the New Zealand Marine Department (Reports on Fisheries between 1929 and 1941), Hounsell (1935), Ralph & Hurley (1952), Maxwell (1965), Paul (1968), Slinn (1968), Booth (1974, 1975), and Hickman (1979). These measurements are often irregular and infrequent, but they do serve as a general guide to conditions in each locality.

Unpublished temperature and/or salinity data were obtained from Kaipara Harbour, Whangaroa Harbour, Leigh, Great Barrier Island, Island Bay (Wellington), Pelorus Sound, Kaikoura, and the Chatham Islands.

During this study additional temperature and salinity data were collected from two sites in Tauranga Harbour, three sites in Pelorus and Kenepuru Sounds, and, as reported by Booth (1975), at three sites in Wellington Harbour.

Temperature records from harbours and other points on the New Zealand coast are summarised in

Table 1 Records of shipworm activity from deep water (>50 m) around New Zealand. All identifiable specimens were *Bankia neztalia* (–, not found; NZOI, N.Z. Oceanographic Institute; MAF, Ministry of Agriculture & Fisheries; Nat.Mus., National Museum Collection).

Lat. (° 'S)	Long. (° 'E)	Depth (m)	No. of pieces of wood with Live animals	Shells & pallets only	Tunnels only	Source
Westport		55	1	–	–	Nat.Mus.
Palliser Bay		55–75?	1	–	–	Suter (1911)
Cape Campbell		73	1	–	–	Nat.Mus.
44 42	167 33	95	1	–	3	NZOI
Cape Campbell		127	1	–	–	Hurley (1961)
45 20	166 47	134	1	1	2	NZOI
37 21	176 26	330	1	–	–	NZOI
37 20	176 29	366	1	–	–	NZOI
38 39	172 38	691–751	1	–	–	NZOI
43 23	169 03	823	1	–	–	NZOI
42 43	169 15	978–1067	1	–	–	NZOI
43 23	168 05	1213–1221	1	–	–	NZOI
46 02	166 47	88–168	–	1	–	NZOI
35 29	174 45	143–146	–	1	–	NZOI
43 23	169 27	206–252	–	1	–	NZOI
45 20	166 45	226–251	–	1	–	NZOI
41 24	175 58	285–315	–	1	–	NZOI
36 51	176 15	364–382	–	1	–	MAF
36 56	176 16	364–417	–	1	1	MAF
37 29	176 35	364–427	–	1	–	MAF
37 29	176 36	400	–	1	–	MAF
29 15	178 00w	90	–	–	1	NZOI
42 24	173 50	91	–	–	1	NZOI
46 02	166 35	238–258	–	–	1	NZOI
38 00	178 45	271–278	–	–	2	NZOI
45 57	166 39	282–287	–	–	1	NZOI
37 34	177 35	282–311	–	–	2	NZOI
39 57	177 37	150–995	–	–	1	NZOI
37 29	176 37	364–391	–	–	1	MAF
36 57	176 17	382	–	–	1	MAF
37 34	176 43	499–518	–	–	1	NZOI
45 59	166 50	633	–	–	5	NZOI
37 23	178 00	631–645	–	–	1	NZOI
38 01	178 59	669–772	–	–	1	NZOI
42 37	175 58	1118–1138	–	–	1	NZOI
42 40	174 45	1147–1195	–	–	5	NZOI
42 43	168 42	1256	–	–	1	NZOI
42 48	174 32	1324	–	–	1	NZOI
37 18	178 11	1357	–	–	2	NZOI
40 31	177 46	2080	–	–	3	NZOI
42 33	178 27	2295–2304	–	–	2	NZOI

Table 2. Where possible, data for the years 1970–72 are given; otherwise the most recent appropriate data are included.

Sea surface temperatures at selected sites in Pelorus and Kenepuru Sounds, measured with a continuous recording thermograph aboard m.v. *Tirohia* during a series of cruises in 1970–72, are shown in Fig. 4.

DISTRIBUTION OF NEW ZEALAND SPECIES

Bankia neztalia Turner & McKoy

NEW ZEALAND RECORDS (Fig. 5)

Bankia neztalia was collected from fixed wood at sites around the South Island, except Nelson. It occurred commonly around the North Island as far north as Tauranga on the east coast and New Plymouth on the west coast. A single specimen was found in a test block from Whangaroa Harbour, Northland, in 1974 and several dead specimens were found in a rock lobster pot used only in the North Cape area.

This species was collected from driftwood between the Poor Knights Islands (35°30′S) and the Auckland Islands (50°50′S) and as far east as the Chatham Islands (176°30′W), and was the only shipwork found in wood from deep water. It was found at all sampling sites in Wellington Harbour and Pelorus and Kenepuru Sounds, although it was less common than *B. australis* in the inner parts of Kenepuru Sound. *B. neztalia* was equally abundant at all sites tested in Tauranga Harbour.

GENERAL DISTRIBUTION

The northernmost Australian records at Newcastle (Turner & Marshall 1973) and Townsville (Smith (1963) as *B. brevis*; see Turner & McKoy (1979)) indicate that this species is capable of establishing itself in warm-temperate to subtropical waters, although in both Australia and New Zealand it is most abundant in cool-temperate waters.

THERMAL AND HALINE LIMITS

The temperature data available do not allow the estimation of upper thermal limits. An estimate of upper and lower thermal limits for *B. neztalia* might be made on the basis of seasonal settlement patterns (McKoy 1973). From a study of seasonal settlement in Otago Harbour, Hurley (1959) suggested that the lower limit for successful spawning and/or settlement was around 10°C.

The salinity data are limited, and nothing is known of the haline requirements of this species.

Bankia australis Calman

NEW ZEALAND RECORDS (Fig. 6)

Bankia australis was collected from fixed wood, including mangrove branches, at sites around the North Island except for Porirua and Wellington Harbours. Sampling in Wellington Harbour throughout the year showed no incidence of *B.*

Locality	Period	Temperature (°C) Monthly mean Max.	Monthly mean Min.	Daily Max.	Daily Min.	Source
Whangaroa Hbr	1973–75	–	–	25.6	12.0	MAF
Wairoa Bay	1971	24.0	11.6	28.0	10.5	MAF
	1972	22.6	13.8	27.9	12.2	MAF
Whangarei Hbr	1938	20.4	10.4	–	–	Marine Dept
Kaipara Hbr	1930–32	23.7	11.2	–	–	Hounsell (1935)
	1933–39	23.9	10.0	–	–	Marine Dept
	1969	22.2	11.0	23.8	9.5	MOWD
Gt Barrier I.	1973–75	–	–	25.0	13.5	MAF
Leigh	1967–72	22.1	13.3	22.9	12.3	Director, Marine Lab.
Auckland Hbr	1938	23.0	12.7	–	–	Marine Dept
	1954–55	22.1	11.4	24.4	8.7	Skerman (1958)
	1963	22.5	12.2	–	–	Slinn (1968)
Coromandel	1934–40	24.3	11.7	–	–	Marine Dept
Tauranga Hbr	1970–72	22.8	11.2	27.0	9.2	Bay of Plenty Hbr Bd
Wellington Hbr	1953–55	17.8	8.8	20.0	8.5	Skerman (1958)
	1970–72	19.1	10.0	20.5	7.0	Booth (1975)
	1974–75	–	–	21.7	7.8	MAF
Pelorous Sound	1968–69	19.0	10.8	–	–	VUW
	1970–72	–	–	20.9	9.8	McKoy (1973)
	1975	–	–	21.1	10.0	MAF
Kaikoura	1968–69	16.4	7.2	18.8	6.4	Univ. of Canterbury
Lyttelton	1953–55	19.9	7.2	21.1	6.1	Skerman (1958)
Timaru	1952–55	17.5	9.0	17.7	7.6	Skerman (1958)
Portobello	1953–67	16.0	6.4	20.2	4.4	Univ. of Otago
Bluff	1952–55	16.0	8.0	16.8	7.6	Skerman (1958)
Chatham Is.	1970	16.3	10.0	18.5	8.7	MAF

Table 2 Summary of sea surface temperature data for selected points on the N.Z. coast. –, not available (MAF, Ministry of Agriculture & Fisheries; MOWD, Ministry of Works & Development; VUW, Victoria University of Wellington).

australis. Around the South Island this species was collected only from the inner parts of Pelorus and Kenepuru Sounds and from Nelson.

B. australis was commonly found in driftwood in in-shore areas around the north of the North Island and on the west coast as far south as Tasman Bay (Fig. 6) where almost all infested driftwood examined contained *B. australis*.

In Kaipara Harbour live specimens of *B. australis* were collected from mangrove branches and old wharf structures at all the sites except Mititai, Tokatoka, and Naumai (Fig. 1). Evidence of past infestation was observed in old wharf piles and mangrove wood at Naumai.

B. australis was equally abundant at the four Tauranga Harbour sites.

Collections from test panels in Pelorus and Kenepuru Sounds showed that *B. australis* was absent from sites in the outer sound (Maud Island, Deep Bay, and Port Ligar), but was abundant in the

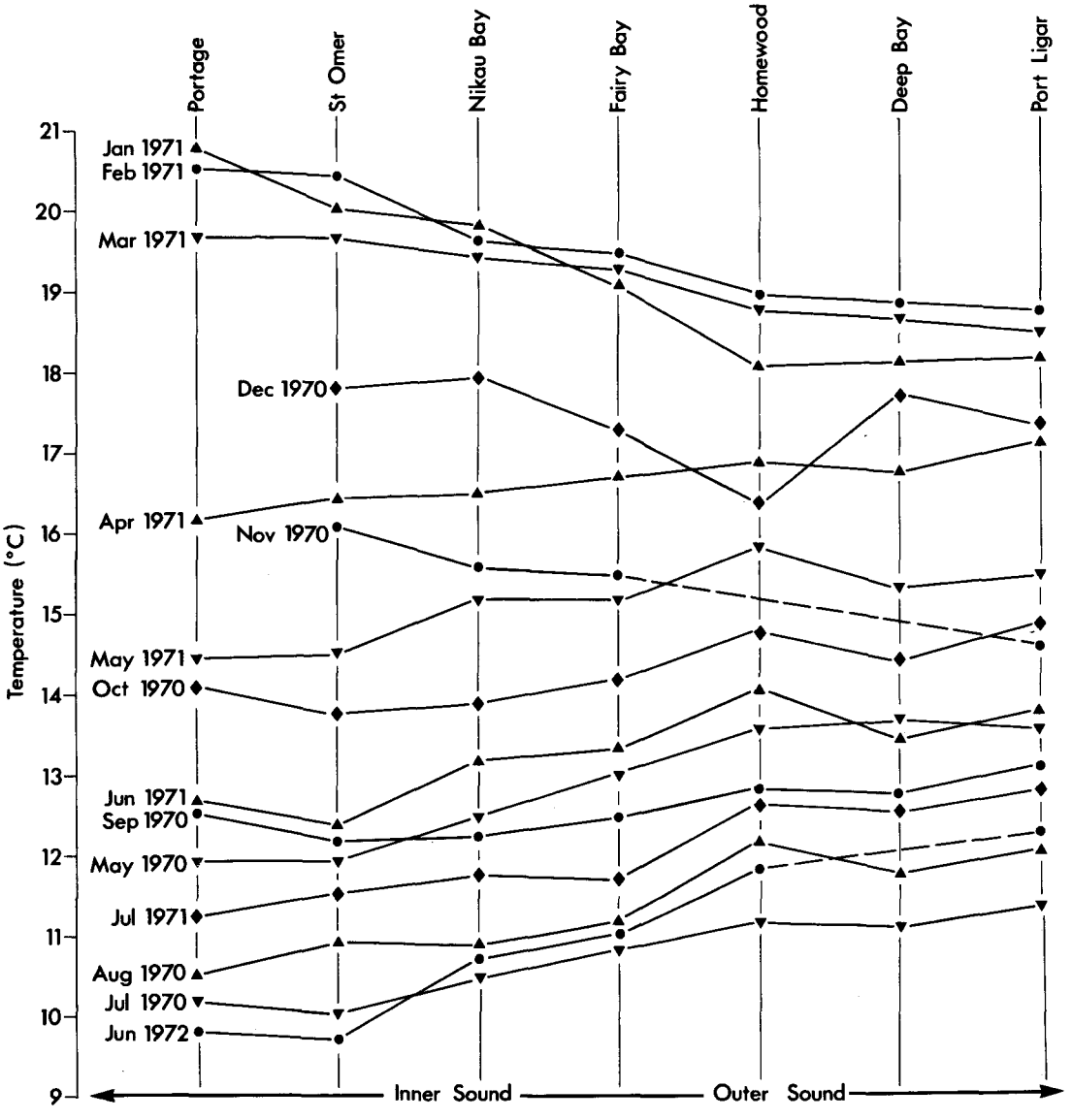


Fig. 4 Sea surface temperatures at sites in Pelorus Sound, based on a series of runs with a continuous recording thermograph between May 1970 and June 1972.

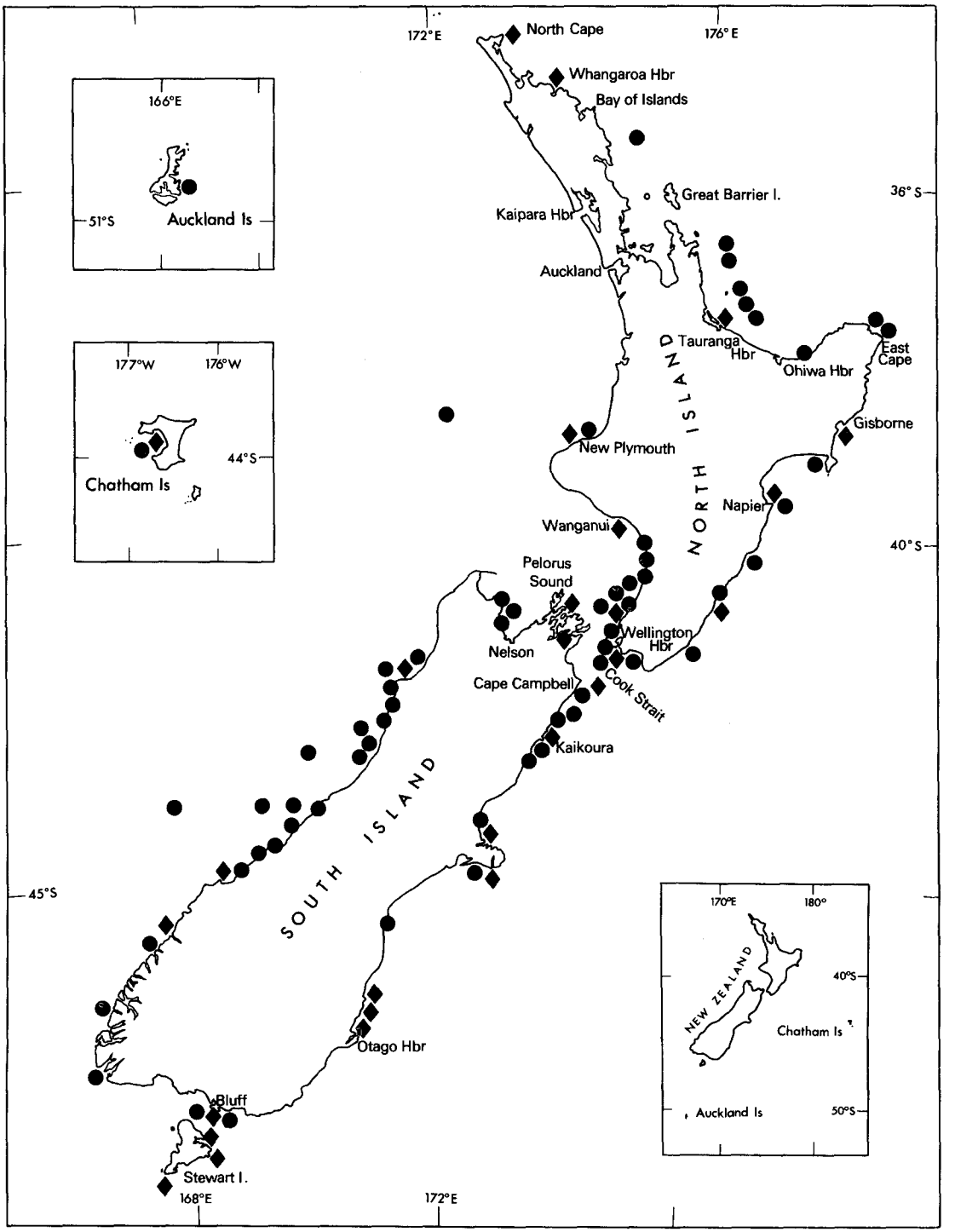


Fig. 5 Records of *Bankia neztalia* from fixed wood (◆) and driftwood (●) showing localities mentioned in the text.

inner sound (Homewood, Nikau Bay, Double Bay, St. Omer, Weka Point, and Portage) (Fig. 3).

General Distribution

B. australis was regarded as a subtropical to cool-temperate species in Australia by Turner (1971b) and Turner & Marshall (1973). It ranges from Gladstone (24°S) to Hobart (43°S). The occurrence of an isolated population in Rabaul, Papua New Guinea, may mean that *B. australis* should be regarded as a tropical to temperate species (Rayner 1974).

The southern limit of the range of *B. australis* in Australia roughly corresponds with the southern limit in New Zealand (the Cook Strait area).

Thermal and Haline Limits

B. australis is well established in Tasman and Golden Bays, but is notably absent from the southern end of Cook Strait, including Wellington Harbour. No regular records of sea temperatures are available for the Nelson area, but data from Garner (1961), Heath (1971), and Webb (1973) indicate that in-shore surface temperatures in Tasman Bay, Golden Bay, and northern Cook Strait tend to be 2–3 °C warmer than in southern Cook Strait and Wellington Harbour. These data suggest that temperature may be the primary factor delimiting the distribution of *B. australis* in this region, and that a temperature above 18–20 °C is necessary for successful spawning and settlement.

Further evidence of the lower thermal limit for settlement of *B. australis* comes from the collections made in Pelorus and Kenepuru Sounds. The restriction of *B. australis* to the inner sounds is probably related to differences in hydrological conditions, particularly temperature, between the inner and outer sounds. Subsurface salinities in the area sampled showed no marked trends from outer to inner parts of the sounds below about 5 m, although surface salinities varied greatly, especially after heavy rain. Temperature records from both sounds (Fig. 4) suggest that water temperatures in the outer sounds were not warm enough at any time during the year to allow successful settlement of *B. australis,* but that in the inner sound the higher temperatures reached during the summer were adequate for successful spawning, larval development, and settlement. Temperature maxima at Weka Point were about 20–21 °C during the summer of 1969–70 (Brunnette 1970). Surface temperatures up to 21 °C were recorded at Homewood in the 1969–70 summer, but at Port Ligar during the same period temperatures were no higher than 18.9 °C. Thus, if temperature is limiting the spawning and settlement of *B. australis* as suggested above, the lower limit would appear to be about 19–20 °C.

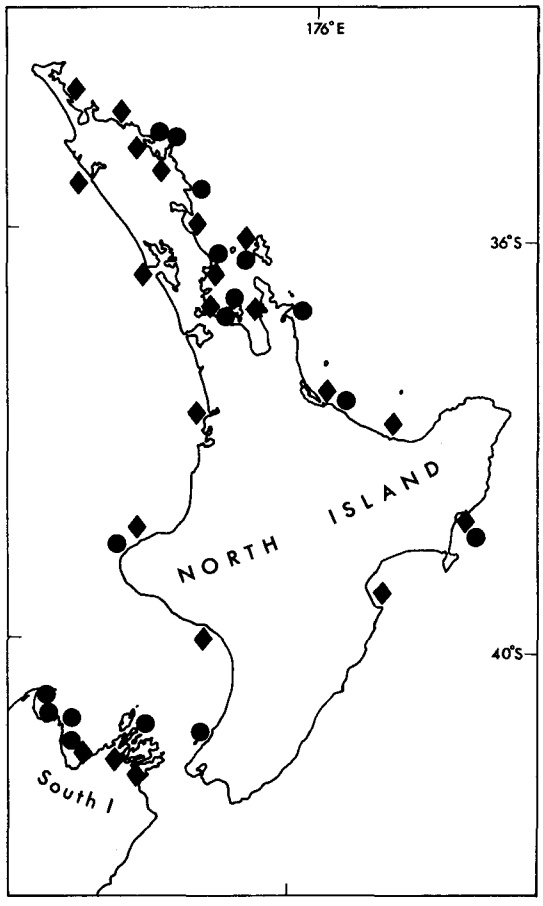
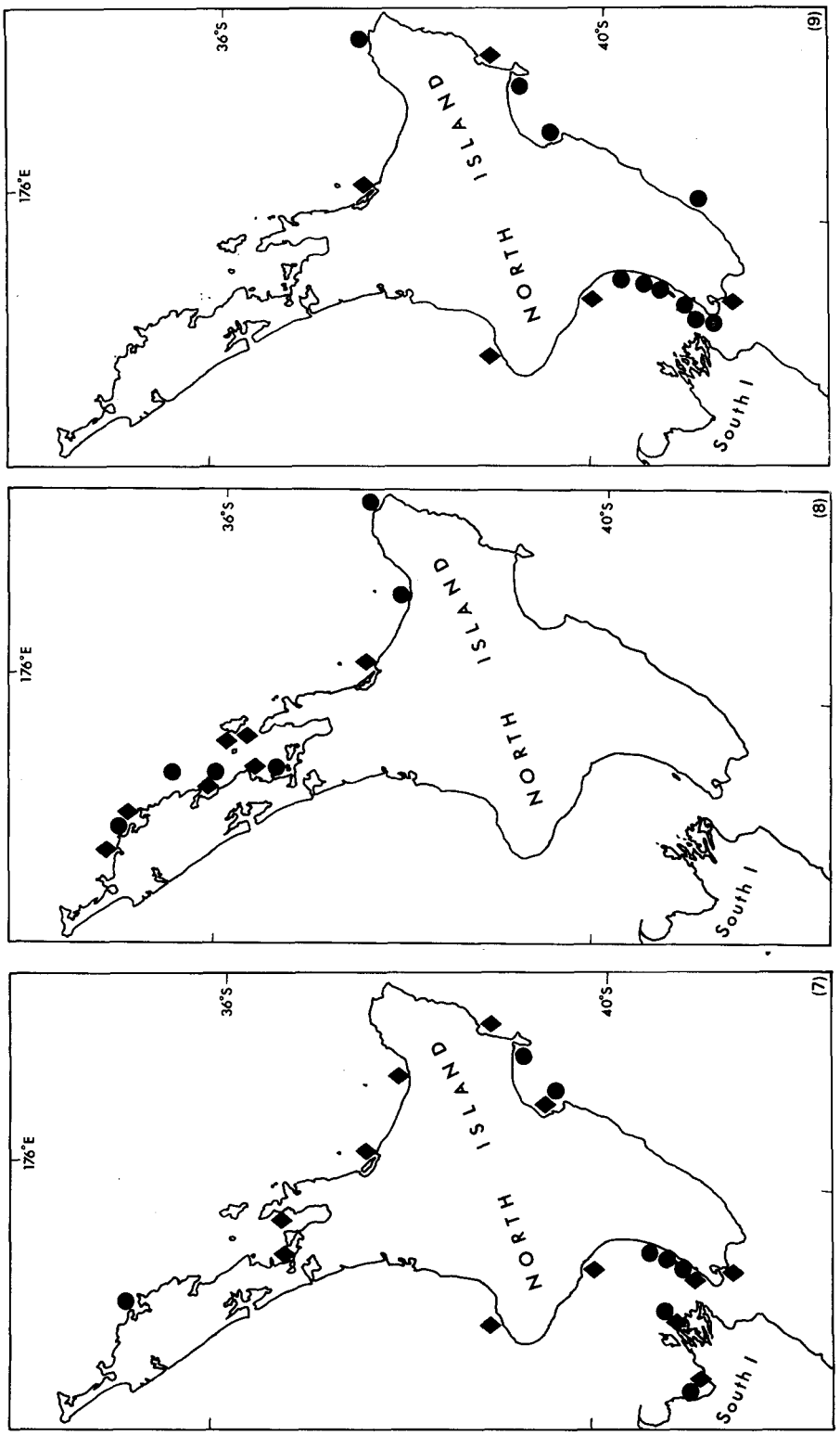


Fig. 6 Records of *Bankia australis* from fixed wood (◆) and driftwood (●).

All other sites from which *B. australis* was recorded and for which temperature data are available experienced maximum monthly means greater than 20 °C (Table 2). None of the sites from which *B. australis* was absent experienced maximum monthly means greater than 20 °C.

The collections from northern Kaipara Harbour show that *B. australis* is capable of settling and surviving on wood in the intertidal zone in the Wairoa River almost to the point where the mangroves are limited by fresh water. *Avicennia marina* probably has the widest range of salinity tolerance of all mangroves; it can grow in almost fresh water (Macnae 1968). In this area *B. australis* is a successful estuarine species, and both the larvae and the adults probably tolerate conditions of very low salinity associated, in the intertidal zone, with periodic exposure to air.



Figs 7–9 Records of shipworms from fixed wood (◆) and driftwood (●).
7 *Lyrodus pedicellatus* (excludes record from Bluff (McQuire (1964), see text)).
8 *L. medilobatus*. **9** *Nototeredo edax*.

Lyrodus pedicellatus (Quatrefages)

New Zealand Records (Fig. 7)

Lyrodus pedicellatus was found irregularly in fixed wood at sites around the North Island and in the Marlborough Sounds and Nelson area in the South Island. McQuire (1964) collected *L. pedicellatus* from test blocks in Bluff Harbour in 1962, but it was not found south of Nelson during the present study.

L. pedicellatus was not particularly abundant in any collections in the present study, although McQuire (1964) regarded it as the dominant species in Waitemata and Tauranga Harbours. No intensive sampling has been done at Auckland recently, but many samples collected at Tauranga during 1970–74 show that *L. medilobatus* is now the most numerous species there. Although *L. pedicellatus* was collected from Tauranga, it was relatively uncommon.

L. pedicellatus was not found in mangrove wood and it was not found in collections from north of Auckland, although a large number of samples of both intertidal and subtidal wood were examined. McQuire (1964) did not record this species from his Opua or Whangarei test panels.

L. pedicellatus was uncommon in driftwood collections, being found predominantly in the western Cook Strait - Marlborough Sounds area (Fig. 7). This is probably a reflection of the intensity of collection of infested driftwood, which was greatest in the Wellington area.

In Tauranga Harbour *L. pedicellatus* was found in equal numbers at each of the test panel sites. In Pelorus and Kenepuru Sounds it was found at all the test panel sites, and at 8 of the 10 collecting sites from other fixed wood. In Wellington Harbour *L. pedicellatus* was uncommon, occurring in small numbers at only three (Shelly Bay, Ferry Terminal, and Evans Bay) of the nine test panel sites and at a collecting site at Petone Beach (Fig. 2).

General Distribution

L. pedicellatus is found in tropical to temperate waters throughout the world (Turner 1966, Rayner 1974); the limits of its distribution are about 40° latitude, north and south. In New Zealand, *L. pedicellatus* is at the southern limit of its range in the Cook Strait region. The absence of this species from the Northland collections is difficult to explain since optimum conditions (as described below) can be shown to exist locally. Hobart (43 °S) is the southernmost limit of *L. pedicellatus* in Australia (Turner & Marshall 1973).

Thermal and Haline Limits

Laboratory studies on thermal and haline tolerances of *L. pedicellatus* larvae and adults (Roch 1940, Eckelbarger & Reish 1972) show that the minimum temperature for successful tunnelling by larvae is 12–14 °C, and the minimum salinity is about 20 °/oo. Optimum conditions for settlement of larvae range from 14 to 24 °C and 25 °/oo salinity. Adults are unable to survive for more than a few weeks below 10–11 °C and 22–25 °/oo; optimum conditions for adult survival and spawning are 14–24 °C and 25–28 °/oo.

These temperature limits seem to apply to this species in New Zealand. *L. pedicellatus* was generally absent from collecting sites where minimum monthly mean sea surface temperatures were lower than 10–11 °C. The species was uncommon at the southern limit of its range (Wellington Harbour) where minimum monthly temperature means fluctuate between 9.6 and 11.2 °C (Table 2).

Lyrodus medilobatus Edmondson

New Zealand Records (Fig. 8)

Lyrodus medilobatus was found in fixed wood at most of the sampling sites on the north-east coast of the North Island between Whangaroa Harbour and Tauranga, and was common in mangrove wood in this area. It did not occur in any samples, including mangrove wood, from the west coast of Northland.

Collections from driftwood showed a similar distribution to that in fixed wood, with an extension of the range south to Ohiwa and east to East Cape.

L. medilobatus was equally abundant at all collecting and test panel sites in Tauranga Harbour.

The absence of *L. medilobatus* from the Kaipara and Hokianga Harbours is unexpected as the range of hydrological conditions in these harbours appears little different from those in Tauranga Harbour, where the species is particularly abundant. Numerous dead specimens were collected at Whakapirau (Kaipara Harbour) from wooden sticks used to transport oyster "seed" from Mahurangi Harbour (east coast of Northland) where *L. medilobatus* is abundant. Many of the dead specimens contained developing larvae. Although no live specimens were collected in this area, this species may have established itself in Kaipara Harbour through infested sticks introduced from Mahurangi over a number of years.

General Distribution

L. medilobatus has been recorded from tropical to warm-temperate seas in the south-west Pacific and south-eastern Indian Oceans, including the Hawaiian Islands (Edmondson 1942), the New Hebrides Islands and New Caledonia (Smith 1963), New Zealand, Australia, Norfolk and Lord Howe Islands, and the Cocos Islands (Turner & Marshall 1973). The southernmost limit of *L. medilobatus* in New Zealand is at about the same latitude (37 °S) as in Australia (Eden, N.S.W.).

HALINE LIMITS

L. medilobatus seems to be a moderately euryhaline species. Many specimens were collected from mangroves at Kerikeri and at Haruru Falls in the Bay of Islands, which are at the outlets of rivers (the Kerikeri and Waitangi Rivers) where surface salinities of 10‰ and 7‰, respectively, were recorded at the time of collection.

Nototeredo edax (Hedley)

NEW ZEALAND RECORDS (Fig. 9)

Nototeredo edax was collected from fixed wood at five sites in the North Island, from Tauranga in the north to Wellington in the south. No specimens were obtained from the South Island. McQuire (1964) recorded *N. edax* from Tauranga, Gisborne, and New Plymouth. New records from this study include Wanganui and Wellington.

N. edax was moderately common in driftwood from the west coast of the Wellington region and near Nelson (Fig. 9). Other specimens were collected near East Cape and Napier.

N. edax was found at all the sampling sites in Tauranga Harbour, but was rare in Wellington Harbour, occurring in small numbers at only two (Ferry Terminal and Evans Bay) of the nine test panel sites (Fig. 2).

GENERAL DISTRIBUTION

Nototeredo edax is a tropical to warm-temperate species occurring throughout the Indo-pacific region from India, the Philippines, Japan (Turner 1966), Australia (Turner & Marshall 1973), and Papua New Guinea (Rayner 1976) to New Zealand. New Zealand records reported in this paper are all from warm-temperate waters.

THERMAL AND HALINE LIMITS

Little information is available on the thermal and haline limits of this species. The New Zealand records indicate that a temperature above 18–20 °C is required for successful spawning and settlement. Rayner (1974, 1976) noted that *N. edax* was common in estuarine areas in Papua New Guinea and concluded that it was a euryhaline species.

TEREDINIDAE FROM DEEP WATER AROUND NEW ZEALAND

World records of shipworms from deep water were reviewed by Turner (1966). Most data are from wood which has been dredged or trawled from depths greater than 50 m, and so the depth of settlement is impossible to determine. These records do show, however, that "teredinids are capable of living and growing for considerable periods of time at great depths..." (Turner 1966, p. 56).

Information on shipworms actually settling at depth includes that of Roch (1940), who obtained *Teredo utriculus* (*Nototeredo norvagica*) from the jute layer of a cable at 700 m in the Mediterranean Sea, Turner (1966), who obtained *Bankia carinata, Teredothyra atwoodi*, and *T. matocotana* from test panels at 100 m off Fort Lauderdale, Florida, and Tipper (1968), who obtained *Bankia setacea* from test panels at 200 m depth off Oregon. Tipper did not observe any settlement on boards immersed at 500 m and 1000 m over the same period as the boards from 200 m.

Hurley (1961) reported the settlement of *Bankia australis* (subsequently re-identified as *B. neztalia* by Turner & McKoy (1979)) on a wooden guard rail of known origin, recovered not far from where it was lost, in 127 m of water off Cape Campbell, New Zealand. It is likely that the settlement of *B. neztalia* on this wood occurred at that depth, since the wood probably sank immediately after it was lost overboard. The only other record of shipworms in deep water around New Zealand is that of Suter (1911) who reported *Teredo saulii* from wood trawled in Palliser Bay by the *Nora Niven* expedition in 1907. This material has been re-examined and found to be *Bankia neztalia.* The depth of this station was not given, but, from the position marked on Suter's figure, it was probably between 55 and 75 m.

The New Zealand Oceanographic Institute (NZOI) has sampled more than 1250 biological stations at depths greater than 50 m around the coast between 30 °S and 48 °S (Luckens 1972), using various methods including trawls, dredges, and grabs. Pieces of wood were recovered from about 50 (4%) of the stations, and most of this material has been examined for evidence of shipworm activity. Such evidence, either empty tunnels, shells and pallets, or whole animals, was found in the wood from 31 stations (Table 1). The only species identified from these samples was *Bankia neztalia,* which was obtained as shells and pallets at six stations and as whole animals at nine stations.

In addition to the material from the NZOI stations, other specimens were obtained from deep water (Table 1). Most of this material is from the Bay of Plenty area and was collected by Dr P. M. Hine (Ministry of Agriculture & Fisheries). One further interesting record, probably from deep water, is that of a well preserved shell and front half of the body of an unidentified specimen taken from the stomach of a groper caught in the Bay of Plenty in 1958 (National Museum Collection).

Although it is impossible to determine from the above records whether or not *B. neztalia* can settle at the depths at which whole (and presumably live at the time of collection) specimens have been found, the

number of whole specimens recorded suggests that *B. neztalia* is capable of surviving at depths to 1200 m. Low water temperatures probably prevent this species from successfully reproducing below about 300 m.

The absence of species other than *B. neztalia* from these deep-water samples is probably a reflection of the abundance of this species in in-shore areas around New Zealand, rather than a special ability of *B. neztalia* to survive at great depths. However, specimens of other wood-boring bivalves, probably *Xylophaga galathaea, X. wolffe,* and *Xyloredo* sp. (identified by R. D. Turner, Museum of Comparative Zoology, Harvard University, pers. comm.) of family Pholadidae, were found in wood from some of the deeper stations. In warm-temperate waters species of subfamily Xylophagainae are usually restricted to deep water below the known depth range of shipworms (Turner 1967, 1972), although the vertical distribution of the two groups overlaps to some extent so that members of both groups may be found in the same piece of wood (Turner 1966, Tipper 1968).

DISPERSAL OF SHIPWORMS AROUND NEW ZEALAND

Shipworms are dispersed either as adults (in driftwood, wooden-hulled ships, wooden oyster trays, or through other human activities) or as larvae in the plankton. The extent to which the various genera have become distributed around the world is associated largely with the type of larval life (Turner 1966).

Driftwood is often cited as an important means of transport and dispersal for sedentary marine animals (Ekman 1953, Thorson 1961) and for shipworms in particular (Edmondson 1942, 1962, Turner 1966). Of over 1500 pieces of shipworm-infested driftwood examined from around the New Zealand coast, only 3 were found to contain material not of New Zealand origin; a piece of *Cryptomeria japonica* containing shells and pallets of *Teredora princesae* (Sivickis) was found at Paekakariki Beach, and two other pieces of driftwood containing *T. princesae* were collected at Macauley Island in the Kermadec group to the north of New Zealand. *T. princesae* has been collected from fixed wood in India (Nair & Saraswathy 1971), the Philippines (Sivickis 1928), and north Australia and New Guinea (Turner & Marshall 1973, Rayner 1976), but it is more commonly found in driftwood and boat hulls and is generally regarded as a tropical to subtropical oceanic species (Edmondson 1962).

The limits of distribution of all five New Zealand species were greater on driftwood than on fixed wood, indicating that much of the dispersal of these species around the coast is by driftwood. Further dispersal of shipworms around New Zealand is certainly aided by movements of wooden-hulled boats; the record of *Lyrodus pedicellatus* from Bluff (McQuire 1964) may be a result of such dispersal.

Shipworms may be accidentally dispersed by oyster farming operations, e.g., by the transport of the wooden apparatus used for collecting oyster spat from one area to another. Transport of *Lyrodus medilobatus* from the east coast of North Auckland to Kaipara Harbour is an example of such dispersal, although the shipworm has not apparently established itself in the new area.

The absence of some species from the New Zealand shipworm fauna is interesting considering their distribution in Australia and the Pacific Islands and their thermal and haline limits. *Teredo navalis* is widely distributed around the world, and Turner (1966) noted that its success was probably due to the great range of temperature and salinity which it can tolerate; it has been reported as spawning in water of salinity as low as 9‰ (Miller 1926) and temperatures of 11–12 °C (Grave 1928). Larvae can settle at above 10‰ and between 14 and 26 °C (Imai *et al.* 1950). In Australia, *T. navalis* is widely distributed in subtropical to cool-temperate waters as far south as Launceston (41°20'S) (Turner & Marshall 1973). It is, therefore, a little surprising that despite the extensive traffic of wooden ships between Australia (and other places where *T. navalis* is and was abundant) and New Zealand since the early 19th century and general trans-Tasman sea surface currents in the direction of New Zealand, *T. navalis* has not established itself in New Zealand. The unexpected absence of this species from islands in the central Pacific was noted by Edmondson (1962), and Marshall-Ibrahim (1975) noted the absence of *T. navalis* from collections in Tasmania.

Other shipworms which have been reported as well established in cool-temperate waters in south-eastern Australia, but which have not yet been recorded in New Zealand, are *Teredo fragilis, T. clappi, T. furcifera, Bankia carinata,* and *Lyrodus bipartita* (Turner & Marshall 1973).

CONCLUSIONS

Bankia neztalia is found in cool-temperate waters around New Zealand, mainly south of Tauranga and New Plymouth. It is the most abundant shipworm around the South Island. The lower temperature limit for successful spawning and settlement is probably about 10 °C. No evidence is available to indicate upper thermal or lower haline limits. This species is capable of surviving at depths of 1200 m, but probably does not reproduce at depths greater than about 300 m.

Bankia australis occurs in warm-temperate waters in New Zealand north of Nelson and the Marlborough Sounds. It is a euryhaline species and

requires water temperatures above 19–20 °C for successful spawning and settlement.

Lyrodus pedicellatus is found in New Zealand over almost the same range as *Bankia australis,* but it is able to settle successfully at slightly lower temperatures, the lower limit for its survival is about 10 °C.

In New Zealand *Lyrodus medilobatus* occurs only in the warm-temperate waters on the north-east coast of the North Island north of Tauranga. The species is moderately euryhaline, but no data on thermal limits are available.

Nototeredo edax is relatively uncommon in New Zealand waters, and is restricted to warm-temperate waters over approximately the same range as *Bankia australis.* Its thermal limits are unknown, but the species is probably euryhaline.

Much of the dispersal of all five species around the coast is by driftwood.

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