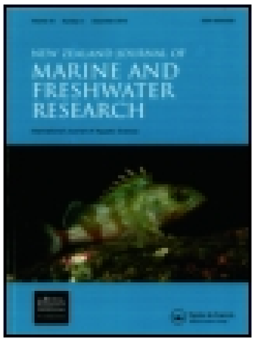

New Zealand Journal of Marine and Freshwater Research

ISSN: 0028-8330 (Print) 1175-8805 (Online) Journal homepage: http://www.tandfonline.com/loi/tnzm20

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NEW ZEALAND
JOURNAL OF MARINE AND FRESHWATER RESEARCH

Department of Scientific and Industrial Research, Wellington

Editor: E. K. Saul

VOLUME 11 | SEPTEMBER 1977 | NUMBER 3

COMMON BIVALVE LARVAE FROM NEW ZEALAND: MYTILACEA

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ABSTRACT

The late stage larvae of five common mytilid bivalves (Mollusca: Pelecypoda: Mytilacea) are described and provisionally identified as *Mytilus edulis aoteanus, Modiolus areolatus, Perna canaliculus, Xenostrobus pulex,* and *Modiolarca impacta.* All are readily distinguishable on the basis of larval shell features, including hinge structure. However, one common species, *Aulacomya maoriana,* was not discerned, and thus the identifications must remain tentative.

The larvae were recovered from plankton samples from Bay of Islands (35° 15′ S, 174° 10′ E), Wellington Harbour (41° 16′ S, 174° 51′ E), and Raumati Beach (40° 56′ S, 174° 58′ E), New Zealand, during 1970–72. Their seasonal occurrences in the plankton are described and related to the condition index of the adults as far as possible.

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Received 17 June 1976; revision received 17 February 1977.

Fisheries Research Division Publication 304

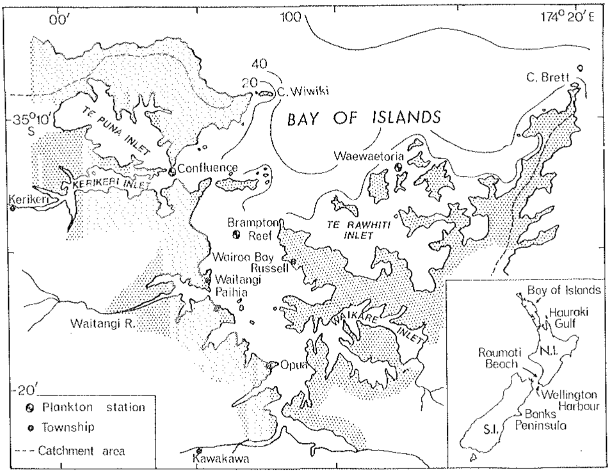


FIG. 1—Position of plankton stations and other features, Bay of Islands; bathymetry in metres. Inset gives location of other places mentioned in text.

INTRODUCTION

The identification of the larval stages of commercially important bivalves assists in the determination of the spawning periods of species and is essential in determining the onset and intensity of spatfall. With the development of mussel farming in New Zealand, it is important that the larvae of different mytilid species can be distinguished.

This study deals mainly with late stage veligers (veliconchae) and early pediveligers of mytilids; these are the stages at which the species are most readily distinguishable.

LARVAL FEATURES OF THE MYTILACEA

Most mytilid species have veliger larvae with a long planktotrophic (plankton-feeding) development.

Chanley (1970) and Chanley & Andrews (1971) found that pelagic mytilid larvae are characterised by the following features: long hinge line, taxodont dentition with larger teeth nearer the ends of the provinculum, the umbo usually low, rounded and inconspicuous during development, larva often "egg-shaped" and "dark" or brown coloured. Chanley (1970) also noted that mytilid larvae attain a comparatively large pelagic size, and often vary widely within the same species in the size at settlement. Other workers have noted the occurrence of a prominent eyespot in the late stage veligers and pediveligers of several mytilid species.

SAMPLING AREAS AND METHODS

Bivalve larvae were sampled at the three localities in the North Island, New Zealand, shown in Figs 1 & 2; Table 1 gives the precise location and depth of all stations.

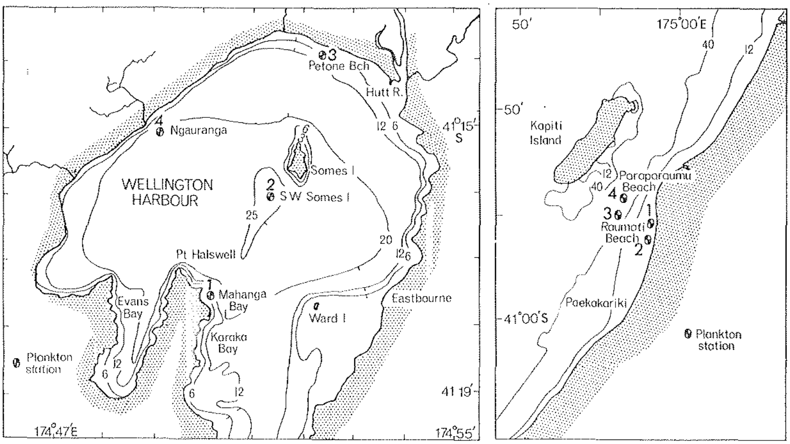


FIG. 2—Position of plankton stations and other features, Wellington Harbour (*left*) and Raumati Beach (*right*); bathymetry in metres.

Bay of Islands (35° 15′ S, 174° 10′ E) is an open embayment of approximately 240 km² and has hydrological conditions ranging from estuarine to oceanic. The hydrology of the bay during the sampling period, based mainly on observations at three stations, has been described by Booth (1974). The main physiographic features and the three plankton sampling stations, coincident with the hydrological stations, are shown in Fig. 1. The plankton sampling programme in Bay of Islands extended from April 1970 to December 1971.

Wellington Harbour (41° 16′ S, 174° 51′ E) is a more enclosed embayment of about 76 km² with much less estuarine area. The hydrology of the harbour has been discussed in Booth (1975), and Fig. 2 shows the general physiography and the location of the four plankton sampling stations, again coincident with the hydrological stations. Plankton sampling here extended from May 1970 to February 1972.

Raumati Beach (40° 56′ S, 174° 58′ E) is a 10 km section of open sandy beach on the west coast, approximately 35 km north of Wellington. Kapiti Island lies 8 km offshore and gives the beach some protection from severe wave action. Surface currents flow south to south-east (Heath 1969), and except for changes in salinity caused by occasional flooding of nearby rivers, the tidal variations in hydrological parameters are small (Mr P. Roberts, Fisheries Research Division, Ministry of Agriculture and Fisheries, Wellington, pers. comm., November 1974). The four plankton sampling stations are given in Fig. 2. The main period of plankton sampling was from June 1971 to June 1972.

TABLE 1—Position of plankton stations, Bay of Islands, Wellington Harbour, and Raumati Beach, 1970–72

Locality	Station	Latitude (° ′ ″S)	Longitude (° ′ ″E)	Depth (m)
Bay of Islands	Confluence	35 11 45	174 03 40	15
	Brampton Reef	35 14 20	174 05 40	18
	Waewaetoria	35 12 45	174 12 25	16
Wellington Harbour	Mahanga Bay	41 17 45	174 50 05	14
	SW Somes Island	41 16 10	174 51 30	26
	Petone Beach	41 14 00	174 52 20	5
	Ngauranga	41 15 00	174 49 00	18
Raumati Beach	Station 1	40 55 00	174 58 00	3
	Station 2	40 56 00	174 58 00	3
	Station 3	40 55 30	174 56 30	65
	Station 4	40 54 30	174 56 30	65

Plankton was sampled at approximately monthly intervals at the stations shown in Figs 1 and 2. Sampling could not be done at the same stage of the tide on each date; the dates, times, and tides are given in Appendices 1 and 2. The net used at all stations, except Raumati Beach St 1 and 2, was a free-fall truncate cone type, based on the design given by Smith *et al.* (1968). The net was modified for a vertical drop instead of a vertical haul by fitting a 7 kg galvanised ring (0.5 m diameter) at the mouth. This ring was sufficiently heavy to drag the net down the water column; a fast drop was not required since bivalve larvae are incapable of rapid avoidance reactions. The galvanised ring was attached to the mesh panels (120 μm mesh) by a canvas collar, around which ran the throttling rope. The truncate cone had a mesh area of 1.36 m^2, while the cylinder had a mesh area of 1.78 m^2, giving a total area of mesh panels of 3.14 m^2, more than 1 m^2 greater than the specifications given by Smith *et al.* (1968). The extra filtering area would have helped to maintain the 85% or better filtering efficiency specified for this net, even in the estuaries where the net often clogged with silt and phytoplankton. The truncate cone terminated in a bucket at the end of which a 120 μm mesh silk panel filtered the plankton.

The net was released at the surface, and as soon as the metal collar touched the bottom (or reached 20 m depth at Raumati Beach St 3 and 4), the recovery line was pulled, thereby throttling the net. The throttled net was hauled to the surface, and the plankton was carefully washed into the collecting bucket as the net was removed from the water. The net filtered approximately 200 litres of seawater for every 1 m of fall. At the shallow water Raumati Beach St 1 and 2, plankton samples were taken with a 0.35-m-diameter mouth, 120-μm-mesh tow net; each tow lasted 3 min.

Plankton samples were preserved within 2 h of collection in a solution of 3% formalin neutralised with sodium bicarbonate, with sugar added

TABLE 2—Monthly abundance of late stage larvae of Mytilids 1–5 at Raumati Beach, 1970–72. Tow-net data, listing from most abundant species present in order of decreasing abundance, from two 3-min tows (Stns 1 and 2, right part of Fig. 2); free-fall net data, in numbers of larvae per 1000 litres, from the average of two net drops (Stns 3 and 4, right part of Fig. 2) (– = no sample; * = 1 tow only)

Date	Sea Temp. (°C)	TOW NET	FREE-FALL NET Mytilid 1	2	3	4	5	Total Late Stage Bivalve Larvae
26 Nov 1970	19.0	Mytilid 1, 3, 2	–	–	–	–	–	–
12 Dec 1970	21.0	Mytilid 4*	0	0	0	0.30	0	2.5
17 Jun 1971	12.3	Mytilid 4, 3	0	1.56	2.35	0.38	0	9.8
25 Jul 1971	12.5	Mytilid 3, 4	0	0	0.56	0	0	11.1
30 Sep 1971	13.8	Mytilid 4, 3, 5	0.14	0	1.98	2.12	0	6.8
4 Nov 1971	15.9	Mytilid 4	0	0	0	0.82	0	0.9
15 Dec 1971	19.2	Mytilid 4	0.14	0	0.14	0	0.14	5.5
17 Jan 1972	19.6	Mytilid 4, 5	0	0	0	0.51	0.26	11.6
15 Feb 1972	17.5	Mytilid 4	0	1.36	0	1.87	0	11.7
18 Mar 1972	18.3	Mytilid 4, 5*	0	56.1	4.76	17.0	4.08	176.0
15 Apr 1972	16.2	Mytilid 4, 2*	0.68	0.68	0.34	1.02	0	5.4
4 Jun 1972	12.8	Mytilid 4, 2, 3*	0	1.50	3.86	5.77	0	16.8

as a precaution against accidental evaporation (Carriker 1950). In the laboratory, the bivalve larvae were isolated by swirling the plankton sample in a round bowl. The number of each species of late stage larvae, as well as an estimate of the total number of D-shaped larvae, were recorded, except for the inner Raumati Beach samples, which were often sandy, and where only details of the most abundant bivalve larvae present were noted.

In all areas, the whole sample was analysed where possible, but sometimes the large number of larvae made subsampling necessary, and Brinton's (1962) method of taking aliquots from an agitated measuring cylinder was used. This simple technique involved the least manipulation of the larvae, and it also eliminated the problem inherent in many other subsampling devices of larvae being caught unnoticed in the compartments and corners.

The seasonal occurrences of the larvae of each mytilid species from Bay of Islands and Wellington Harbour are presented, on a modified log scale, after the larval descriptions (see Figs 5, 8, 10, 13 and 15). The larval occurrences at Raumati Beach are given in Table 2. The occurrence and abundance of the adults of the six most abundant mytilid species found at the three sampling areas are shown in Table 3.

LARVAL TERMINOLOGY, DESCRIPTIONS, AND IDENTIFICATIONS

Larval descriptions are based on larval shell dimensions, shape, colour, texture, hinge characters, and the presence of features such as eyespots. The terminology used is that of Chanley & Andrews (1971) (see Fig. 3) for most features, and of Rees (1950) for hinge characters

TABLE 3—Relative abundance of the adult mytilid species in the sampling localities, 1970–72. The most abundant species present in each locality are listed in order of decreasing abundance (a = abundant; c = common; f = frequent). Other mytilid species were, in each locality, either much less common or absent. Sources of data: shore and benthic surveys of author (Booth unpublished 1972); Flaws (unpublished 1968); Beu & Climo (1971); and reports from Victoria University Biological Society, Victoria University Diving Club, and Wellington Shell Club

Species	Abundance	Distribution
Bay of Islands		
Mytilus edulis aoteanus	c	Intertidal rock (estuaries)
Perna canaliculus	c	Intertidal and subtidal rock (lower estuaries and basin)
Xenostrobus pulex	c	Intertidal rock (basin)
Modiolarca impacta	f	Subtidal substrates (lower estuaries and basin)
Modiolus areolatus	f	Subtidal substrates (basin)
Wellington Harbour		
Mytilus edulis aoteanus	a	Intertidal rock
Perna canaliculus	a	Intertidal and subtidal rock
Aulacomya maoriana	c	Intertidal and subtidal rock
Modiolarca impacta	c	Subtidal substrates
Raumati Beach		
Xenostrobus pulex	a	Intertidal rock (Paekakariki)
Mytilus edulis aoteanus	c	Intertidal rock (Paekakariki)
Perna canaliculus	c	Intertidal and subtidal rock (Paekakariki)
Modiolus areolatus	c	Subtidal substrates (off shore)
Aulacomya maoriana	f	Intertidal and subtidal rock (Paekakariki)
Modiolarca impacta	f	Subtidal substrates (off shore)

in particular. The larval dimensions give the size of late stage larvae most often observed. Hinge line length is the length of the provinculum. "Late stage larvae" refers to both the late veliger and pediveliger stages.

Whole larvae and single valves were observed and photographed in a light microscope, often using Nomarski differential interference contrast (DIC) to accentuate features.

To examine hinges, the larval valves were separated using sodium hypochlorite (Rees 1950), and the hinges studied and photographed in a Cambridge 600 stereoscan electron microscope.

CONDITION INDEX

The condition of adult bivalves of many species has been demonstrated to decrease rapidly on spawning (Giese 1959), and hence the cycle in the adult populations in the study areas could give some indirect evidence about the identity of the newly hatched larvae occurring in the plankton. Therefore, the condition index of those species most readily available and of sufficient size for this type of analysis (*Mytilus edulis aoteanus*

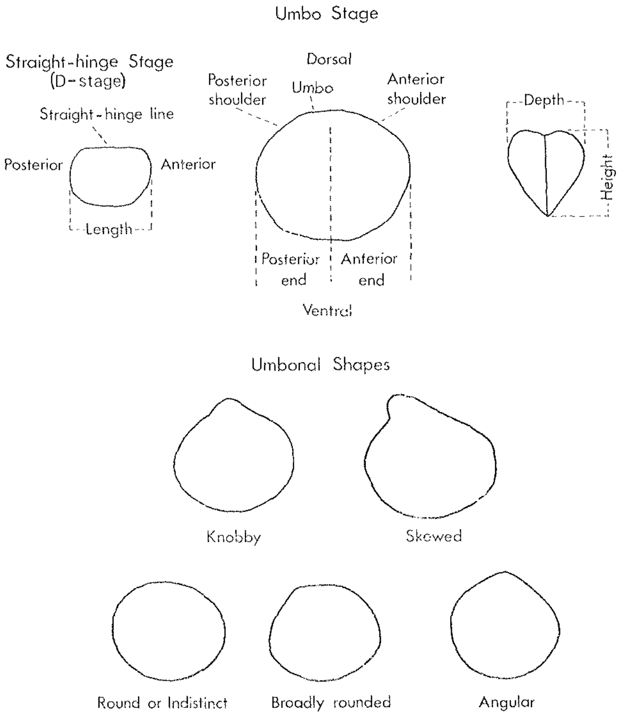


FIG. 3—Terminology used to describe dimensions and shapes of bivalve larvae, from Chanley & Andrews (1971, fig. 1, p. 49).

and *Perna canaliculus* in Bay of Islands and Wellington Harbour, and of *Modiolarca impacta* in Wellington Harbour) was studied. The condition index of 25 animals, all of similar size and always taken from the same locality and from the same tidal level was measured, usually monthly, in five groups of five animals.

Mytilus edulis aoteanus and *P. canaliculus* from Bay of Islands were collected in Wairoa Bay from August 1970 to January 1972, and those from Wellington Harbour were collected in Karaka Bay from December 1970 to January 1972. *Modiolarca impacta* were collected in Mahanga Bay, Wellington Harbour, from December 1970 to January 1972.

Two methods of assessing condition index were used for formalin-preserved animals:

(i) By wet weight: animals were thoroughly cleaned of encrusting growth, opened, and byssal threads removed. The flesh of five individuals was removed from the shells, rinsed, and the shells and flesh separately drained for a standard time (15 minutes) on filter paper and then weighed.

$$\text{Condition index} = \frac{\text{Weight of flesh (g)}}{\text{Weight of flesh and shell (g)}} \times 100$$

TABLE 4—Summary of main occurrences of late stage mytilid larvae, Bay of Islands, Wellington Harbour, and Raumati Beach, 1970–72. (a = abundant, i.e., $\geqslant 100$ larvae per 1000 litres seawater; c = common, i.e., $\geqslant 10$, but < 100; f = frequent, i.e., $\geqslant 1$ but < 10; o = occasional, i.e., < 1)

Species	Bay of Islands	Wellington Harbour	Raumati Beach
Mytilid 1	Aug–Nov (f)	May–Oct (f, c) Dec–Jan (f, c, a)	Nov–Dec (o) April (o)
Mytilid 2	May–Sep (f) Nov–Dec (f) Feb (c)	Insignificant numbers	Feb–Jun (o, f, c)
Mytilid 3	Sep–Oct (f)	Jul–Oct (f, c) Dec–Mar (f, c) May (f, c)	Mar-Sep (o, f) Dec (o)
Mytilid 4	Aug–Oct (o, f)	Insignificant numbers	Most of year (o, f)
Mytilid 5	Jun–Dec (f, c) Jan (c) Feb–Mar (f, c)	Aug–Sep (f, c) Dec–Feb (f, c, a) Apr–Jun (f, c, a)	Dec–Mar (o, f)

(ii) By dry weight: the same procedure as above, except the flesh was dried at 60°C for 48 h.

$$\text{Condition index} = \frac{\text{Weight of dried flesh (g)}}{\text{Weight of dried flesh and shell (g)}} \times 100$$

LARVAL DESCRIPTIONS AND PROVISIONAL IDENTIFICATIONS

MYTILID 1 (? **Mytilus edulis aoteanus** Powell)

Figs 4–6 & 17, Tables 2–4

LARVA – *Dimensions*: Eyed larvae 250–330 μm in length, with average length to height ratio of 1: 0.9 and ratio of length of larva to length of hinge line of 1: 0.5.

Shape (Fig. 4): In the late stage larva the umbos are knobby to broadly rounded, and equal in size; anterior end is much more pointed and slightly longer than the posterior end, the posterior shoulder is more rounded than the anterior shoulder, and the ventral margin is rounded.

Hinge (Fig. 4): Hinge teeth not as prominent in this late stage larva as they are in the other four mytilid larvae. In larvae 280 μm in length, hinge of both valves has taxodont dentition with the thickened provinculum bearing 5–8 teeth at each end separated by a narrow region bearing 14–18 small teeth. Ligament attachment point lies behind and towards posterior end of provinculum.

Other Features: Late stage larva is often dark yellow and usually has a purple or brown tinge around the umbos; central eyespot usually occurs

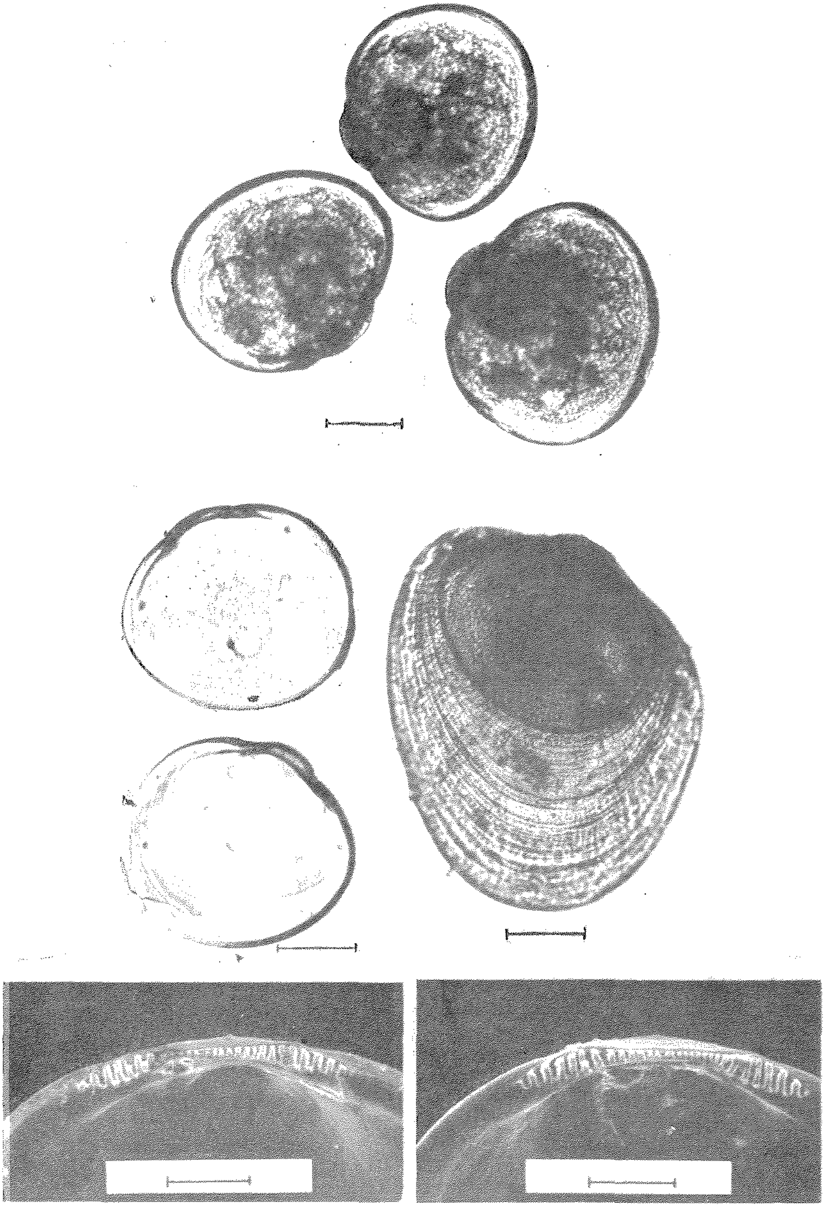
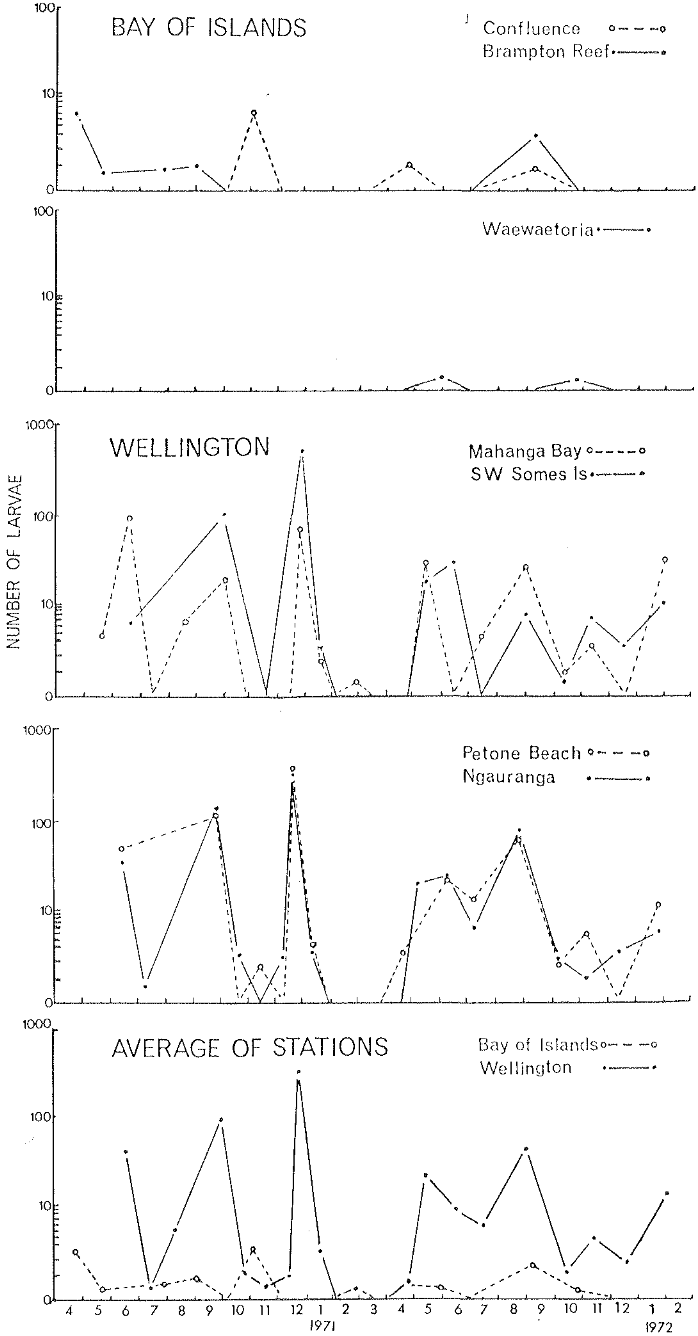


FIG. 4—Late stage larvae (*upper*) and single valves of late stage larva (*middle left*) of Mytilid 1; early postlarva (*middle right*) taken from settlement of *Mytilus edulis aoteanus* in Wellington Harbour; scale lines = 100 μm. Hinge of left valve (*lower left*) and right valve (*lower right*) of late stage larva (length 280 μm) of Mytilid 1 (not both from the same larva); scale lines = 40 μm.


BAY OF ISLANDS
Confluence
Brampton Reef
Waewaetoria
WELLINGTON
Mahanga Bay
SW Somes Is
Petone Beach
Ngauranga
AVERAGE OF STATIONS
Bay of Islands
Wellington
NUMBER OF LARVAE
1000
100
10
0
4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2
1971
1972

in larvae over 220 μm in length; marked concentric lamellae in outer prodissoconch 2 shell seen under Nomarski DIC; no radial striae; prodissoconch 1 shell often more punctate. The early dissoconch shell of a mytilid (Fig. 4) recovered from recent settlement of *M. edulis aoteanus* clearly displays this prodissoconch 2 shape.

Comparison with Other Species: This larva closely resembles the shape and dimensions of *Mytilus edulis* larvae given by many authors including Nelson (1928), Jorgensen (1946), Sullivan (1948), Rees (1950), Loosanoff *et al.* (1966), and Le Pennec & Masson (1976).

DISTRIBUTION AND SEASONAL ABUNDANCE (Figs 5 and 17, Tables 2–4) – This larva, as well as the adults of *M. edulis aoteanus*, occurred at all sampling localities. In Bay of Islands the larva occurred in greatest numbers at the stations with most estuarine influence (Confluence and Brampton Reef), estuaries also being the areas of greatest abundance of the adults of *M. edulis aoteanus*.

Peak densities of this larva in all areas occurred sometime during summer, late autumn and spring. These larval occurrences correspond in general with those inferred for *M. edulis aoteanus* from the results of previous authors. Ralph & Hurley (1952) observed settlement of *Mytilus planulatus* (= *M. edulis aoteanus*) throughout the year in Wellington Harbour during 1949–50. Colgate (unpublished 1971) studied settlement from March to June 1971 in Wellington Harbour and recorded *M. edulis aoteanus* settling during May and June. MacDonald's (unpublished 1963) histological studies on *M. edulis aoteanus* at Banks Peninsula suggested spawning between late September and May.

ADULT CONDITION CYCLE – *Bay of Islands* (Fig. 6): The maximum and minimum condition indices preceded the maximum and minimum water temperatures by approximately one month in 1971. The condition index rose from a low value in September 1970 to reach a peak in January 1971. A decline occurred throughout the autumn and early winter, although a slight increase occurred in March. A further slight improvement in condition occurred in early spring, followed by a drop in September–October, and a subsequent rise as summer approached. The larval densities in the plankton were too low for significant correlations to be apparent between them and the adult stock condition, although peak larval densities occurred during spring of both years at water temperatures of 15–17°C.

Wellington Harbour (Fig. 6): The wet and dry weight condition index cycles had similar curves. The condition index rose from a low value in December 1970 to a peak in April 1971. This peak occurred almost 2 months after the highest water temperature in the harbour.

OPPOSITE

FIG. 5—Monthly variations in abundance (numbers per 1000 litres of sea water) of late stage larvae of Mytilid 1, Bay of Islands and Wellington Harbour, April 1970–February 1972.

The condition index dropped rapidly during April and May 1971, when the water temperature was between 14°C and 16°C, and continued to drop during the winter. Improvement in the condition index began in September 1971, about 2 months after the lowest water temperature in the harbour. Peak condition was reached in November 1971, followed by a drop in the index in December 1971.

The variation in the condition index showed a fairly close correlation with the larval abundance in the plankton, with rapid drops in the index usually preceding peak larval occurrences.

Comments: The seasonal condition cycles of adults at Bay of Islands and Wellington Harbour appeared to follow the general water temperature curves, but were not entirely dependent on them. During 1970–71, adults from Bay of Islands had a lower overall condition index than those from Wellington Harbour.

MYTILID 2 (? **Modiolus areolatus** (Gould))

Figs 7, 8, & 17, Tables 2–4

LARVA – *Dimensions*: Eyed larvae 270–340 μm in length, with average length to height ratio of 1 : 0.8 and ratio of length of larva to length of hinge line of 1 : 0.45.

Shape (Fig. 7): In the late stage larva, the umbos are knobby, equal in size, and more conspicuous than in Mytilid 1; the anterior end is much more pointed and slightly shorter than the posterior end, the posterior shoulder is more rounded and higher than the anterior shoulder, and the ventral margin is almost flat.

Hinge (Fig. 7): Well-developed taxodont dentition in late stage larva. Larvae 290 μm in length have in both valves 5–8 large teeth at each end of the provinculum with a narrow region of 6–10 small teeth between. Ligament attachment point lies behind and towards posterior end of provinculum.

Other Features: Late stage larva is yellow with red-brown tinge near umbos; approximately central eyespot usually occurs in larvae over 250 μm in length; valves and hinge heavy and strong; fine concentric lamellae in both prodissoconch shells seen under Nomarski DIC; no radial striae; outer prodissoconch 2 shell often slightly more punctate in appearance than rest of valve, but two prodissoconch shells usually not clearly delineated.

Comparison with Other Species: This larva resembles the shape of the larvae of *Modiolus demissus* described by Sullivan (1948) and Loosanoff *et al.* (1966), and the late stage larvae of *Lithophaga bisulcata* described by Culliney (1971).

DISTRIBUTION AND SEASONAL ABUNDANCE (Figs 8 and 17, Tables 2–4) – The larva occurred in significant numbers at Bay of Islands and Raumati Beach, the localities at which the adults of *M. areolatus* were most abundant. Times of peak densities differed at each locality, with summer

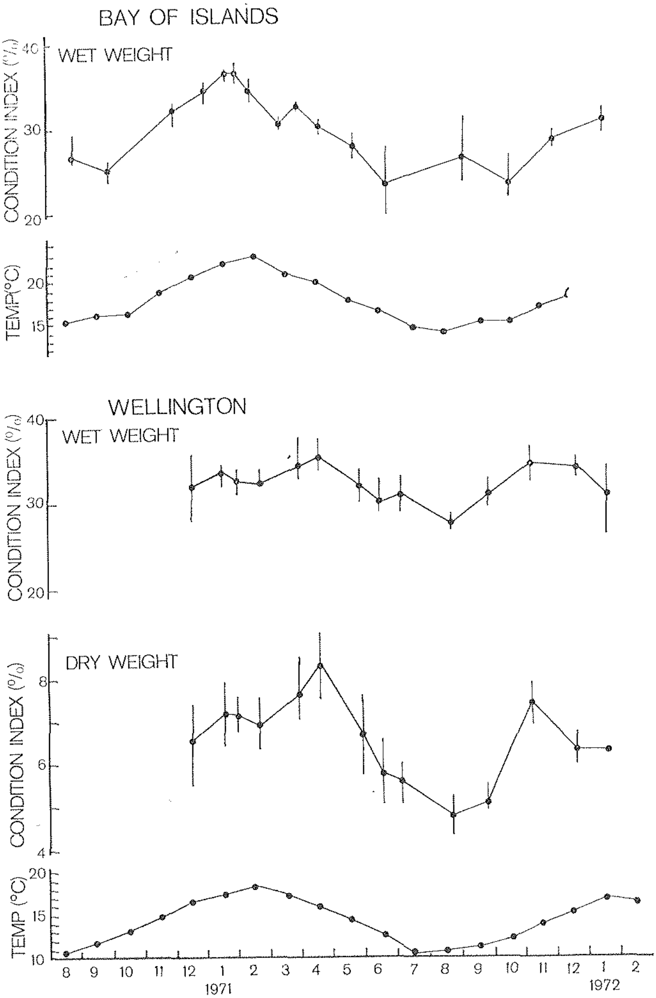


FIG. 6—Condition indices of adult *Mytilus edulis aoteanus* from Bay of Islands (Wairoa Bay) and Wellington Harbour (Karaka Bay), 1970–72. The vertical lines give the range of values for each group of five animals; mean values are joined. Monthly mean sea surface temperatures from Booth (1974, 1975).

and winter being the seasons in common. In Bay of Islands this larva occurred in greatest numbers at Waewaetoria, the station most open to the sea and also the area of greatest abundance of the adults of *M. areolatus*.

MYTILID 3 (? **Perna canaliculus** (Gmelin))

Figs 9–11 & 17, Tables 2–4

LARVA – *Dimensions*: Eyed larvae 250–340 μm in length, with average length to height ratio of 1 : 0.95 and ratio of length of larva to length of hinge line of 1 : 0.4.

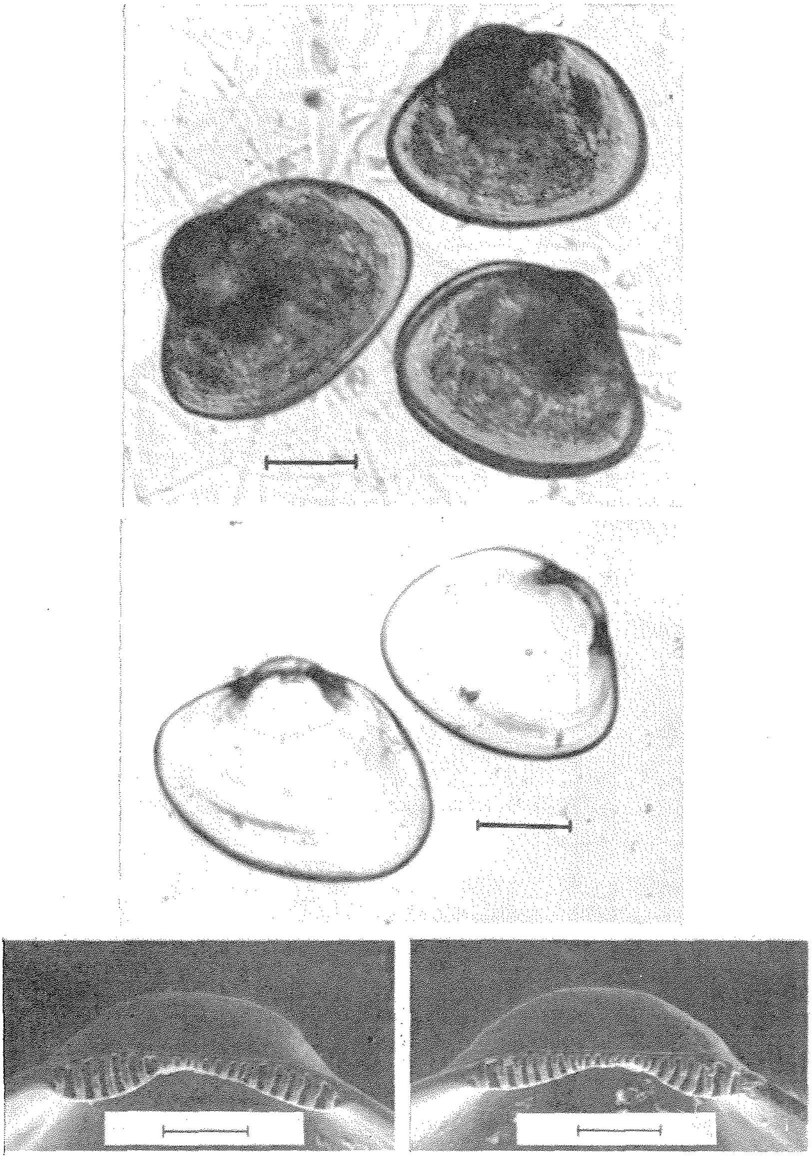


FIG. 7—Late stage larvae (*upper*) and single valves of late stage larva (*middle*) of Mytilid 2; scale lines = 100 μm. Hinge of left valve (*lower left*) and right valve (*lower right*) of late stage larva (length 290 μm) of Mytilid 2 (not both from the same larva); scale lines = 40 μm.

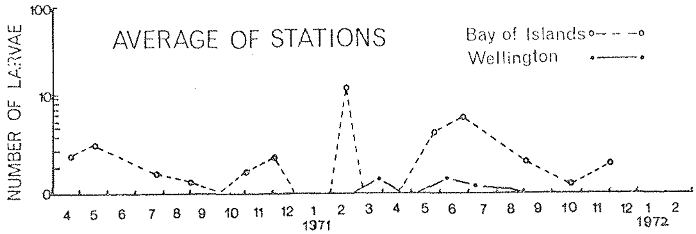


FIG. 8—Monthly variations in abundance (numbers per 1000 litres of sea water) of late stage larvae of Mytilid 2, Bay of Islands and Wellington Harbour, April 1970–February 1972.

Shape (Fig. 9): In the late stage larva the umbos are equal in size and more knobby than in Mytilid 1; anterior end is more pointed and about the same length as the posterior end, the short, straight posterior and anterior shoulders are similar in height, and the ventral margin is almost circular.

Hinge (Fig. 9): Well-developed taxodont dentition in late stage larva. In larvae 295 μm in length, the provinculum in both valves is thickened and bears 5–8 large teeth at each end separated by a narrow region of 5–8 very small, poorly developed teeth. The posterior shoulder has 4–6 teeth on a thickened section, completely separated from the provinculum. Ligament attachment point lies behind and towards posterior end of provinculum.

Other Features: Late stage larva is grey in colour often with a purplish tinge around the umbos; central eyespot usually occurs in larvae over 240 μm in length; fine concentric lamellae on both prodissoconch shells seen under Nomarski DIC; no radial striae; prodissoconch 1 shell often quite clearly delineated from prodissoconch 2 shell. The early dissoconch shell of a mytilid (Fig. 9) recovered from a recent settlement of *P. canaliculus* clearly displays this prodissoconch 2 shape.

Comparison with Other Species: This larva closely resembles the dimensions and shape of the larva of *Perna perna* (Linné) described by Martinez (1967), which also has teeth on the posterior shoulder.

DISTRIBUTION AND SEASONAL ABUNDANCE (Figs 10 & 17, Tables 2–4) – This larva, as well as the adults of *Perna canaliculus*, occurred at all sampling localities. Peak densities of the larva occurred during spring at all localities, and also during winter in the two southern areas, and in summer in Wellington Harbour. The spring maximum in Bay of Islands is not fully consistent with the observations of Greenway (1969) that the main settlement of *P. canaliculus* occurred in spring and summer during 1967–69 at another northern New Zealand locality (Te Kouma Harbour). Similarly, the maxima of larval occurrence in the southern localities is not fully consistent with MacDonald's (unpublished 1963) histological studies which predicted spawning from January to early April at Banks Peninsula.

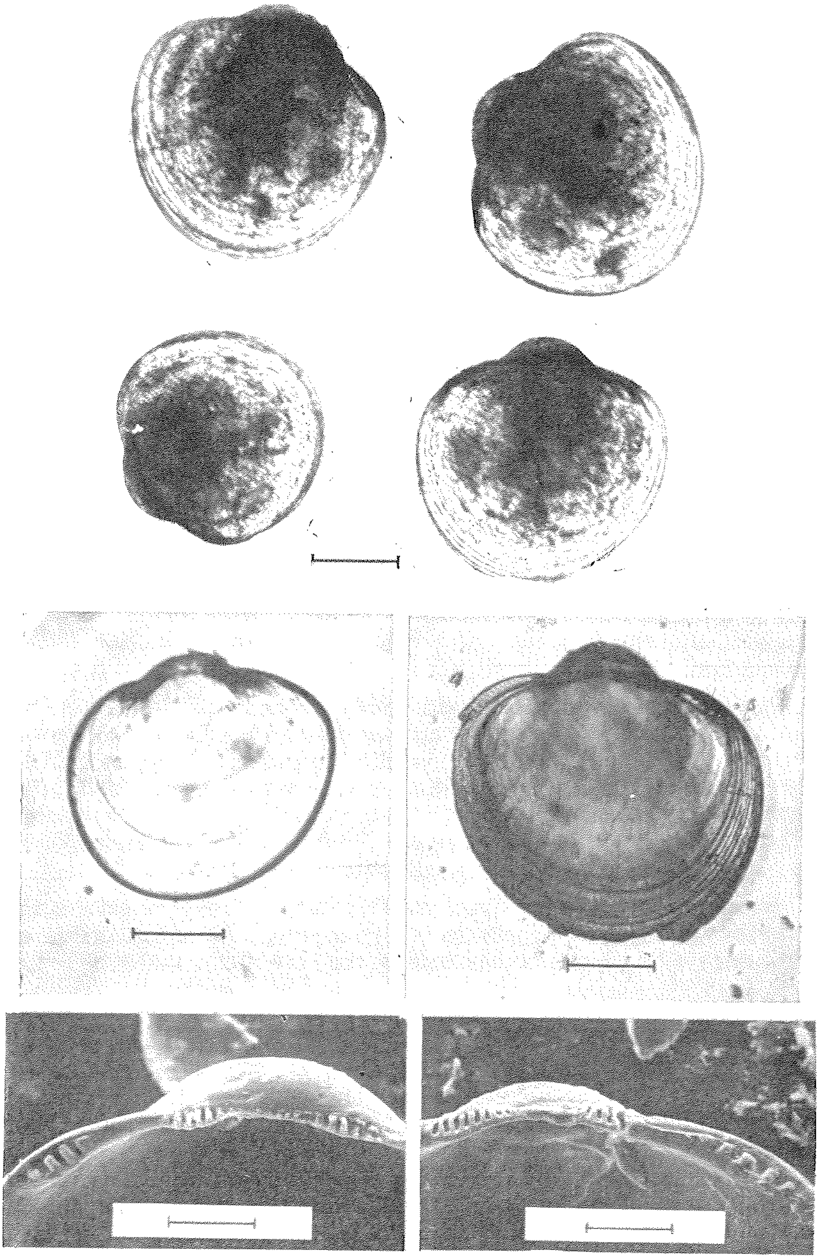


FIG. 9—Late stage larvae (*upper*) and left valve of late stage larva (*middle left*) of Mytilid 3; early postlarva (*middle right*) taken from settlement of *Perna canaliculus* in Wellington Harbour; scale lines = 100 μm. Hinge of left valve (*lower left*) and right valve (*lower right*) of late stage larva (length 295 μm) of Mytilid 3 (not both from the same larva); scale lines = 40 μm.

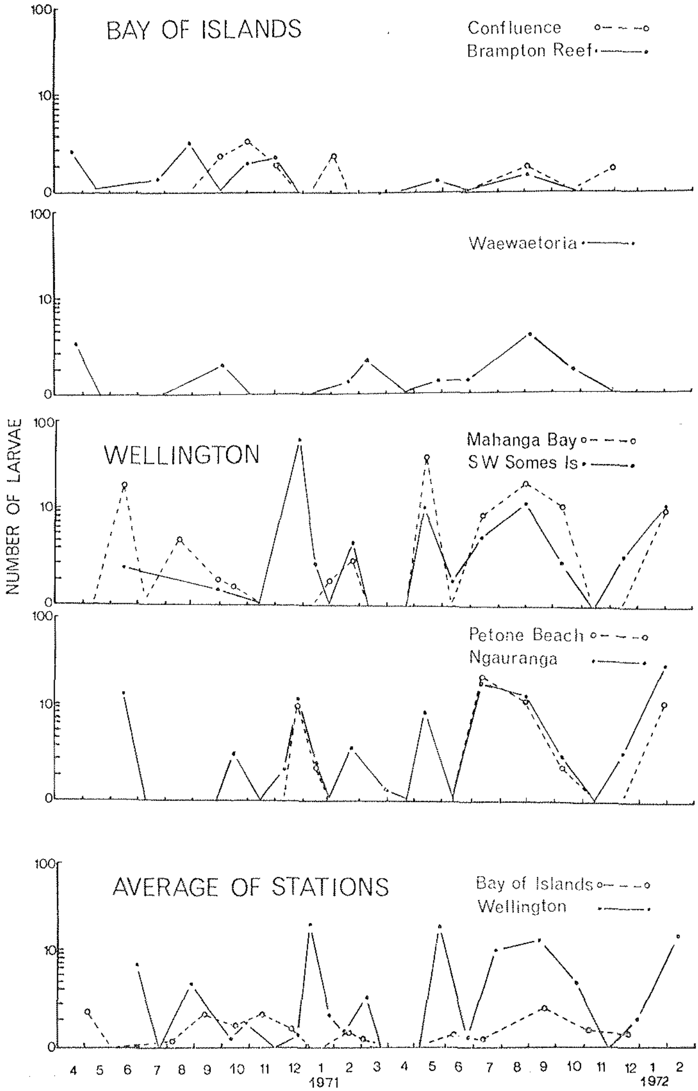


FIG. 10—Monthly variations in abundance (numbers per 1000 litres of sea water) of late stage of larvae of Mytilid 3, Bay of Islands and Wellington Harbour, April 1970–February 1972.

ADULT CONDITION CYCLE – *Bay of Islands* (Fig. 11): The condition index broadly followed the pattern of water temperature, although in 1971 it reached its maximum 2 months after the water temperature. A marked drop in condition occurred during the mid winter of 1971, but this occurred too early to be consistent with the spring peak of larvae in the plankton in the same year.

Wellington Harbour (Fig. 11): Condition indexes by wet and dry weight had similar curves, and both broadly followed the water temperature curve. The peaks in condition index occurred about 1 month after the maximum water temperature in February 1971, and about 2 months before the maximum water temperature in January 1972. Except for the sudden decline in condition of the adults during May–June 1971, which was consistent with larval occurrences in the plankton about this time, there is little correlation between the condition cycle of the adults and the occurrence of the larvae in the plankton.

Comments: The seasonal condition cycles of the adults at Bay of Islands and Wellington Harbour followed the general water temperature curves, but were not entirely dependent upon them. Adults at Bay of Islands and Wellington Harbour had similar values for condition index, although those from Bay of Islands generally showed greater monthly variation in condition throughout the year.

MYTILID 4 (? **Xenostrobus pulex** (Lamarck))

Figs 12, 13 & 17, Tables 2–4

LARVA – *Dimensions*: Eyed larvae 280–360 μm in length, with average length to height ratio of 1 : 1.15 and ratio of length of larva to length of hinge line of 1 : 0.35.

Shape (Fig. 12): In the late stage larva the umbos are knobby and equal in size; shoulders rounded, high, and almost equal in length, although the anterior end is slightly longer and more pointed; height of the larva and the almost circular ventral margin give it an egg-like appearance, but in a vertical sense rather than horizontal, as implied by Chanley (1970) in listing the characteristics of mytilid larvae.

Hinge (Fig. 12): Well-developed taxodont dentition in late stage larva. In larvae 330 μm in length, the provinculum in both valves is thickened and bears 12–20 large, usually uneven teeth extending across its length. Some of the larger teeth may be interspersed with small teeth, particularly near the centre of the provinculum. Ligament attachment point lies behind and towards posterior end of provinculum.

Other Features: Late stage larva is strong and heavy, and dark grey in colour with a purple tinge around the umbos and provinculum; central eyespot usually occurs in larvae 260 μm or more in length; quite marked concentric lamellae seen over shell under Nomarski DIC, but there are usually no radial striae; prodissoconch 1 shell not clearly delineated from prodissoconch 2 shell. The early dissoconch shell of a mytilid (Fig. 12) recovered from a recent settlement of *Xenostrobus pulex* clearly displays this prodissoconch 2 shape.

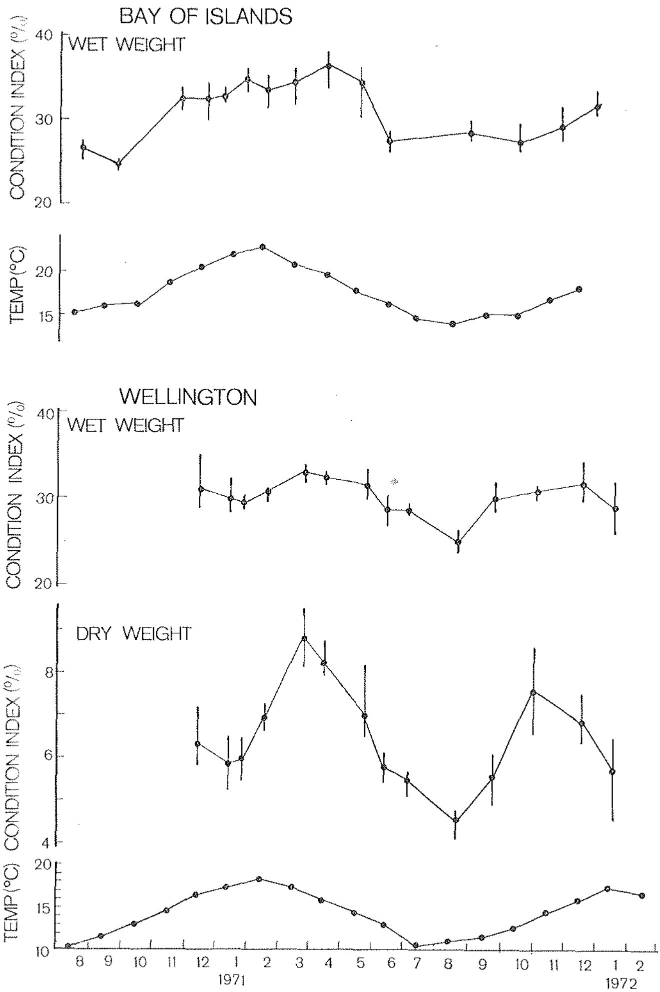
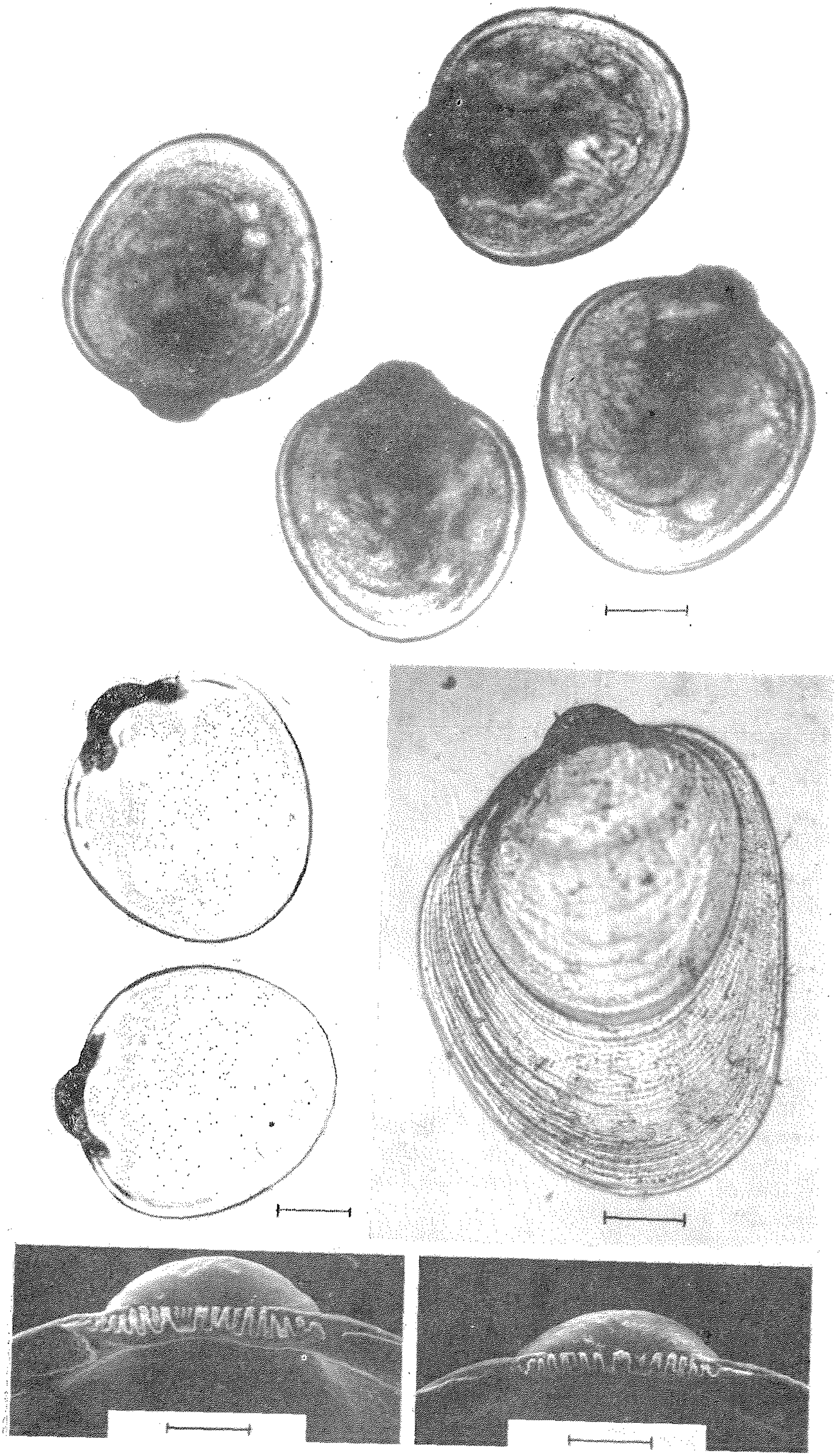


FIG. 11—Condition indices of adult *Perna canaliculus* from Bay of Islands (Wairoa Bay) and Wellington Harbour (Karaka Bay), 1970–72. The vertical lines give the range of values for each group of five animals; mean values are joined. Monthly mean sea surface temperatures from Booth (1974, 1975).

Comparison with Other Species: This larva does not closely resemble any other published mytilid descriptions; its shape is similar to that of some *Teredo* species. The late stage larva described by Rapson (1952) as that of *Amphidesma ventricosum* (figs 3H & I, p. 177; fig. 4G, p. 179) is identified with this larva.

DISTRIBUTION AND SEASONAL ABUNDANCE (Figs 13 & 17, Tables 2–4) – This larva occurred in significant numbers at Bay of Islands and Raumati Beach, the localities at which the adults of *Xenostrobus pulex* were most abundant. The observations suggest that the adults spawn throughout much of the year, probably with a peak during spring.



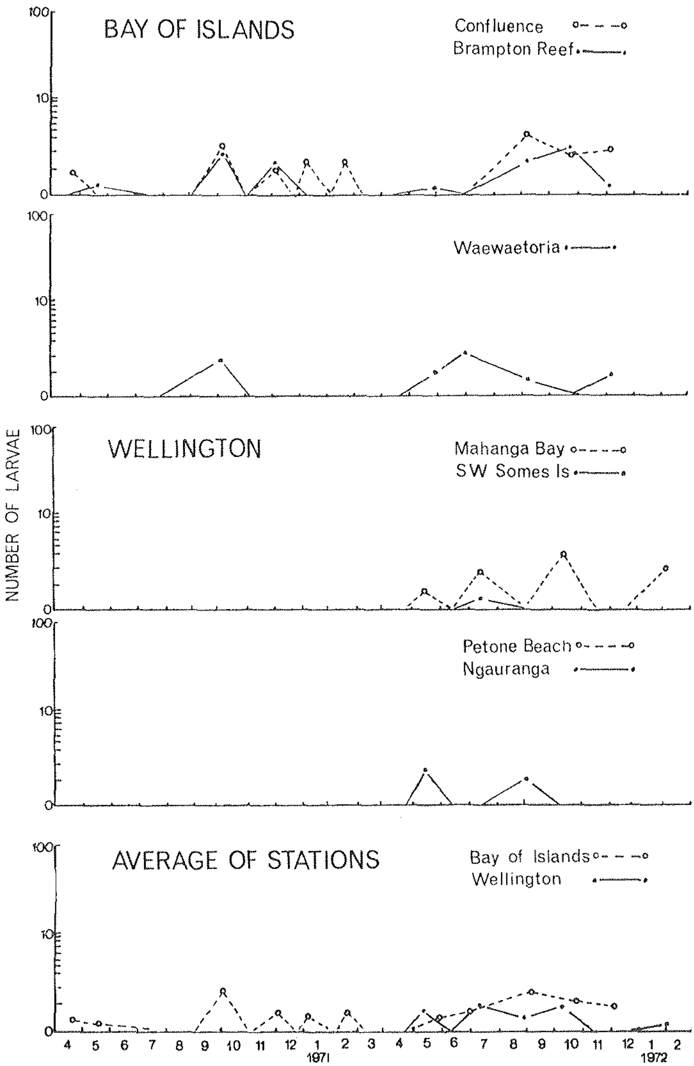


FIG. 13—Monthly variations in abundance (numbers per 1000 litres of sea water) of late stage larvae of Mytilid 4, Bay of Islands and Wellington Harbour, April 1970–February 1972.

OPPOSITE

FIG. 12—Late stage larvae (*upper*) and single valves of late stage larva (*middle left*) of Mytilid 4; early postlarva (*middle right*) taken from settlement of *Xenostrobus pulex* at Paekakariki; scale lines = 100 μm. Hinge of left valve (*lower left*) and right valve (*lower right*) of late stage larva (length 330 μm) of Mytilid 4 (not both from the same larva); scale lines = 40 μm.

Wilson & Hodgkin (1967) reported peak spawnings of *X. pulex* near Fremantle, Western Australia, during 1961–62 to be late winter and spring to mid summer, these times being broadly consistent with the 1971 Bay of Islands observations, although at Raumati Beach there was evidence of a more prolonged spawning period.

MYTILID 5 (? **Modiolarca impacta** (Hermann))

Figs 14–17, Tables 2–4

LARVA – *Dimensions*: Eyed larvae 250–340 μm in length, with average length to height ratio of 1 : 0.8 and ratio of length of larva to length of hinge line of 1: 0.4. Settling size is variable during colder months; larvae generally reach a larger size before settling.

Shape (Fig. 14): In the late stage larva, the umbos are knobby and equal in size, the anterior end is slightly longer and much more pointed than the posterior end, and the overall shape very closely resembles that of mytilid 2, but the posterior and anterior shoulders are of more similar shape and the ventral margin is more rounded.

Hinge (Fig. 14): Well-developed taxodont dentition in late stage larva. In both valves of larvae 310 μm in length the provinculum is thickened and bears 5–7 large, well-developed teeth at each end separated by a narrow region of 10–15 very small teeth. Ligament attachment point lies behind and towards posterior end of provinculum.

Other Features: The larva is strong and heavy and generally has a red-brown or purple tinge around the umbos and provinculum, but lacks the yellow coloration of Mytilid 2. Central eyespot usually occurs in larvae over 250 μm in length; under Nomarski DIC, concentric lamellae seen on both prodissoconch shells, particularly on the second, but the two prodissoconch shells are generally not clearly delineated. The early dissoconch shell of a mytilid (Fig. 14) recovered from a recent settlement of *Modiolarca impacta* clearly displays this prodissoconch 2 shape.

Comparison with Other Species: This larva closely resembles the shape of the line drawings of *Modiolaria marmorata* by Jorgensen (1946).

DISTRIBUTION AND SEASONAL ABUNDANCE (Figs 15 & 17, Tables 2–4) – This larva, as well as the adults of *Modiolarca impacta,* occurred at all sampling localities. The larva occurred throughout most of the year at Bay of Islands and Wellington Harbour, but with peak and minimal densities occurring in the plankton at different times of the year at each harbour.

ADULT CONDITION CYCLE – *Wellington Harbour* (Fig. 16): The condition indexes by wet and dry weight are similar and approximately inversely related to the water temperature: maximum condition index occurs at the time of minimum water temperature. The curves suggest spawnings during December 1971–January 1972, and during late winter and early spring (July–September) 1971. These times are broadly consistent with the observations on the occurrence of the larvae in the plankton, although a peak in larval occurrence was also observed in early winter.

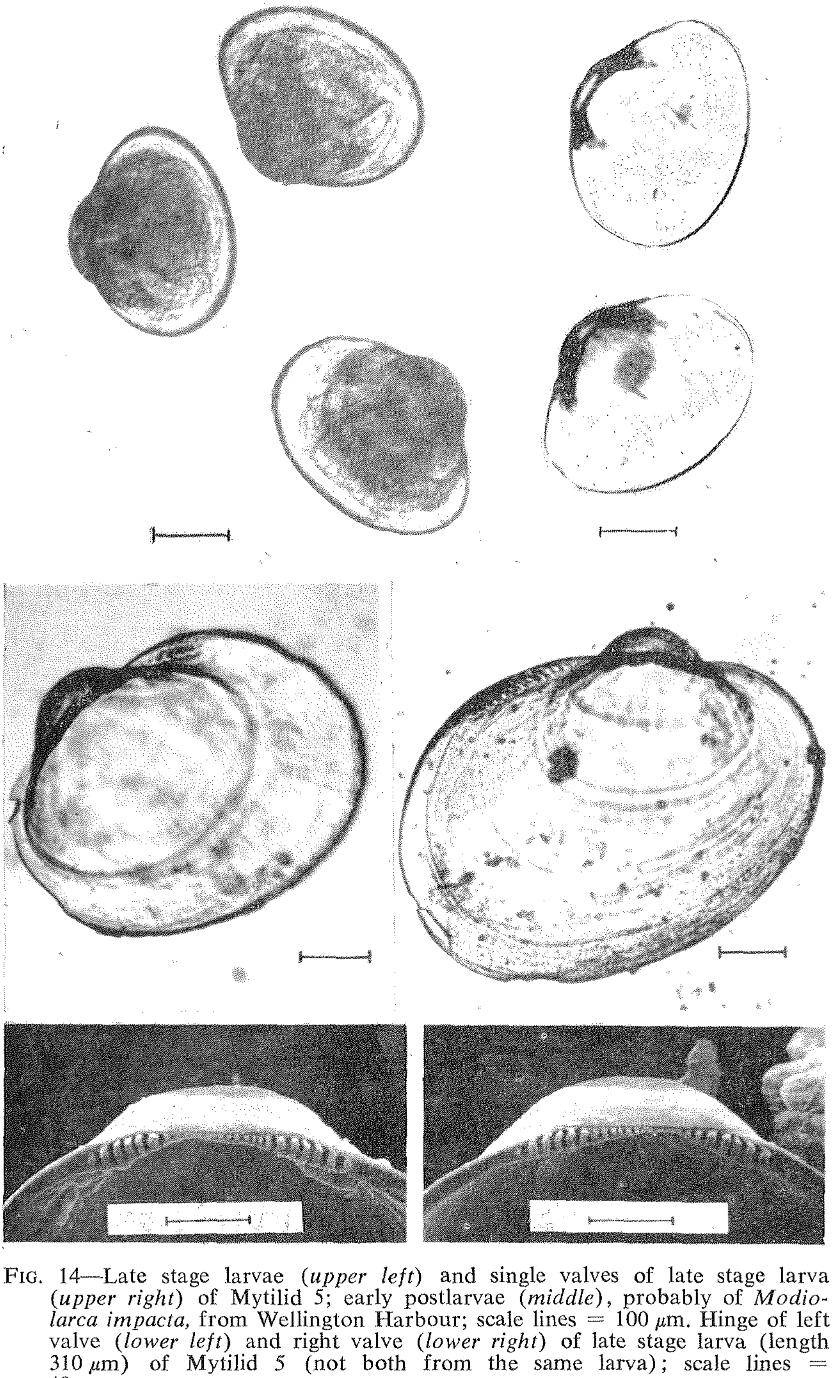
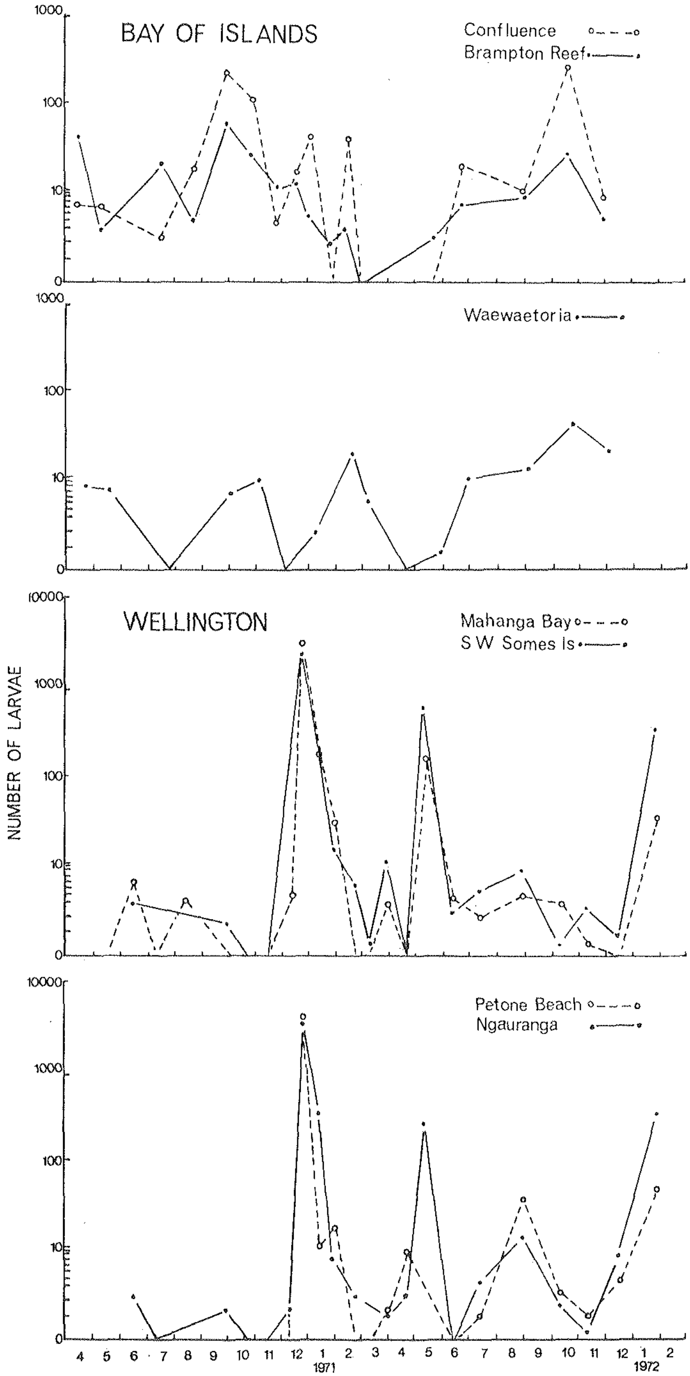


FIG. 14—Late stage larvae (*upper left*) and single valves of late stage larva (*upper right*) of Mytilid 5; early postlarvae (*middle*), probably of *Modiolarca impacta,* from Wellington Harbour; scale lines = 100 μm. Hinge of left valve (*lower left*) and right valve (*lower right*) of late stage larva (length 310 μm) of Mytilid 5 (not both from the same larva); scale lines = 40 μm.


BAY OF ISLANDS
Confluence
Brampton Reef
Waewaetoria
WELLINGTON
Mahanga Bay
S W Somes Is
Petone Beach
Ngauranga
NUMBER OF LARVAE
1000
100
10
0
10000
4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2
1971
1972

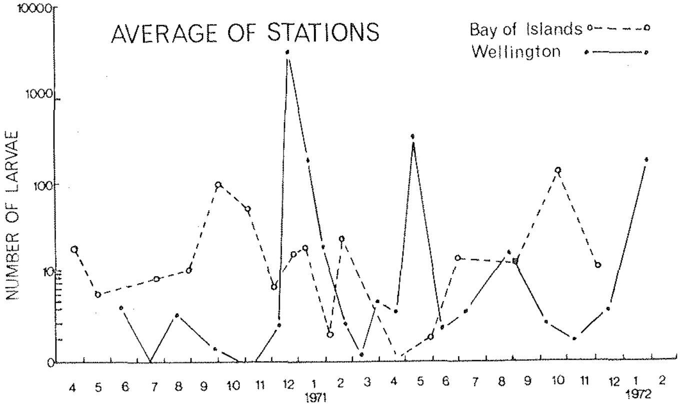


FIG. 15—(*Above and opposite*) Monthly variations in abundance (numbers per 1000 litres of sea water) of late stage larvae of Mytilid 5, Bay of Islands and Wellington Harbour, April 1970–February 1972.

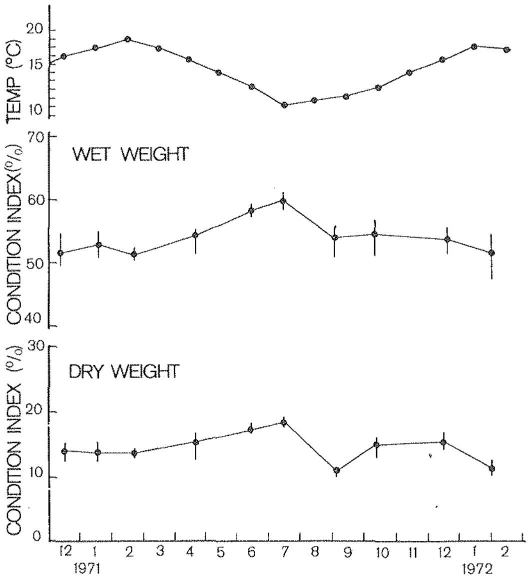


FIG. 16—Condition indices of adult *Modiolarca impacta* from Wellington Harbour (Mahanga Bay), 1970–72. The vertical lines give the range of values for each group of five animals; mean values are joined. Monthly mean sea surface temperatures from Booth (1975).

DISCUSSION

The five larvae described in this study have been allocated to Family Mytilidae and provisionally identified to species by the following criteria:

(1) In all larvae, the hinge structure is consistent with that described for the Mytilacea by Rees (1950) and Chanley (1970). Furthermore, the shape of all the larvae, except that provisionally identified as *Xenostrobus pulex* (Mytilid 4), and their coloration are typically mytilid (Chanley 1970). That all five larvae have prominent eyespots, a feature also observed by several other workers on mytilid larvae, makes this an important addition to Chanley's (1970) list of diagnostic features for many mytilid larvae.

(2) Larvae provisionally identified as *Mytilus edulis aoteanus, Modiolus areolatus, Perna canaliculus,* and *Modiolarca impacta* closely resemble published descriptions of the larvae of species of the same or allied genera elsewhere in the world.

(3) The distribution of each larva is consistent with that of its corresponding adult.

(4) Early dissoconch shells recovered from recent settlements of *M. edulis aoteanus, P. canaliculus, X. pulex,* and *M. impacta* clearly display the prodissoconch 2 shells of Mytilids 1, 3, 4, and 5 respectively.

(5) For *M. edulis aoteanus* and *M. impacta* in Wellington Harbour there was some correlation between the occurrence of the larvae in the plankton and the condition index of the adults (in Bay of Islands and at Raumati Beach either there were insufficient larvae or no condition index analyses were made). There was no correlation for *P. canaliculus* at any locality; condition index analyses were not made for *M. areolatus* and *X. pulex* because of the difficulty in obtaining samples of an adequate size, or else because the small size of the adult makes this type of analysis difficult.

Distinctions between the five larvae described are made primarily on differences in shape, although features of the hinge of the late stage larva readily distinguish all species except Mytilids 2 and 5, which have similar hinges. The key differences between the larvae are summarised in Table 5.

Conclusive identification of all five species can be made only by rearing them in the laboratory. That the larva of *Aulacomya maoriana,* a common or frequent adult mytilid in Wellington Harbour and Raumati Beach, was not discerned must make the identifications presented here only tentative. However, no recently settled dissoconchs of this species were found, and little or no spawning may have occurred during the sampling period.

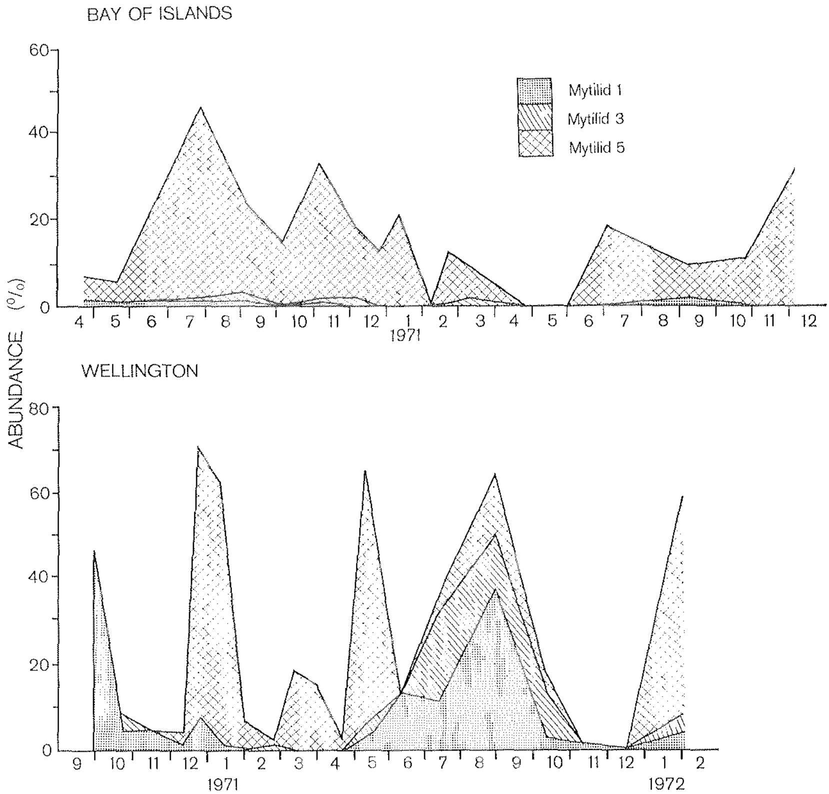


FIG. 17—Variations in relative abundance of the late stage larvae of the most abundant mytilid species in Bay of Islands (*upper*) and Wellington Harbour (*lower*), 1970–72.

Furthermore, because taxodont dentition has been recorded in the larvae of other bivalve superfamilies, the allocation of the five larval species in this study to Family Mytilidae cannot be considered final. Other larvae also known to have taxodont dentition include some Arcacea (Chanley & Andrews 1971) and also the Pectinacea and Anomiacea (Jorgensen 1946, Rees 1950). According to Rees (1950), arcacean teeth differ from those of the Mytilacea in that they are small and numerous, and also the mytilacean provinculum extends beyond the limits of the straight hinge section, a feature of all the larvae in the present study. Chanley & Andrews (1971), however, found the hinges of some arcaceans inconsistent with Rees' (1950) description. For example the hinge of *Noetia ponderosa* consists of 4–6 taxodont teeth at each end of the hinge line with an undifferentiated central area, a description broadly consistent with all of the larvae described in this study except Mytilid 4. In both the Pectinacea and Anomiacea, the provinculum again extends beyond the limits of the straight hinge section, but both Jorgensen (1946) and Rees (1950) note the region between the two thickened parts is so reduced that the teeth are either absent or else extremely minute. Although this hinge description is similar to that of Chanley & Andrews (1971) for *Noetia ponderosa,* it is more explicit and eliminates all larvae in the present study.

With this information, the larvae described here most likely belong to the Superfamilies Arcacea or Mytilacea. The larvae least similar in shape to published mytilid descriptions are Mytilids 4 and 5, although both may still be considered "egg-shaped", the form typical of the Mytilidae (Chanley 1970). Mytilid 4 is most similar in shape to some teredinids, but its hinge is basically taxodont and therefore is not consistent with descriptions of the hinge for this family (e.g., Rees 1950). Mytilid 5, however, is similar in shape to several arcaceans (e.g., *Noetia ponderosa* and *Anadara transversa* – see Chanley & Andrews 1971) as well as to the mytilids *Modiolaria marmorata* (see Jorgensen 1946) and *Modiolus demissus* (see Loosanoff *et al.* 1966). Factors supporting the final allocation of Mytilid 5 in this study to the Mytilacea (Mytilidae) are as follows:

(1) Mytilid 5 occurred at all 3 sampling localities, but in greatest densities at Wellington Harbour and Bay of Islands (Figs 15 & 17). The distribution and abundance of adult *Modiolarca impacta* during 1970–72 (common in Wellington Harbour, frequent in Bay of Islands) were more consistent with this observation than were the distribution and abundance of the most abundant New Zealand arcid, *Barbatia novaezelandiae. B. novaezelandiae* occurred frequently in Bay of Islands, and, although recorded by Beu & Climo (1971) at or near the Wellington Harbour entrance, the species was never taken during the shore and benthic surveys of Wellington Harbour during 1970–72 (Booth unpublished 1972). This limited adult distribution in Wellington Harbour seems unlikely to have accounted for such large numbers of Mytilid 5 larvae in the plankton (Fig. 15).

(2) The postlarval development attributed to Mytilid 5 in Fig. 14 was traced through in what was considered a logical sequence to the juvenile *Modiolarca impacta* form, although this full development has not been presented here.

(3) A common feature of arcid larvae is an overall brown colouration, the anterior end being reddish-brown in the umbonate stages of some species (Chanley & Andrews 1971). Mytilid 5, however, had reddish-brown colour only around the umbos, a feature reported for many mytilid larvae.

(4) Mytilid 5 had many features in common with Mytilid 2, a larva with perhaps more of a characteristic mytilid form. This included considerable similarities in the hinge structure itself (Figs 7 & 14).

Other sources of possible confusion in the identifications of the larvae in this study include:

(1) No postlarval forms of Mytilid 2 were available to support the identification of this larva as *Modiolus areolatus*, but the other more common mytilids present in the sampling areas (*Gregariella barbata* and *Zelithophaga truncata* – see Beu & Climo 1971, Booth unpublished 1972) were far less abundant than the five species considered in this study. Thus identification of Mytilid 2 as *M. areolatus* was most consistent with the data available.

(2) The presence of *Xenostrobus pulex* and *X. securis* in Bay of Islands could have led to confusion between the larvae of these two species. However, *X. securis* occurred in Bay of Islands far less commonly than *X. pulex*, and, unlike *X. pulex*, was confined to upper estuarine areas (Booth unpublished 1972), some distance from the plankton sampling stations. *X. securis* was not recorded from Wellington Harbour or Raumati Beach.

(3) There is always the possibility of confusion in indirect identifications between different species of larvae at similar sizes, or else incorrect assumptions regarding developmental sequences of particular larvae. For example, the arcid *Barbatia novaezelandiae* occurred frequently in Bay of Islands, yet no arcid larvae were discerned in the plankton. This could have been attributable to poor spawnings during the sampling period, or else it is possible that certain stages of development of *B. novaezelandiae* are easily confused with those of *Modiolarca impacta* due to similarity in shape and other features.

The frequency of sampling makes it possible to determine only the broadest patterns of occurrence of the larvae in the plankton in the localities sampled. However, the following features are evident:

(1) No species had a short, well-defined spawning season; and

(2) Peak spawnings most often occurred during mid summer, mid winter, and spring, but seldom did spawnings coincide between species or between the same species at different localities.

The frequency of sampling at each locality could not be kept constant and similarly, plankton samples could not always be collected at the same time of the day or stage of the tide. The use of a net to collect plankton from the whole water column largely eliminates the problem of vertical migration due to varying light intensities, but the effect of alternating tides possibly stimulating the movement of bivalve larvae to or from the bottom itself could not be taken into account in the design of the sampling programme.

Even if larval numbers should be grossly affected by the stage of the tide, the proportional composition of the late stage larval species present may be expected to remain fairly constant over the tidal cycle. The use of a modified logarithmic scale for describing the monthly larval abundance (Figs 5, 8, 10, 13, and 15) and of percentage occurrence graphs showing the relative abundance of species (Fig. 17) help to reduce the apparent effect of excessively variable data due to tidal or other effects.

TABLE 5—Summary of some key features for separating the five late stage mytilid larvae

MYTILID 1 (? *Mytilus edulis aoteanus*)

1. Height approximately equal to length.
2. Umbos knobby to broadly rounded.
3. Anterior end much more pointed than posterior end.
4. Posterior shoulder more rounded than anterior shoulder.
5. Ventral margin rounded.
6. Dark brown or yellow coloration.
7. Hinge has thickened provinculum bearing 5–8 large teeth at each end, separated by a narrow region bearing 14–18 small teeth.

MYTILID 2 (? *Modiolus areolatus*)

1. Length considerably exceeds height (≥1.2 : 1).
2. Umbos knobby.
3. Anterior end much more pointed than posterior end.
4. Posterior shoulder more rounded than anterior shoulder.
5. Ventral margin flattened.
6. Yellow coloration.
7. Hinge has thickened provinculum bearing 5–8 large teeth at each end, separated by a narrow region bearing 6–10 small teeth.

MYTILID 3 (? *Perna canaliculus*)

1. Height approximately equal to length.
2. Umbos knobby.
3. Anterior end more pointed than posterior end.
4. Ventral margin rounded.
5. Usually grey coloration.
6. Hinge has thickened provinculum bearing 5–8 large teeth at each end, separated by a narrow region bearing 5–8 small teeth. Posterior shoulder has thickened area bearing 4–6 teeth.

MYTILID 4 (? *Xenostrobus pulex*)

1. Height considerably exceeds length (≥1.1 : 1).
2. Umbos knobby.
3. Anterior end slightly more pointed than posterior end.
4. Ventral margin rounded.
5. Usually grey coloration.
6. Hinge has thickened provinculum bearing 12–20 large, usually uneven teeth extending across its length, sometimes interspersed with smaller teeth.

MYTILID 5 (? *Modiolarca impacta*)

1. Length considerably exceeds height (≥1.2 : 1).
2. Umbos knobby.
3. Anterior end much more pointed than posterior end.
4. Ventral margin broadly rounded.
5. Usually grey coloration.
6. Hinge has thickened provinculum bearing 5–7 large teeth at each end, separated by a narrow region bearing 10–15 very small teeth.

Correlations between condition index of adults and occurrence of larvae in the plankton were not always good. Although based on preserved material, these results suggest that condition index as an indicator of the spawning season may not be satisfactory for all species, particularly when the spawning season extends over several months. Comparison of the condition index cycles of *Mytilus edulis aoteanus* and *Perna canaliculus* between Bay of Islands and Wellington Harbour, the different times of peak larval occurrence between the two areas, and the discrepancy between the observations in this study and those of workers on the same species at other localities (Ralph & Hurley 1952, MacDonald unpublished 1963, Greenway 1969) suggest that the spawning seasons of the same species may vary considerably throughout New Zealand, and possibly even from year to year.

ACKNOWLEDGMENTS

I thank my brother, Mr Robin Booth, for the use of his launch in the Bay of Islands. Also, Messrs W. B. MacQueen and L. G. Robinson of r.v. *Tirohia* for assistance with plankton sampling in Wellington Harbour.

I wish to thank Dr R. B. Pike, Victoria University of Wellington, for general guidance during my PhD study, of which this formed part. Also Mr M. Loper for assistance with the photographing of the larvae, particularly the scanning electron microscope photographs, and Mr G. Grainger for general assistance during the sampling programme.

This study was carried out with the assistance of a UGC Postgraduate Scholarship and a Fisheries Research Division Research Fellowship, both of which are gratefully acknowledged.

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APPENDIX 1—Details of plankton collections, Bay of Islands and Wellington Harbour, 1970–72 (Under tide column, HW = high water, LW = low water, + = number of hours after, − = number of hours before)

Date	Time	Tide	Date	Time	Tide
Confluence					
23 Apr 70	1045	HW+2	4 Feb 71	1010	LW+2.5
20 May 70	1550	LW+3	14 Feb 71	0945	HW
25 Jul 70	1530	HW+3	27 Apr 71	1800	LW+3
30 Aug 70	1100	LW−1	28 May 71	1400	LW−2
2 Oct 70	1315	LW−1	30 Jun 71	1230	HW
3 Nov 70	1140	HW+1.5	10 Sep 71	1135	HW
4 Dec 70	0810	HW−3.5	24 Oct 71	0750	HW−2.5
27 Dec 70	1110	LW−1	3 Dec 71	0915	HW+1
9 Jan 71	1010	LW−1			
Brampton Reef					
23 Apr 70	1145	HW+3	9 Jan 71	1145	LW+0.5
20 May 70	1615	HW−2.5	5 Feb 71	1145	HW−2.5
25 Jul 70	1445	HW+2	14 Feb 71	1010	HW
30 Aug 70	1130	LW−0.5	28 May 71	0900	HW−1
2 Oct 70	1005	HW+1.5	29 Jun 71	0825	LW+2.5
3 Nov 70	1320	LW−2.5	10 Sep 71	1150	HW+0.5
4 Dec 70	0845	HW−3.5	24 Oct 71	0730	HW−3
27 Dec 70	1715	HW−1.5	3 Dec 71	0845	HW+1
Waewaetoria					
22 Apr 70	1105	HW+2.5	12 Mar 71	1500	LW+1
21 May 70	1145	LW−1.5	28 Apr 71	0930	HW
30 Jul 70	1415	HW−3	28 May 71	1000	HW
2 Oct 70	1050	HW+2.5	29 Jun 71	1710	LW−0.5
3 Nov 70	1440	LW−1	10 Sep 71	1020	HW−1
4 Dec 70	1300	HW+1.5	24 Oct 71	0850	HW−1.5
9 Jan 71	1400	LW+2.5	3 Dec 71	1000	HW+2
14 Feb 71	1345	LW−2			
Mahanga Bay					
16 May 70	1520	HW+1.5	7 Mar 71	1435	HW+1
16 Jun 70	1535	HW+1.5	29 Mar 71	1150	LW−1
9 Jul 70	1420	LW−0.5	22 Apr 71	1405	HW
16 Aug 70	1230	HW−3	12 May 71	1000	LW−2.5
28 Sep 70	1000	LW+1	11 Jun 71	1005	LW−2.5
15 Oct 70	1005	LW−1	12 Jul 71	1550	LW+2
16 Nov 70	0945	HW+2.5	2 Sep 71	1300	HW−1
10 Dec 70	0915	LW+1	7 Oct 71	1100	LW−2
21 Dec 70	1300	HW+2	15 Nov 71	1120	LW+2.5
14 Jan 71	1015	LW−3	16 Dec 71	0930	LW−0.5
27 Jan 71	1100	LW	2 Feb 72	1230	LW−1
21 Feb 71	1225	HW−0.5			
Somes Island					
17 Jun 70	1225	HW−2.5	29 Mar 71	1210	LW−1
28 Sep 70	1120	LW+2.5	22 Apr 71	1435	HW+0.5
15 Oct 70	1100	LW	12 May 71	1020	LW−2
16 Nov 70	1050	LW−2.5	11 Jun 71	1040	LW−2
10 Dec 70	0945	LW+1.5	12 Jul 71	1525	LW+1.5
21 Dec 70	1230	HW+1.5	2 Sep 71	1200	HW−2
14 Jan 71	1110	LW−2	7 Oct 71	1045	LW−2.5
27 Jan 71	1115	LW	15 Nov 71	1100	LW+2
21 Feb 71	1240	HW−0.5	16 Dec 71	1100	LW+1
7 Mar 71	1500	HW+1.5	2 Feb 72	1120	LW−2
Petone Beach					
17 Jun 70	1055	LW+2.5	22 Apr 71	1510	HW+1
28 Sep 70	1145	LW+3	12 May 71	1115	LW−1
15 Oct 70	1345	HW−3	11 Jun 71	1130	LW−1
16 Nov 70	1200	LW−1.5	12 Jul 71	1420	LW+0.5
10 Dec 70	1025	LW+2	2 Sep 71	1020	LW+3
21 Dec 70	1145	HW+0.5	7 Oct 71	1005	LW−3
14 Jan 71	1200	LW−1	15 Nov 71	1025	LW+1.5
27 Jan 71	1145	LW+0.5	16 Dec 71	1130	LW+1.5
21 Feb 71	1305	HW	2 Feb 72	1020	LW−3
29 Mar 71	1235	LW−0.5			

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APPENDIX 1—(*Continued*)

Date	Time	Tide	Date	Time	Tide
Ngauranga					
17 Jun 70	0945	LW+1	29 Mar 71	1350	LW+1
9 Jul 70	1445	LW−0.5	22 Apr 71	1605	HW+2
28 Sep 70	1230	HW−2.5	12 May 71	1215	LW
15 Oct 70	1450	HW−2	11 Jun 71	1250	LW
16 Nov 70	1350	LW+0.5	12 Jul 71	1345	LW
10 Dec 70	1140	LW+3	2 Sep 71	0950	LW+2
21 Dec 70	1115	HW	7 Oct 71	0925	HW+3
14 Jan 71	1240	LW−0.5	15 Nov 71	0945	LW+1
27 Jan 71	1210	LW+1	16 Dec 71	1215	LW+2
21 Feb 71	1335	HW+0.5	2 Feb 72	0955	HW+3
7 Mar 71	1520	HW+2			

APPENDIX 2—Details of plankton collections, Raumati Beach, 1970–72. (Under tide column, HW = high water, LW = low water, + = number of hours after, − = number of hours before; under station columns, – = no sample).

Date	Times Station 1	Station 2	Station 3	Station 4	Tide
26 Nov 70	1610	1620	–	–	LW+3
12 Dec 70	1500	–	1430	1445	LW
17 Jun 71	1030	1100	1040	1050	LW+0.5
25 Jul 71	1410	1455	1430	1440	LW−2.5
30 Sep 71	1300	1335	1315	1325	LW+2
4 Nov 71	1335	1415	1350	1405	LW−2
15 Dec 71	1215	1255	1235	1245	LW−1
17 Jan 72	1610	1600	1540	1550	LW
15 Feb 72	1535	1515	1445	1500	LW−0.5
18 Mar 72	–	1530	1515	1520	LW−2
15 Apr 72	–	1625	1610	1615	LW
4 Jun 72	–	1525	1500	1510	HW+1