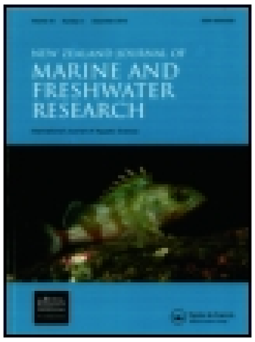

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Seasonal and tidal variations in the hydrology of Wellington harbour

J. D. Booth

SEASONAL AND TIDAL VARIATIONS IN THE HYDROLOGY OF WELLINGTON HARBOUR

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ABSTRACT

Observations were made on several hydrological features of Wellington Harbour, New Zealand (41° 16′ S, 174° 51′ E) during 1970 to 1972. These suggest that the harbour is topographically partially isolated from oceanic influences, and that waters within the harbour undergo efficient mixing.

Monthly mean sea-surface temperatures ranged seasonally between 10.5°C and 18.5°C, and some stratification was observed during summer and winter. Salinities usually ranged from 33.5‰ to 34.5‰, and water transparency by Secchi disc from 3 m to 6 m. Dissolved oxygen content ranged from 96% to 127% saturation, usually exceeding 100% saturation in surface waters.

Under normal discharge conditions during winter, the Hutt River was observed to markedly affect surface temperatures and salinities as far south as Somes Island to a depth of about 5 m.

INTRODUCTION

The data presented here were collected during a study of the bivalve larvae of Bay of Islands and Wellington Harbour (Booth unpublished 1972). The hydrological observations for Bay of Islands are given in Booth (1974).

Wellington Harbour (Port Nicholson; 41° 16′ S, 174° 51′ E) is a small (76 km²) enclosed harbour at the southern end of the North Island of New Zealand (Fig. 1). Ralph & Hurley (1952), Johannesson (1955), Maxwell (1956), Brodie (1958), Skerman (1958), Hurley (1959), R. M. Cassie (1959, 1960), V. Cassie (1960), Gilmour (1960), Wear (1965), Van der Linden (1967), and Ritchie (1970) have presented hydrological data for the harbour. These and the present observations provide a useful background for biological research and for planned developments such as reclamation within the harbour.

The greatest depth of water is 31 m, south-west of Somes Island (NZ Hydrographic Office 1969), but the average depth is 20 m (Gilmour 1960). The total catchment area of the harbour is 725 km² (Brodie 1958), the main freshwater source being the Hutt River with a catchment area of 630 km² (Johannesson 1958). The minimum and maximum daily

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freshwater discharges of the Hutt River are approximately 2.6×10^6 m^3 (2.6×10^6 tons) and 180×10^6 m^3 (180×10^6 tons), respectively (Maxwell 1956). Other smaller freshwater inflows are the Ngauranga and Korokoro streams, which may carry large volumes of water during flooding. Brodie (1958) described the tidal currents in the harbour; in its simplest form, the tide floods in a clockwise direction and ebbs in an anticlockwise direction, with current speeds varying from a maximum of 0.25 m.s^{-1} at the harbour entrance channel to 0.10 m.s^{-1} or less in the inner harbour. Brodie (1958) also made observations on the movement in the harbour of discoloured water resulting from flooding, in particular of the Hutt River, and found that the layer was thin and confined to the surface, and that its movements were dependent mainly upon wind and tidal currents. Under northerly or north-westerly winds, the Hutt River outflow is confined to a narrow zone down the eastern shore of the harbour, while during southerly winds, the discoloured water spreads broadly throughout the northern part of the harbour. Gilmour (1960) gives the tidal range as varying between 3 ft and 4 ft (approximately 0.9 m and 1.2 m). Leakages of artesian water from the Hutt Valley aquifer have been reported in the harbour south of Somes Island, and also near the eastern end of Petone Beach (Mr J. A. Jones, Rivers Control Engineer, Wellington Regional Water Board, pers. comm.).

According to both Maxwell (1956) and Gilmour (1960), the channel connecting Wellington Harbour to the open sea is large enough to ensure good mixing of the harbour water with that outside. It would therefore be expected that although some special hydrological characteristics would be generated within the harbour, these would soon be assimilated by the circulation system, and would be reduced by the exchange with waters from outside the harbour. With Brodie's (1958) plan of tidal currents in mind, areas near the harbour mouth and in central and western regions of the harbour would undergo the most regular exchange with Cook Strait waters.

Most of the hydrological observations for this study were made monthly from May 1970 to February 1972 at the hydrological stations shown in Fig. 1. These were supplemented with observations made less frequently at other stations, and with surface temperature readings at three temperature stations (Fig. 1), made daily when possible.

Climatic data 1970–72 were taken from the New Zealand Meteorological Service records for Kelburn Station; wind speed is expressed in m.s^{-1}.

CLIMATE

Gabites (1960) emphasised the windiness of the Wellington region and the lack of extreme air temperatures due to the closeness of the sea and the continual wind. Wellington lies in the 12.2–12.8°C belt of mean annual air temperature at sea-level (Kidson 1931), and the mean

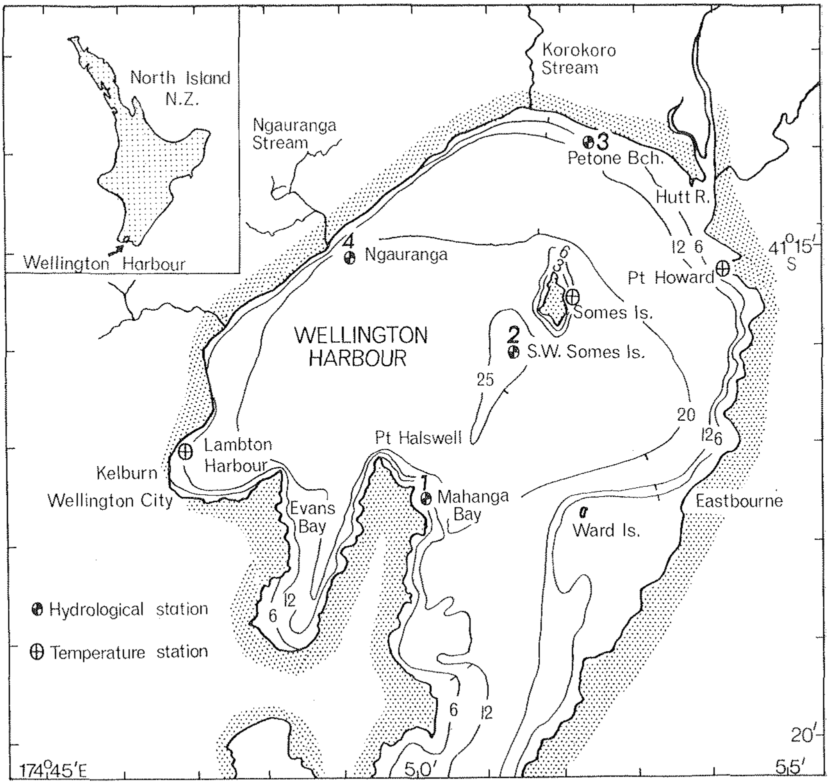


FIG. 1—Location of study area (inset), position of hydrological stations in Wellington Harbour, New Zealand, and of features referred to in the text. Bathymetry in metres.

annual rainfall at Kelburn is 122 cm, with highest monthly rainfalls during winter (Seelye 1944). Monthly mean air temperatures and rainfall are given in Fig. 2. The most frequent prevailing wind directions for 1939–48 were north-west during 32.2% of the time and south during 17.5% of the time (N.Z. Meteorological Service 1966). Watts (1947) records 28 gales per year for the area, which is the highest annual frequency in the country. Kidson & Crust (1932) noted an average diurnal variation in air temperature of 4.5°C in summer and 2.8°C in winter for the period 1928–31. Macky (1938) compared climatological observations made at Eastbourne and Kelburn and noted considerable differences, particularly in air temperatures, with Eastbourne being on average 1.2°C warmer than Kelburn. Both the factors of wind and air temperature will influence sea surface temperatures in the harbour.

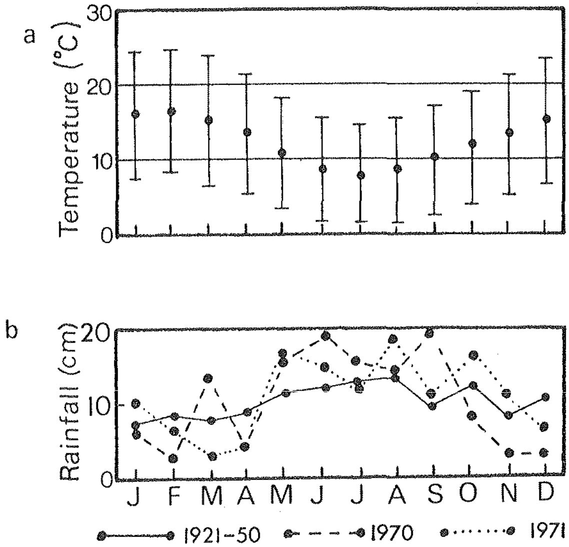


FIG. 2—Meteorological observations for Kelburn, Wellington, from New Zealand Meteorological Service (1966) and records kept at Kelburn Station:

(a) Monthly mean air temperatures (°C) with monthly mean maxima and minima (based on observations at 0900 h, 1928–60);

(b) Rainfall (cm) for 1921–50 (mean), 1970 and 1971.

METHODS

Water temperature was measured with either a mercury thermometer, or a Beckman RS5-3 portable salinometer, or a Murayama Electronic Resistance Thermorecorder. Temperature readings had an accuracy of ± 0.1°C.

Salinity was determined in the laboratory with either a Beckman RS7-B salinometer (quoted accuracy ± 0.003‰) or a Zeal hydrometer (accuracy better than ± 0.2‰), water samples being collected with a Knudsen's modified Pettersson water bottle (described by Barnes 1959) Also some field measurements were made with a Beckman RS5-3 portable salinometer (quoted accuracy ± 0.05‰). This instrument had been tested and calibrated by Physics Department, Victoria University of Wellington.

Dissolved oxygen (Winkler titration), water turbidity (Secchi disc) and relative current speeds (mounted flow meter) were measured as in Booth (1974).

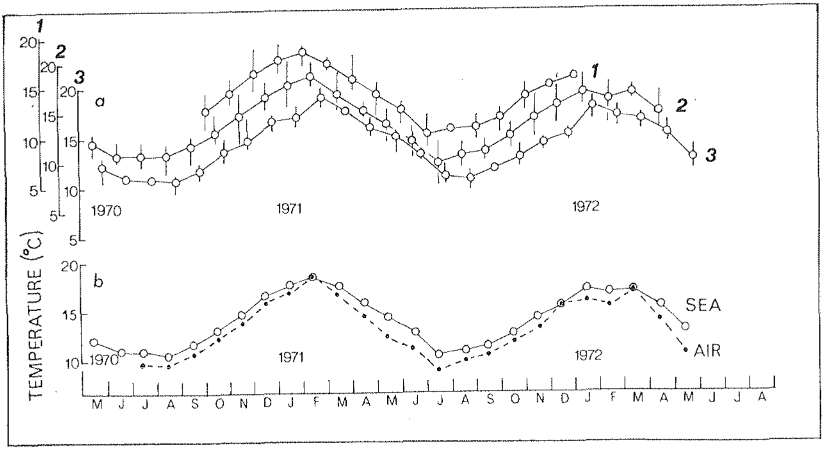


FIG. 3—Sea surface temperatures (°C), Wellington Harbour:
(a) Observations at three temperature stations, 1970–72 (Stations: 1 = Somes Island Wharf; 2 = Point Howard Wharf; 3 = Inter-Island Wharf) giving mean and range for each month (from Table 1);
(b) Average monthly mean sea surface temperature, derived from (a), compared with monthly mean air temperature at Kelburn, Wellington.

HYDROLOGICAL OBSERVATIONS 1970–72

TEMPERATURE

Sea Surface Temperatures were recorded at Somes Island Wharf, Point Howard Wharf, and Inter-Island Wharf (Table 1). Mean sea surface temperatures for the three stations were consistently higher than the mean air temperatures (Fig. 3b). The maximum monthly mean sea surface temperatures occurred in February 1971 and January 1972 (18.7°C and 17.4°C respectively), the minima in August 1970 and July 1971 (10.6°C and 10.7°C respectively).

The differences between sea surface temperatures in Cook Strait just off Wellington Harbour and those in the harbour itself varied seasonally. During winter (see later diagrams), Cook Strait sea surface temperatures exceeded harbour surface temperatures by up to 3.8°C. By comparison, Heath's (1971) ship thermograph records showed Wellington Harbour surface temperatures during winter 1969 up to 2.0°C cooler than those of Cook Strait, and Brodie (1958) showed a similar difference in 1953. During spring, Heath (1971) showed differences of less than 1.0°C, while Garner's (1953) observations in Cook Strait for October 1950 were less than 1.0°C cooler than the October Wellington Harbour surface temperatures for 1970–72 (Table 1). In summer the temperature difference between Wellington Harbour and Cook Strait increased, with harbour surface temperatures in 1970–72 being up to 4.0°C warmer than the temperatures given by Garner (1961) for Cook Strait in 1955; Heath (1971) showed a similar temperature difference between Wellington Harbour and Cook Strait for summer 1969. Autumn

TABLE 1—Sea surface temperature at three stations in Wellington Harbour, 1970–72. Stations : 1 = Somes Island Wharf, readings taken off wharf at 0730–0900h; 2 = Point Howard Wharf, readings taken off wharf at 0900–1000h; 3 = Inter-Island Wharf, readings taken from r.v. *Tirohia* at 0900–1000h; (– = no readings)

	Month	Number of Observations (days)			Highest Recording			Lowest Recording			Mean Recording			Overall Average
		1	2	3	1	2	3	1	2	3	1	2	3	
1970	M	0	9	9	–	12.9	12.8	–	11.0	11.0	–	12.1	12.4	12.3
	J	0	17	3	–	12.2	11.4	–	8.5	11.2	–	10.8	11.2	11.0
	J	0	16	3	–	12.0	11.0	–	9.5	10.9	–	10.9	11.0	11.0
	A	0	20	15	–	11.8	11.0	–	8.5	9.6	–	10.6	10.5	10.6
	S	0	19	9	–	12.9	12.5	–	10.0	11.1	–	11.7	11.9	11.8
	O	23	23	12	14.5	15.0	15.1	11.0	12.1	12.6	12.9	13.0	13.6	13.2
	N	21	18	17	16.0	17.1	17.2	13.5	11.8	14.3	14.7	14.9	14.9	14.8
	D	26	21	12	19.0	18.2	17.4	15.0	15.5	16.3	16.6	16.8	16.9	16.8
1971	J	28	19	9	19.3	20.5	18.3	16.5	16.0	16.7	17.8	17.8	17.2	17.6
	F	14	7	9	18.5	20.2	20.2	17.5	18.0	18.4	18.2	18.8	19.1	18.7
	M	22	8	13	18.0	19.0	18.2	17.0	16.0	17.7	17.6	17.3	17.9	17.6
	A	29	11	14	18.5	16.2	17.5	15.0	15.0	15.5	16.2	15.6	16.6	16.1
	M	31	21	14	16.0	15.8	16.0	11.5	12.1	13.6	14.5	14.2	15.2	14.6
	J	30	23	14	13.5	13.8	13.6	11.5	11.0	12.9	12.9	12.4	13.3	12.9
	J	29	23	12	12.5	12.4	12.5	9.0	7.0	10.7	10.6	10.0	11.6	10.7
	A	31	22	13	12.0	12.1	11.7	8.0	9.4	9.9	11.1	11.0	11.2	11.1
	S	28	13	9	12.5	12.5	12.5	10.0	10.5	12.1	11.2	11.4	12.3	11.6
	O	31	20	15	13.0	14.0	14.3	11.0	11.5	12.4	12.2	12.9	13.1	12.7
	N	28	27	10	16.0	17.5	15.3	13.0	12.8	14.1	14.4	14.8	14.9	14.7
	D	22	18	4	16.7	19.0	16.0	14.0	14.0	15.2	15.5	16.3	15.5	15.8
1972	J	20	22	10	18.0	19.0	19.2	14.0	16.4	17.1	16.4	17.4	18.3	17.4
	F	0	22	13	–	18.3	18.3	–	14.2	16.4	–	16.7	17.5	17.1
	M	0	8	10	–	17.8	17.8	–	17.0	16.6	–	17.4	17.1	17.3
	A	0	20	11	–	17.5	17.0	–	13.4	14.8	–	15.4	16.0	15.7
	M	0	0	13	–	–	14.6	–	–	12.1	–	–	13.4	13.4

(April) 1969 surface temperatures in the harbour were 1.0–1.5°C warmer than Cook Strait surface temperatures off Wellington Harbour (Heath 1971).

Subsurface Temperatures. Isopleth diagrams giving the seasonal variation with depth of temperature at the four hydrological stations are given in Figs. 4 and 5, where it can be seen that sea temperatures at all depths reached a maximum value in late February 1971 and a minimum in August 1971. Although the observations could not all be made on the same stage of the tide, the transects from Ngauranga to Eastbourne on the ebb and flood tides (see Fig. 7) suggest that the basic sea temperature structure remains the same throughout a tidal cycle. Figures 4 and 5 show the occurrence of a marked negative temperature gradient during the summer at all stations (up to 3.0°C at SW Somes Island in January 1971) and a smaller positive temperature gradient during winter; the water was largely isothermal during the autumn and early spring. Figure 5 stresses the similarity in temperature structure between the four stations at any one sampling time.

Several transects were made of the harbour under various tide and wind (except strong southerly) conditions during the winters of 1970 and 1971 to determine the influence of the Hutt River upon the harbour water, mainly under normal discharge conditions, and the relationship between harbour water and Cook Strait water. Cool fresh water emerging

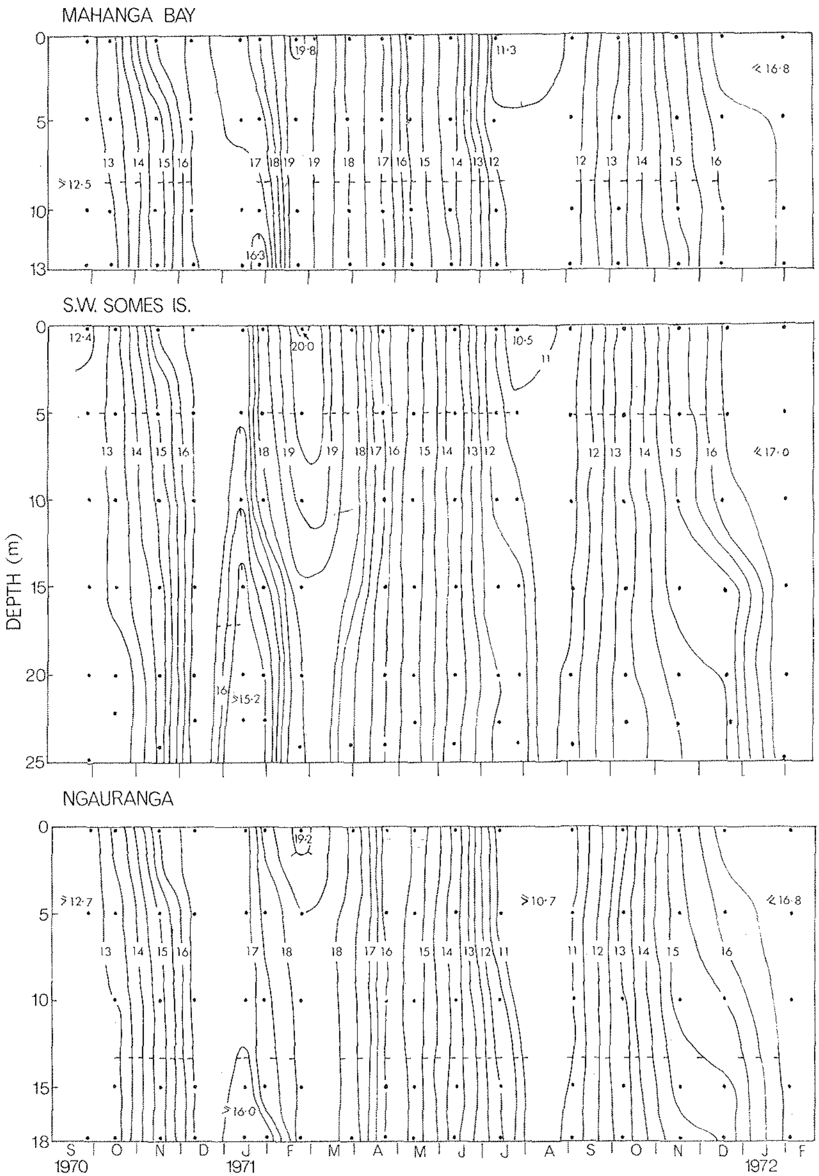
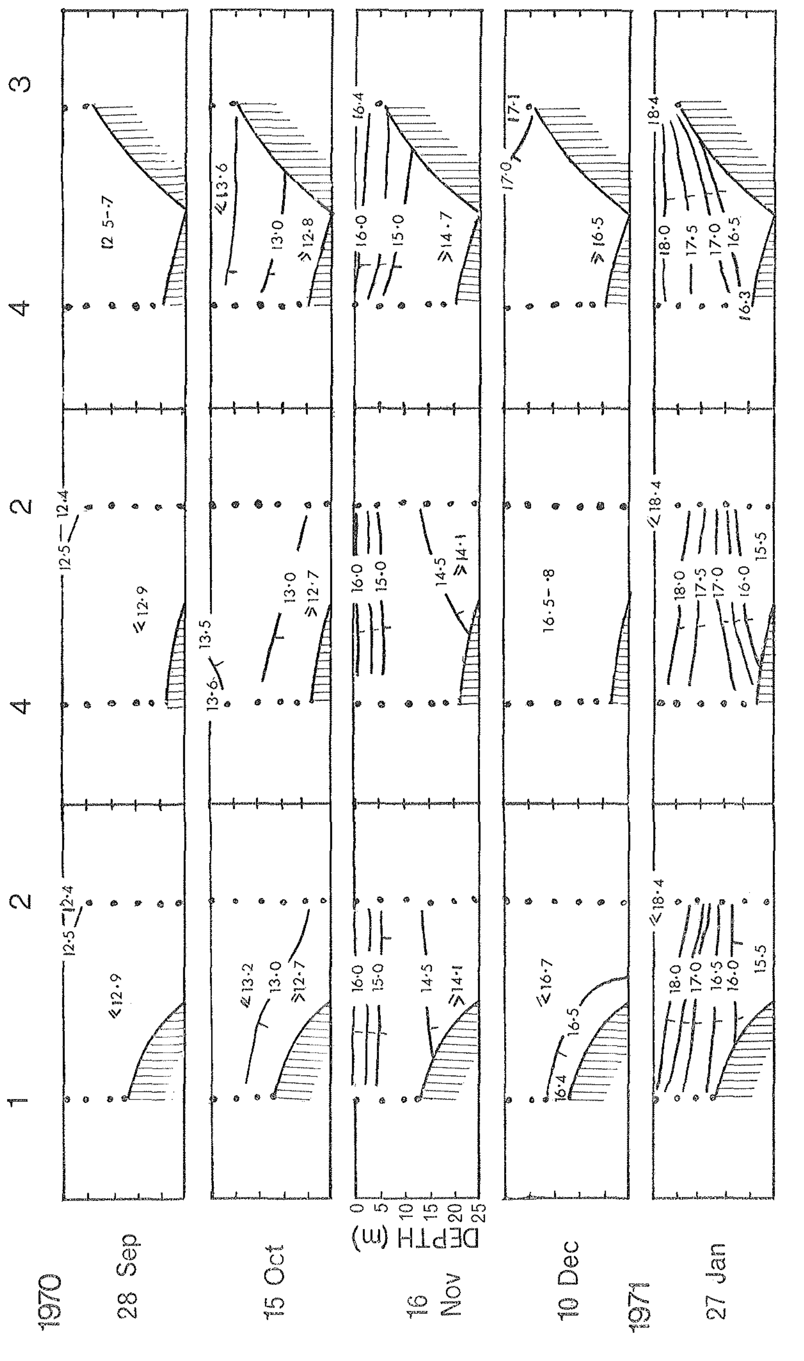


FIG. 4—Profiles of temperature (°C) at three stations, Wellington Harbour, September 1970–February 1972. All measurements with Murayama Thermo-recorder.


1970
28 Sep
15 Oct
16 Nov
10 Dec
1971
27 Jan
DEPTH (m)
0 5 10 15 20 25
1 2 4 2 4 3

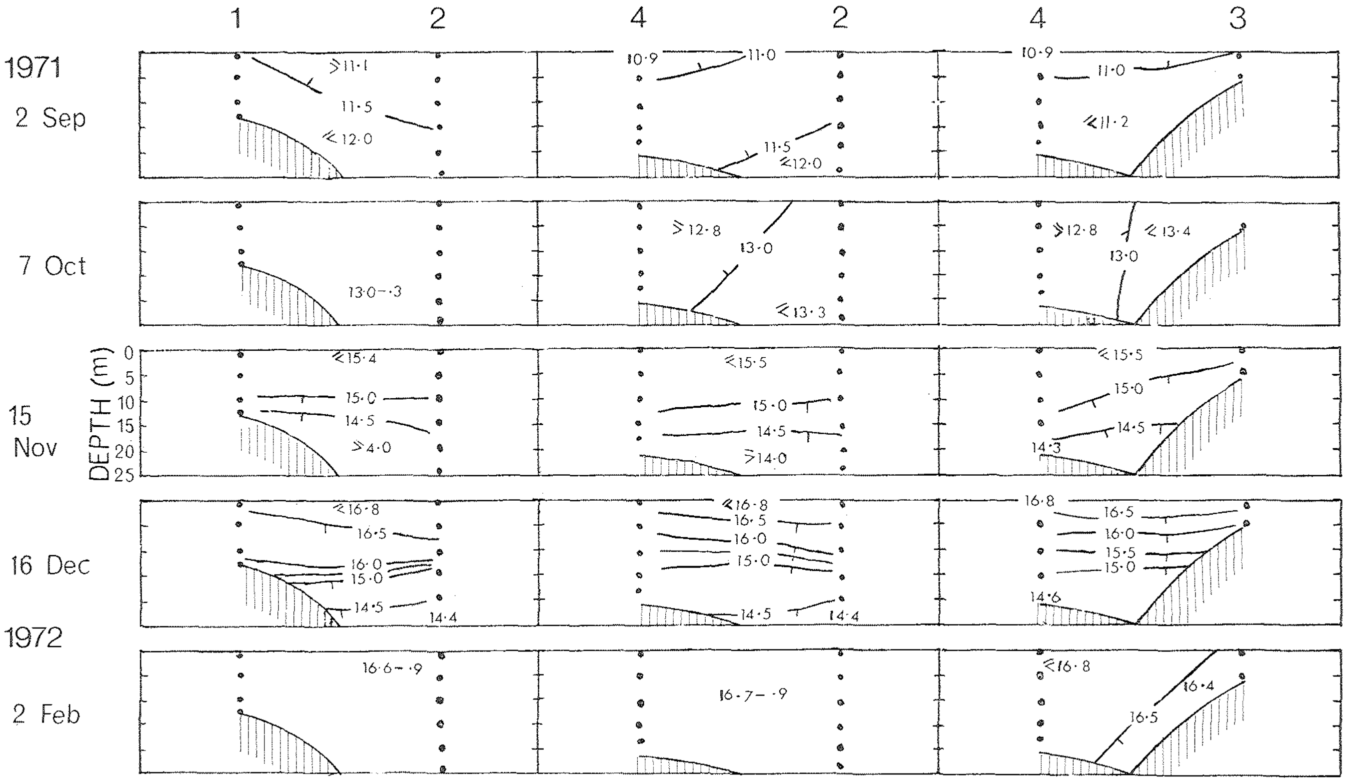


Fig. 5—(*Continued with caption on next page*).

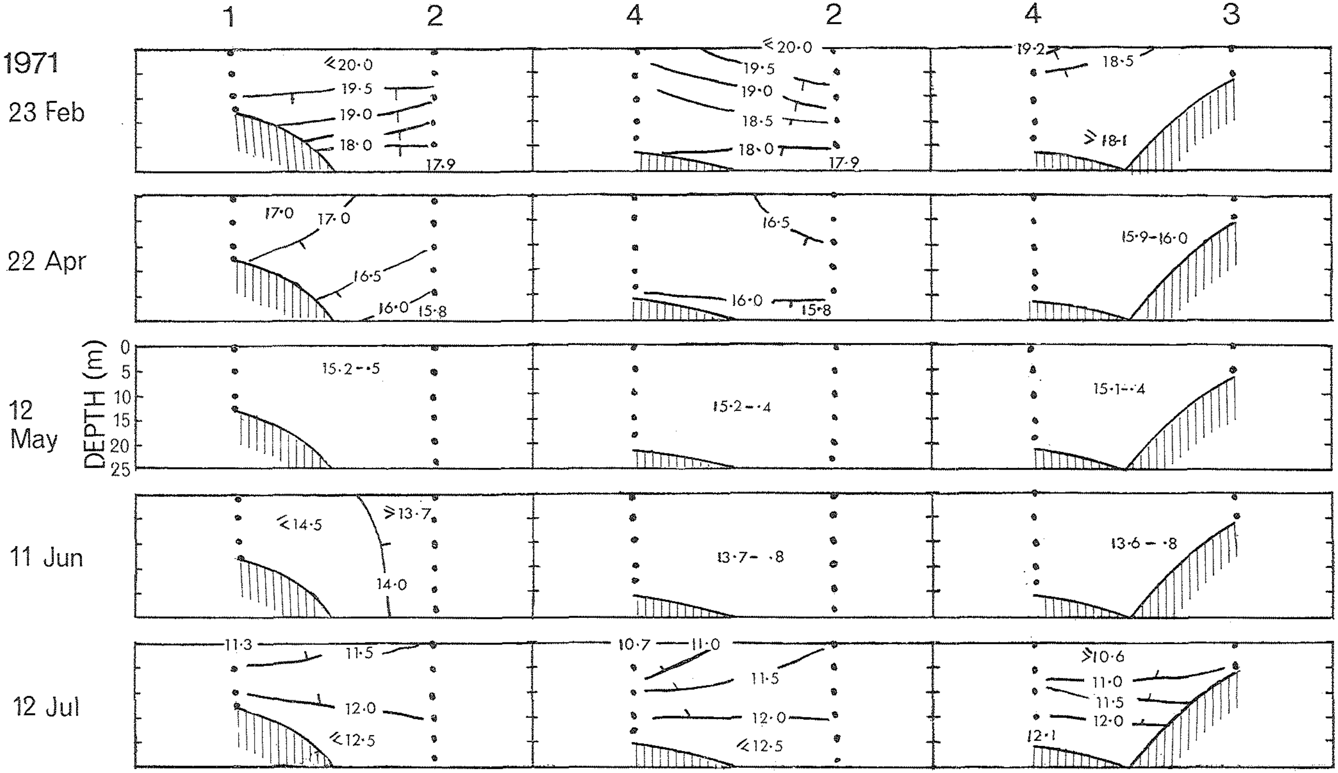


FIG. 5—Profiles of temperature (°C) between four stations, Wellington Harbour, September 1970–February 1972. (Stations: 1 = Mahanga Bay; 2 = SW Somes Island; 3 = Petone Beach; 4 = Ngauranga). All measurements with Murayama Thermorecorder.

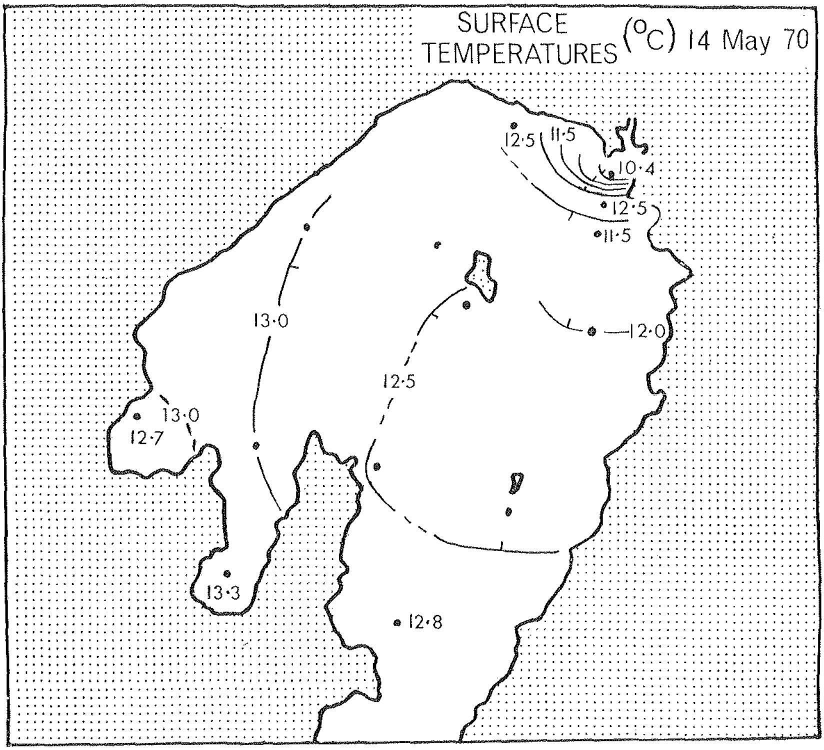


FIG. 6—Distribution of sea surface temperature (°C) during the ebb tide with 1.5–3.0 $m.s^{-1}$ southerly winds, Wellington Harbour, 14 May 1970. Measurements with thermometer. Approximately 53.0 mm rainfall early in previous week.

from the Hutt River undergoes some mixing with the surrounding saline water, but its movements in the harbour can be traced because it forms a cool, lower salinity surface layer extending to about 5 m depth as far south as Somes Island (Figs 6–10). The depth of this surface layer would be expected to vary with the Hutt River outflow, and with the degree of mixing in the harbour caused by tide, wind, and temperature differences. Beyond Somes Island the surface layer becomes more dispersed into the harbour system, contributing to the general winter feature of less saline, cooler water occurring in the upper regions of the water column. However, on 6 July 1970 tongues of low salinity water occurred at stations 4 and 8 (Fig. 10b and 10f), and these suggest artesian water leakages. Also in Fig. 10 (stations 6 and 5), the cooler, less saline water from the Hutt River can be seen to extend along Petone Beach at the surface. On 26 July 1971 east–west temperature profiles across the harbour (Fig. 7c) showed little variation between ebb and flood tides, with warmer water confined to the bottom in deeper areas.

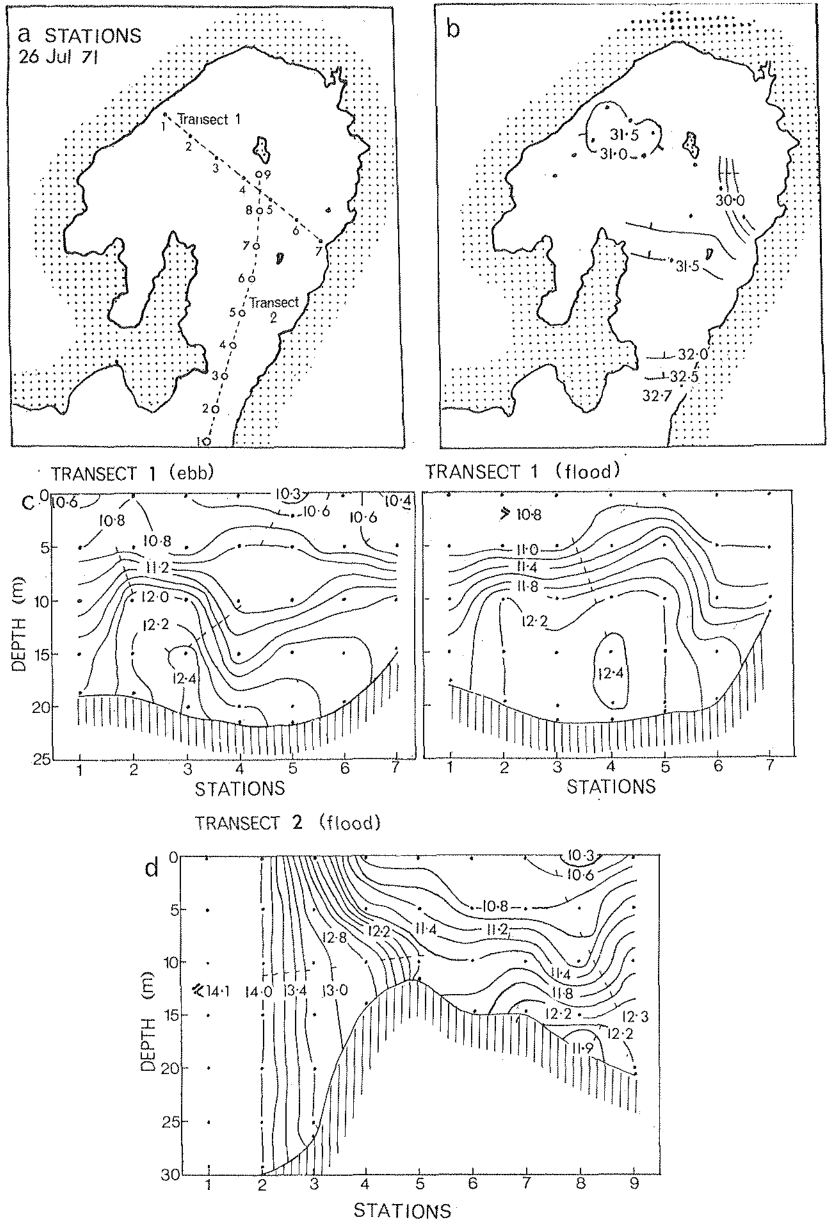


FIG. 7—Distribution of surface salinity (‰) and profiles of temperature (°C) along two transects during light, variable winds, Wellington Harbour, 26 July 1971:

(a) Stations,

(b) Distribution of surface salinity (‰),

(c) Profiles of temperature (°C) along Transect 1 during ebb and flood tides,

(d) Profile of temperature (°C) along Transect 2 during early flood tide. Approximately 17.5 mm rainfall in previous week; for Secchi disc visibility values see Fig. 11. Salinities measured with hydrometer, temperatures with Murayama Thermorecorder.

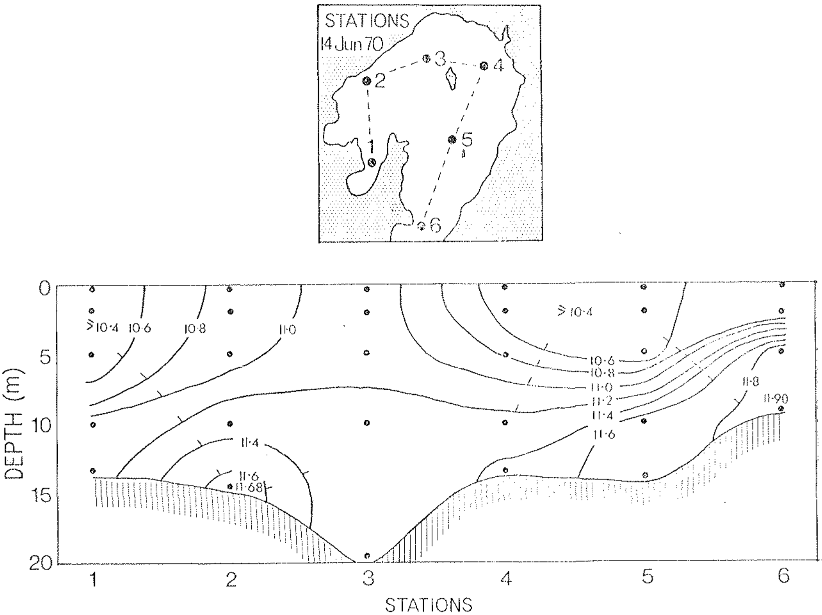


FIG. 8—Profile of temperature (°C) at stations shown in upper diagram during 3–8 m.s^{-1} northerly winds, Wellington Harbour, 14 June 1970. Approximately 11.0 mm rainfall in previous week. Measurements with Murayama Thermo-recorder.

The relationship between Cook Strait and harbour waters during winter is shown in Fig. 7d, where the warmer Cook Strait water is seen to wedge beneath the harbour water during the early flood tide. Brodie (1958) showed a similar effect on 26 May 1953.

SALINITY

Cook Strait salinities range between 34.5‰ and 35.0‰ (Garner 1953, Heath 1971). Wellington Harbour is topographically partially restricted in its contact with the near-coast waters and is therefore prone to lowering of salinities by freshwater inflow.

Surface Salinities. The maximum surface salinity was 35.13‰, recorded at SW Somes Island on 25 February 1971 after several weeks of low rainfall, and the minimum 21.3‰ near the mouth of the Hutt River on 17 June 1970 (see Figs 7, 9, 10, 12, and 13 and Appendix 1; data for 25 February 1971 not presented here). Surface salinities at the four hydrological stations under normal freshwater discharge ranged from 33.5‰ to 34.5‰, this being up to 1.0‰ less than those for Cook Strait. When the rivers were in flood, surface salinities decreased to 25–30‰, especially at Petone Beach and Ngauranga, although salinities in the central part of the harbour seldom fell below 30.0‰.

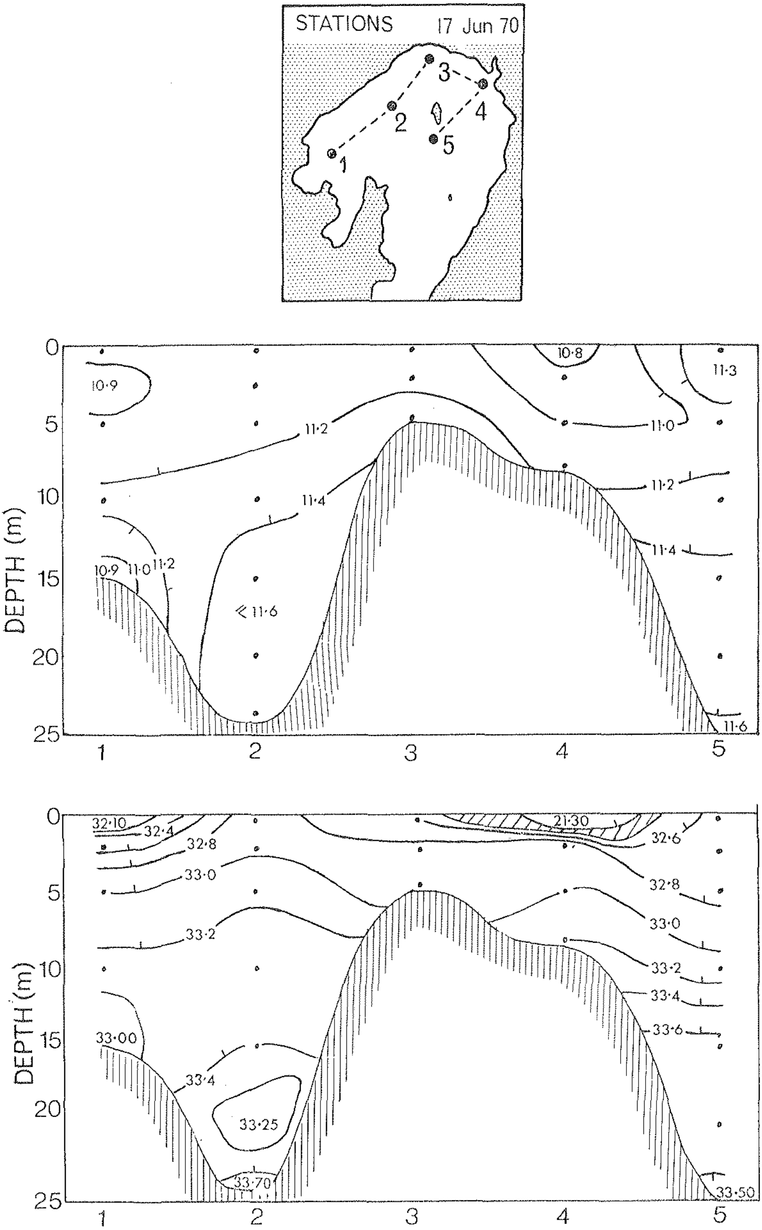


FIG. 9—Profiles of temperature (°c) and salinity (‰) at stations shown in uppermost diagram during $5–8\ m.s^{-1}$ northerly winds, Wellington Harbour, 17 June 1970. Approximately 44.5 mm rainfall in previous week, flood conditions; Secchi disc visibility 2–4 m. All measurements with RS5-3 salinometer. Diagonal hatching indicates region of rapid salinity change.

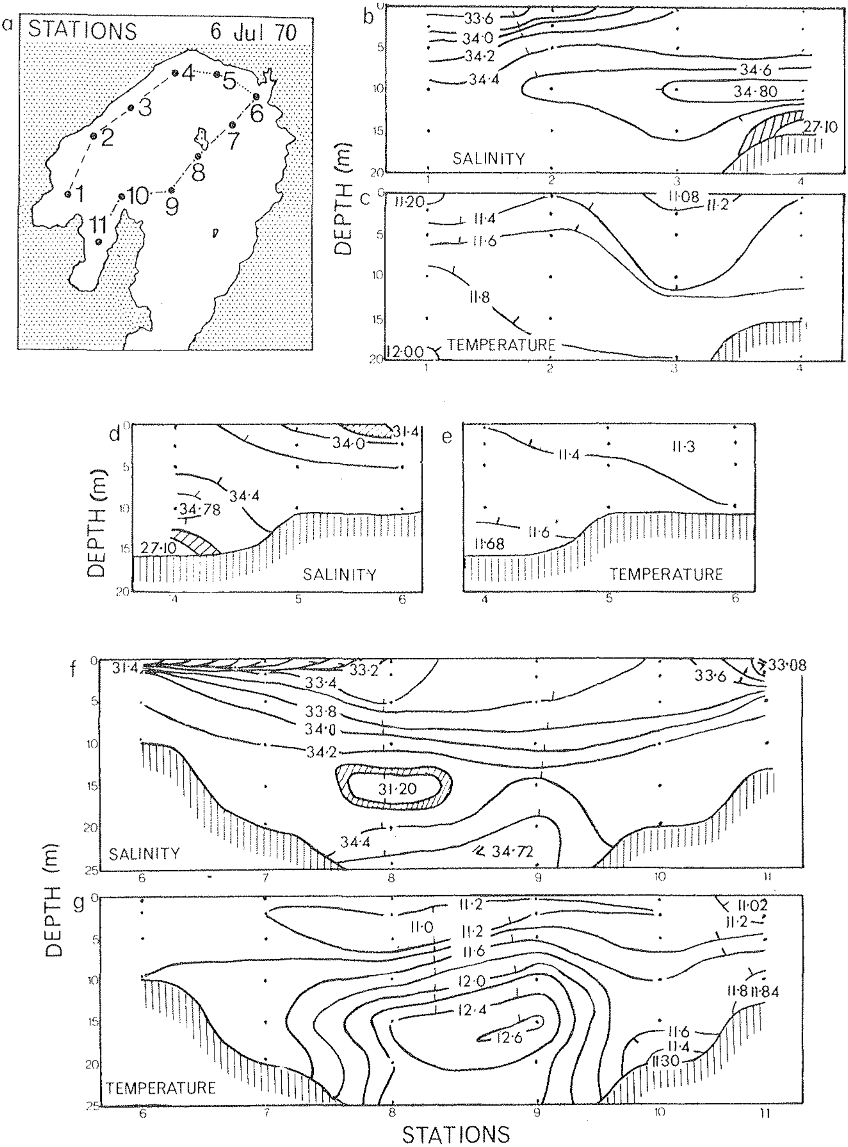


FIG. 10—Profiles of temperature (°c) and salinity (‰) at stations shown in left uppermost diagram during 3–8 m.s^{-1} northerly winds, Wellington Harbour, 6 July 1970. Approximately 18.0 mm rainfall in previous week. All measurements with RS5-3 salinometer. Diagonal hatching indicates region of rapid salinity change.

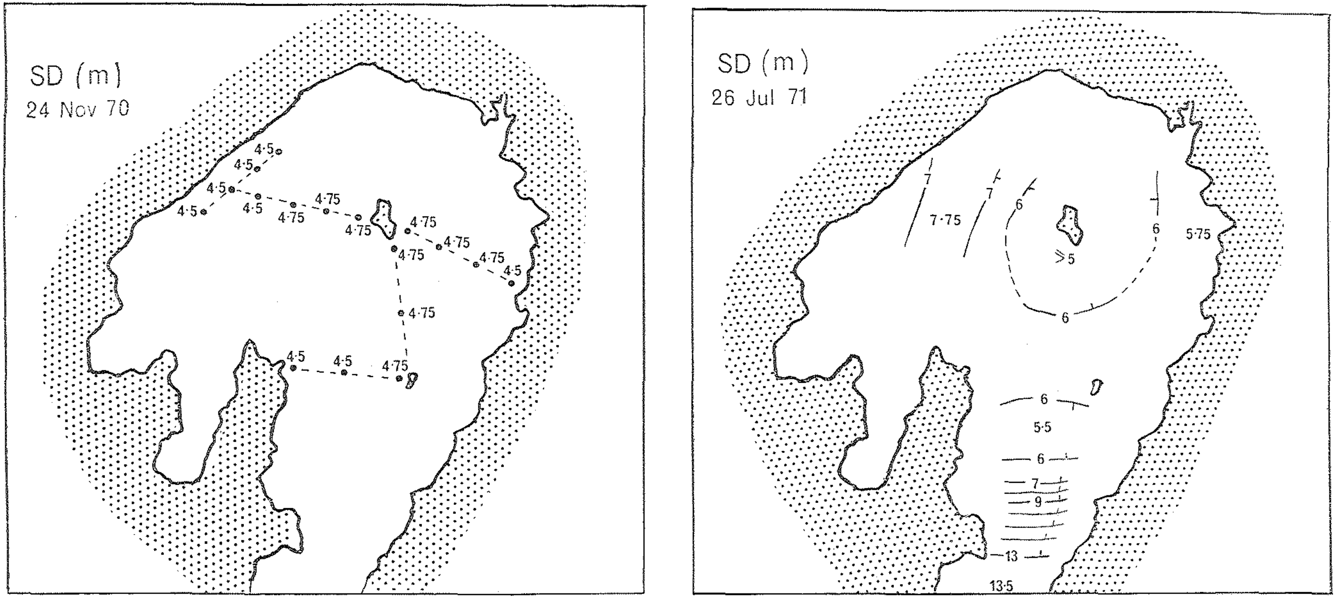


FIG. 11—Distribution of values for Secchi disc (SD) visibility (m), Wellington Harbour, (*left*) 24 November 1970 after 1.5 mm rainfall in previous week, and (*right*) 26 July 1971 after 17.5 mm rainfall in previous week.

Subsurface Salinities. In the main basin of the harbour under normal conditions of freshwater discharge, the salinity was fairly uniform in the vertical column, and surface salinities differed by less than 1.0‰ from bottom salinities (see Figs 9, 10, 12, and 13). The exceptions were places of possible artesian leakages and points directly influenced by the Hutt River, where subsurface salinities differed by up to 12.0‰ from surface salinities.

DISSOLVED OXYGEN

Although relatively few observations were made, the degree of mixing of Wellington Harbour water evidently precludes serious oxygen depletion. The values from all depths observed during this study ranged between 7.18 mg and 12.63 mg oxygen per litre. Expressed as saturation at NTP, most oxygen saturation values exceeded 100%; the minimum observed was 92%.

TURBIDITY

Secchi disc visibility in the main basin of the harbour ranged from 2 m to 8 m, although 3 m to 6 m was the most usual range. Observations made during periods of normal river discharge (Fig. 11) showed higher values at the harbour entrance than in the inner harbour, and little variation in Secchi disc visibility values across the inner harbour. Under flood conditions, mainly during winter, Petone Beach and Ngauranga stations were the most affected and Mahanga Bay station the least affected by suspended silt.

TIDAL CYCLE STUDIES AT MAHANGA BAY

The variation of hydrological parameters during parts of tidal cycles at Mahanga Bay were observed during winter 1970 (Fig. 12) and midsummer 1971 (Fig. 13). During the cycles, sea temperatures varied by less than 2.0°C, salinities by less than 0.5‰ and Secchi disc visibility by less than 0.5 m, and values for dissolved oxygen usually exceeded 100% saturation. There was little stratification of any parameter, probably because of the mixing by tidal currents.

DISCUSSION

The months at which the maximum and minimum sea surface temperatures occurred during 1970–72 were consistent with the observations of previous authors, already mentioned, who showed maxima in January and February and minima in July and August. The temperature ranges were also generally consistent. During 1970–72, Wellington Harbour sea surface cooled at a greater rate (1.75°C per month from mid-March to mid-July) than it warmed (1.55°C and 1.20°C from mid-August to mid-December; compare these values with 1.7°C and 1.5°C respectively for Wellington Harbour 1953–55 given by Skerman 1958). There was no evidence of surface and subsurface temperatures differing by 4.0°C as noted by Skerman (1958), and the figure of 2.0°C suggested by Maxwell (1956) more closely fits the present data.

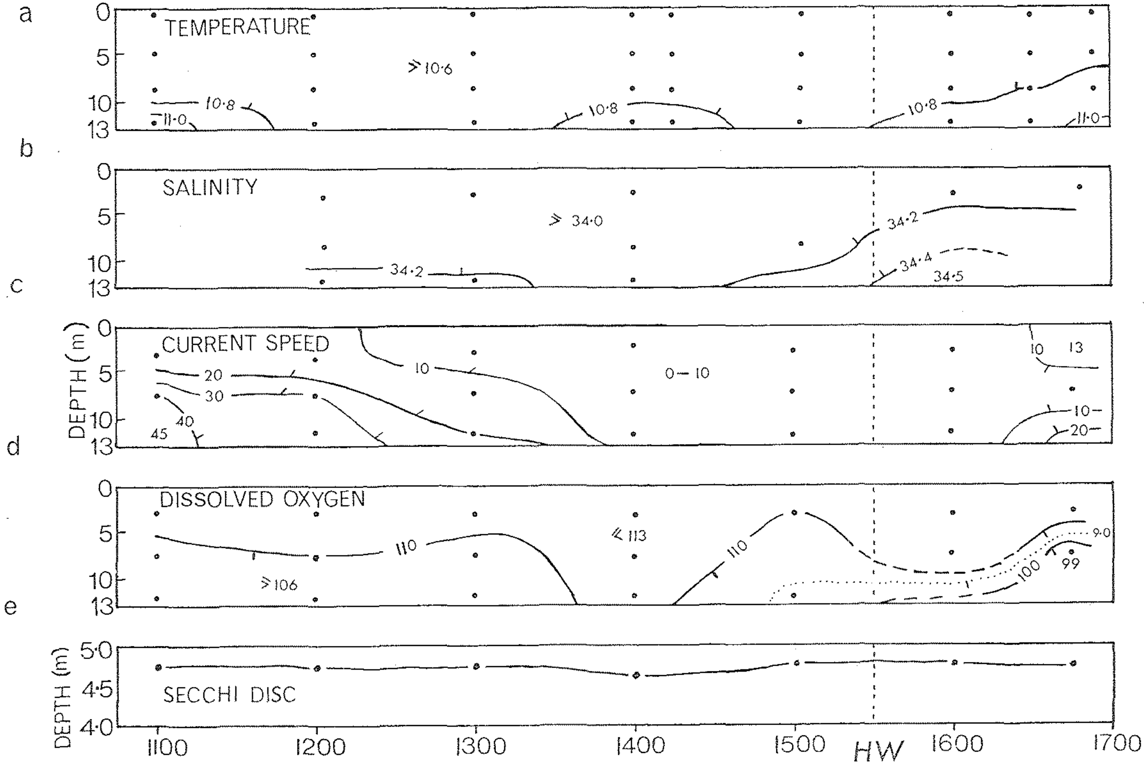


FIG. 12—Variations of hydrological parameters during part of a tidal cycle at Mahanga Bay, Wellington Harbour, 16 August 1970, after 3.3 mm rainfall in previous week. Filled circles denote measurement points. Temperature (°C) measurements were made with an RS5-3 salinometer, salinity (‰) measurements with an RS7-B salinometer. Units of current speed are number of propeller revolutions per 30 s. In dissolved oxygen graph, percent saturation at NTP is shown as a continuous or dashed line, and mg.litre^{-1} as a dotted line. There was a 3–5 m.s^{-1} southerly wind throughout the day.

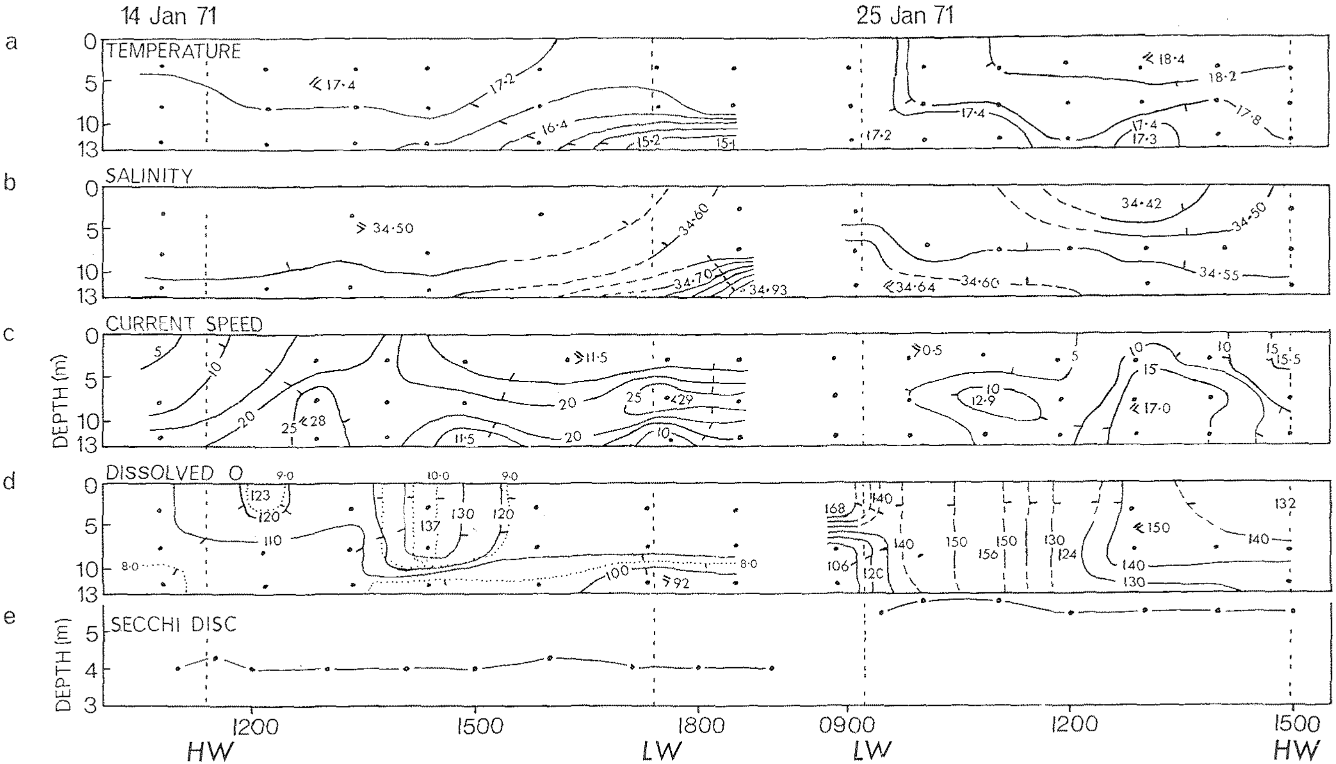


FIG. 13—Variation of hydrological parameters during parts of tidal cycles at Mahanga Bay, Wellington Harbour, 14 January 1971 and 25 January 1971. Rainfall during period 7–25 January 1971 was 9.9 mm. Filled circles denote measurement points. Temperature (°C) measurements were made by thermometer, salinity (‰) measurements by RS7-B salinometer. Units of current speed are number of propeller revolutions per 30 seconds. In dissolved oxygen graph, percent saturation at NTP is shown as a continuous or dashed line, and $mg.litre^{-1}$ as a dotted line. There was a 3–8 $m.s^{-1}$ southerly wind throughout both days.

TABLE 2—Summary of salinity ranges published previously for Wellington harbour (– = no data or not applicable; ? = not stated)

AUTHOR	SAMPLING LOCATION	SAMPLING PERIOD	SALINITY (‰) Min.	Max.	Most Common Range
Maxwell (1956)	Queen's Wharf NE Harbour	1953–54	34.1	35.9	34.4–35.7
Maxwell (1956)	(Theoretical)	–	–	–	32.5–33.5
Brodie (1958)	Whole Harbour	May-Jul 1953	22.28	33.86	32.8–33.7
Cassie (1959)	Central Harbour	Jul 1958	–	–	32.38–33.82
R. M. Cassie (1960)	Harbour Entrance	Sep 1958	34.3	35.1	– –
V. Cassie (1960)	Eastern and Central Harbour	1957–58	29.0	34.9	– –
Gilmour (1960)	Queen's Wharf	?	–	–	34.4–35.2
Present Study	Whole Harbour	1970–72	21.3	35.13	33.5–34.5

Maxwell's (1956) contention that normal discharge of the Hutt River is insufficient to materially upset the hydrological regime of the harbour is supported by my observations; temperature and salinity are markedly influenced only as far south as Somes Island and only to a depth of about 5 m. However, during a flood, the surface water of the entire harbour may become diluted, as demonstrated by the low salinities given by Brodie (1958) and some of the low salinities observed during this study (see Appendix 1).

There is considerable variation in the range of surface salinities given in earlier studies for Wellington Harbour; these are summarised in Table 2. Of the studies based on at least one year of sampling, the values recorded by Maxwell (1956) for 1953–54 and Gilmour (1960) for Queen's Wharf (Lambton Harbour) are 0.5‰ to 1.5‰ higher than those usually observed in western parts of Wellington Harbour during 1970–72. Brodie's (1958) and Cassie's (1959) winter surface salinities are similar to those observed in this study.

The Secchi disc values show that most of the harbour is quite turbid, particularly after flooding, although the dissolved oxygen values remain relatively high. Maxwell (1956), commenting on pollution and turbidity in Wellington Harbour, concluded that shipping activity accounted for much of the turbidity, and Brodie (1958) emphasised the importance of the Hutt River in discolouring surface harbour waters. There have been no values for turbidity published previously for Wellington Harbour, although V. Cassie (1960) gave the turbidity as "moderate–extreme".

The study shows that the harbour is relatively well mixed, and although some special hydrological characteristics are generated within the harbour, the hydrological regime is such that localised distributions of any particular features are rapidly dispersed. Furthermore, the present study suggests that the harbour is more clearly cut off from Cook Strait than suggested by Maxwell (1956) and Gilmour (1960).

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APPENDIX 1—Surface salinity data (‰) for the four hydrological stations, Wellington Harbour, October 1970–February 1972 (* = measurement with Zeal hydrometer; others with Beckman RS7–B salinometer; – = no reading)

STATION	SALINITIES (‰)									
	1970				1971					
	15 Oct	16 Nov	10 Dec	31 Dec	14 Jan	21 Feb *	7 Mar *	29 Mar *	22 Apr *	12 May *
Mahanga Bay	34.15	34.08	34.74	34.44	34.45	33.2	34.5	32.2	34.7	33.6
SW Somes Island	33.61	34.09	34.76	34.42	34.57	33.8	34.7	32.3	34.7	33.8
Petone Beach	33.91	27.15	34.75	33.75	31.97	33.2	–	32.7	34.0	32.7
Ngauranga	34.10	34.15	34.51	34.61	34.36	–	34.3	32.0	34.0	33.8
	1971						1972			
	11 Jun	7 Jul	2 Sept *	7 Oct *	15 Nov *	16 Dec *	2 Feb *			
Mahanga Bay	34.64	33.83	32.7	31.0	33.2	30.8	32.5			
SW Somes Island	34.38	34.08	32.7	30.3	33.7	31.6	31.8			
Petone Beach	34.36	34.47	32.7	21.8	25.3	30.8	29.3			
Ngauranga	34.37	33.35	33.3	24.5	33.7	32.8	31.8			