https://doi.org/10.24199/j.mmv.1966.27.05 2 November 1966

PORT PHILLIP SURVEY 1957–1963.

HYDROLOGY.

By D. J. ROCHFORD.

C.S.I.R.O. Division of Fisheries and Oceanography.

SUMMARY.

Hydrological observations have been made in Port Phillip Bay during 1947–1952. Since the volume of water within the Bay is some ten times the combined annual river discharge of the flood period of 1952–1953, no complete freshwater scouring of the Bay can occur. Between 1947 and 1952 the chlorinity fluctuated each year from minimum values in November–December to maximum values in April–June, with a year by year decrease in the average annual value. This long term decrease was caused by increased river discharge, particularly during early summer when the chlorinity of the Bay normally increases by exchange with Bass Strait waters. Winter temperatures were warmest in 1950 and summer temperatures at their highest in 1951.

Nitrate nitrogen values were always less than 10 ug/l in the centre of the Bay, elsewhere increased to as much as 360 ug/l during increased river discharge. Inorganic phosphates of the Bay were generally less than 10 ug/l in the centre and less than 20 ug/l elsewhere. Quite often phosphates decreased during periods of increased river discharge. The Bay is well ventilated according to its oxygen characteristics. Oxygen values fluctuated around the saturation values except during extremes of chlorinity stratification when bottom values decreased to about 60 per cent. of the saturation values. Such decreases were quite rare however and in any case only of a temporary nature.

DATA AND METHODS.

(a) Sources of data.

The hydrological data were collected at six stations around the Bay (Chart 2 back of volume) during 1947–1952. Samples were collected at surface and depths to the bottom by officers of the Fisheries and Wildlife Department, Victoria and sent to the C.S.I.R.O. laboratory at Cronulla for chemical analysis. Delays of up to several days between collection and analysis of these samples could have caused errors in the nutrient analyses. The hydrological data have been published (C.S.I.R.O. 1952, 1953a, 1953b).

(b) Methods.

The chemical methods were described by Rochford 1951. The figures for inorganic phosphate have been used without salt correction, in this paper. Because of the small number of stations (Chart 2) it was not feasible to prepare charts of the horizontal distribution of hydrological properties of the Bay. In this paper the annual and year by year changes in these properties have been examined at two stations which are considered typical of the two extremes of hydrological environment of the Bay. Station 1 near the mouth of the Yarra River (Chart 2) is typical of the freshwater conditioned environment and Station 5 in the deep central basin is typical of the marine conditioned environment.

GENERAL FEATURES OF PORT PHILLIP BAY.

(a) Geological History.

Port Phillip Bay is part of a larger area called the Port Phillip Sunkland, formed by the down-faulting in Cainozoic times of the region between the Rowsley Fault in the west and Selwyn's Fault in the east. Subsequent flooding of part of this depressed, mainly low-lying area by the sea, due to the eustatic rise of sea level beginning in late Pleistocene and extending to mid-Holocene times, has given rise to Port Phillip Bay. It is believed that most of Port Phillip Bay was a land surface as recently as 7,000 years ago. Evidence from the radiocarbon dating of wood indicates that about 8,750 years ago the sea was at least 73 feet lower than now, so most of Port Phillip Bay is known to have been dry land at that time. The topography of the land before it was submerged has largely controlled the configuration and depth of the Bay.

In Pleistocene and early Holocene times the land surface was drained by a river system of which the Yarra River was part. The early Yarra flowed southwards over what is now the floor of Port Phillip Bay. Keble (1946, p. 73) has reconstructed the valley of the Yarra River during late Pleistocene and early Holocene times by connecting up soundings on Admiralty Chart 1171 into bathymetrical contour-lines; after this was done, the sunken river system showed up distinctly, and the Werribee, Little River, Kororoit Creek, and other streams now discharging into Port Phillip are seen to have been tributaries of the early Yarra. The eustatic rise of sea level drowned the lower part of the river system.

In Upper Pleistocene times, dune building established a bar across the " mouth " of Port Phillip, this is known as the Nepean Bay Bar.

In mid-Holocene times, when the climate was slightly warmer than at present, sea level was of the order of 10 feet higher and the Bay was somewhat larger, covering low-lying, fringing regions particularly in the north-west.

In the course of its geological history therefore, the volume of water within Port Phillip Bay has greatly increased but the area of drainage of its river systems has greatly decreased. Thus from an original freshwater dominated estuarine system the Bay has become progressively more saline and at the present time can absorb the quite large river discharges of 1952 without freshwater domination (page 109).

(b) Dimensions.

The total surface area of Port Phillip Bay inside of a line joining Point Lonsdale and Beacon Rock and excluding rivers is 568 square miles. Of this area about 30 per cent. is less than 5 fathoms (9·1 m.) deep. A central basin which is deeper than 10 fathoms (18·2 m.) has an area of 188 square miles and is cut off by a sill near the entrance from Bass Strait (Chart 2 back of volume). The volume of water in Port Phillip Bay at high water spring tide is 1507 x 10^4 acre feet (186 x 10^8 m^3). The combined annual discharge of all rivers into the Bay during a period of flood discharge in 1952–53 was 164 x 10^4 acre feet (State Rivers and Water

Supply Commission 1964). This is only about 10 per cent. of the volume of water in the Bay, which cannot therefore, be flushed completely of saline waters even during extreme flood conditions.

HYDROLOGICAL FEATURES.

(a) Chlorinity.

In the middle of the Bay the surface chlorinities were at a maximum in April–June and at a minimum in November–December (Fig. 1a, 1b). River discharges from the adjoining Werribee River were at a maximum in June–November and at a minimum in January–May (Fig. 1a–1b). Dilution of waters of the centre of the Bay was a function of river discharge during the dilution phase (Fig. 1c) but chlorinities remained at low values for some time after the diminution of river flow (Fig. 1c). The duration of this recovery period following dilution is governed by the rate of exchange of Port Phillip Bay and the adjoining Bass Strait waters and takes 4–6 months (A–A[1] Fig. 1c) to complete. Any further dilution during this recovery period cannot be compensated by this exchange process before the next winter dilution period (Fig. 1a) and a cummulative lowering of the average annual chlorinity results. This was a striking feature of the year by year changes in chlorinity at Station five during 1947–1952 (Fig. 2a). Despite a well marked annual recovery period, the average chlorinity decreased throughout this period paralleling an increase in river discharge (Fig. 2b). The extent of chlorinity recovery during January–May of each year was inversely proportional to the river discharge during this same period. during the years 1950–1952 (Fig. 2c). During 1949 however the chlorinity recovery was much weaker than the river discharge, based upon the above relation would indicate, and no satisfactory reason for this anomaly has been found. A striking feature of the chlorinity structure in the centre of the Bay was the near homogeneity of values in the 20 m. water column (Fig. 2a). This is in contrast to the chlorinity stratification found at Station 1 in only 5 m. of water (Fig. 3). During 1947–1952 the chlorinity of bottom waters at this station fluctuated seasonally in much the same fashion as those in the centre of the Bay with minimum values around September–October and maximum values around February–May of each year. The year by year average chlorinity decreased to a greater extent than did chlorinities of the centre of the Bay. Surface chlorinities at Station 1 fluctuated more widely than bottom values and showed a more pronounced year by year decrease.

(b) Temperature.

Typical annual cycles of surface temperature are shown in Figure 4. Temperature levels and the month by month changes were very similar at Stations 1 and 5. Vertical temperature stratification was most pronounced at Station 5 during the vernal-summer warming of surface waters (Fig. 5) but never exceeded a 3°C difference in 20 m.

At other stations in much shallower water temperature stratification of this order generally occurred only when there was a marked vertical gradient of chlorinity. Year by year changes in the maximum and minimum temperatures of the annual cycle were found (Fig. 5) with 1950 having the warmest winter and 1951 the warmest summer.

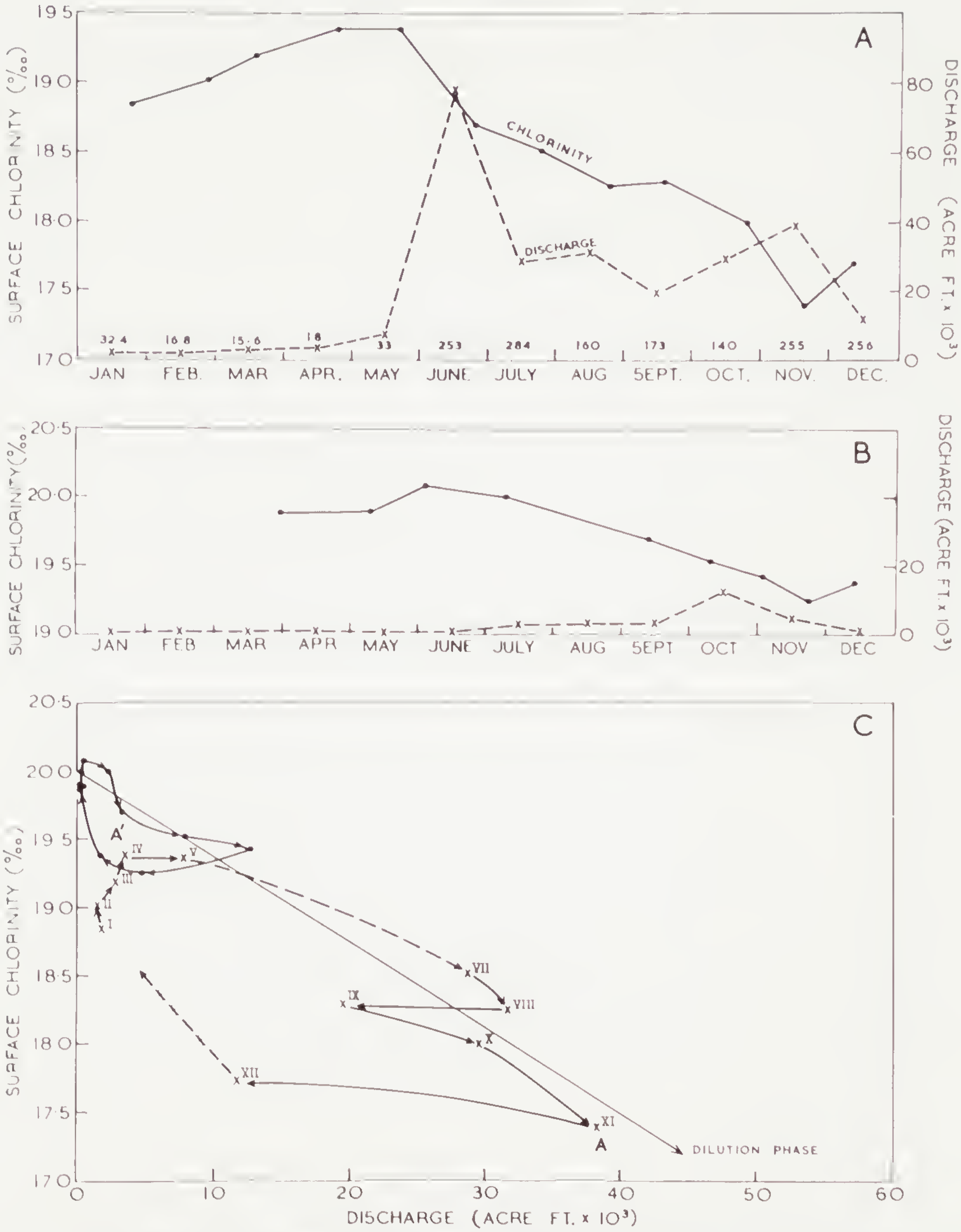

Fig. 1. A. Monthly changes in surface chlorinity at Station 5 (.———.) and in discharge of Werribee River at Melton Reservoir (x— —x) during 1952.

B. Same as 1A during 1947.

C. Surface chlorinity at Station 5 as a function of discharge of Werribee River at Melton Reservoir

·———· 1947

x———x 1952

Roman numerals indicate months.

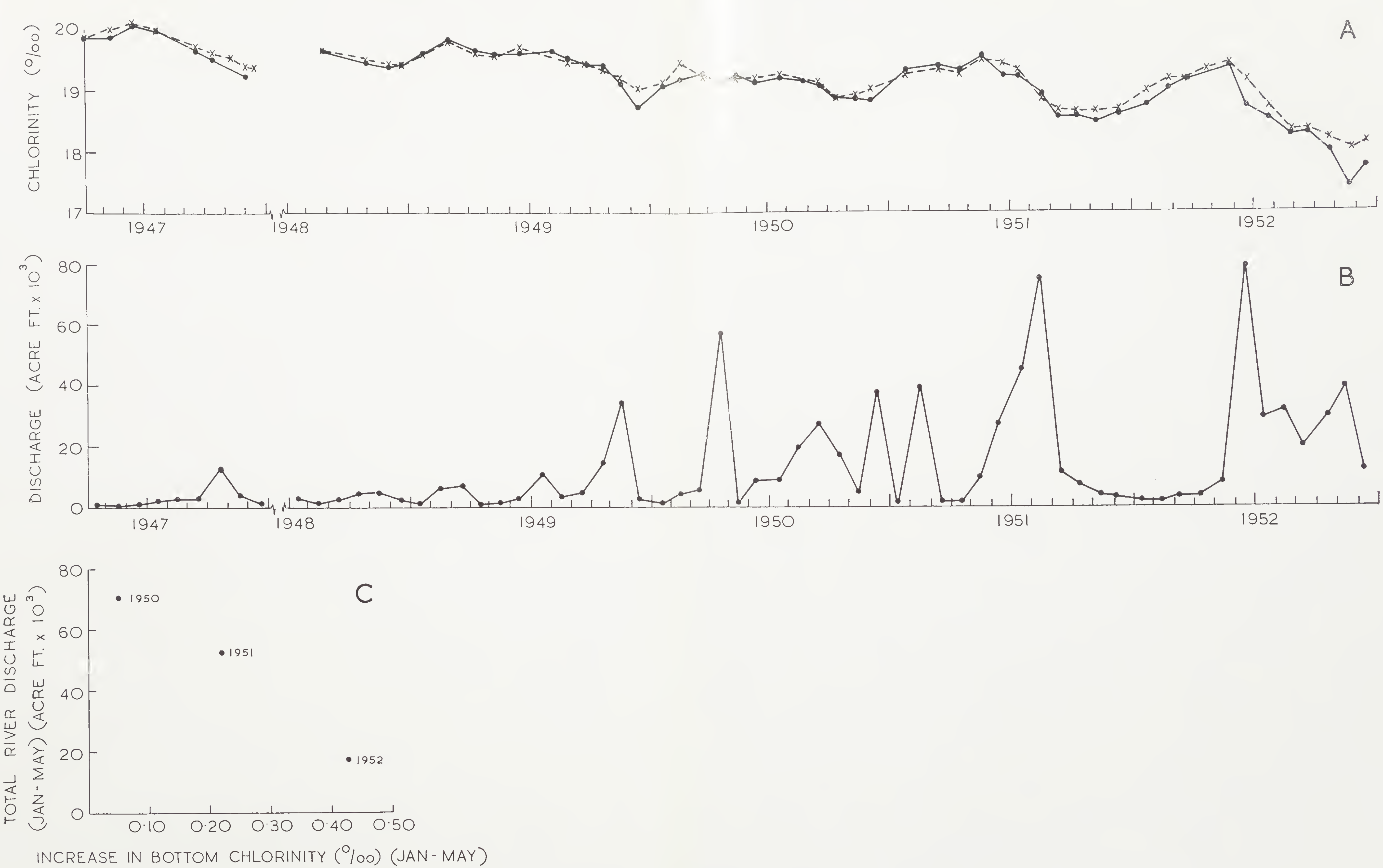

Fig. 2. A. The changes in surface (·) and 20 m. (x) chlorinity at Station 5 during 1947–52.
B. The changes in discharge of Werribee River at Melton Reservoir during 1947–52.
C. The increase in bottom chlorinity at Station 5 from January–May of 1950, 1951, 1952 in relation to changes in river discharge at Melton Reservoir during the same period.

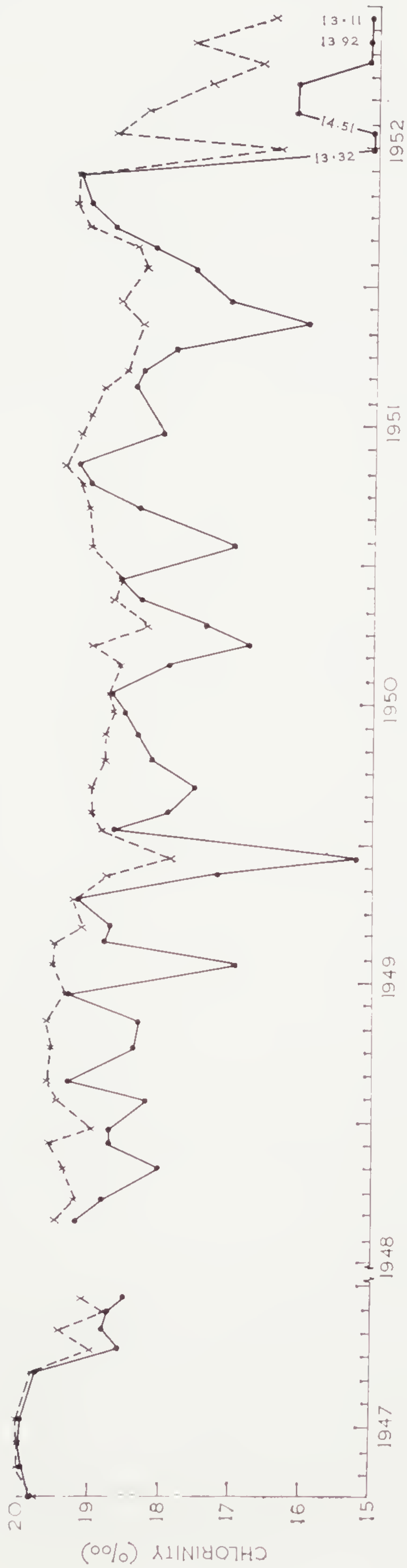

FIG. 3. The changes in surface (.——.) and 5 m. (x— —x) chlorinity at Station 1 during 1947–52.

(c) Nitrate nitrogen.

In 1952 there was a pronounced annual variation in surface nitrates at Station 1 (Fig. 6a). During the chlorinity recovery period (January–May) nitrate concentrations were very low. With the onset of river dilution in June however, nitrate concentrations increased tremendously and were subsequently maintained at levels which were governed to a large extent by the outflow of the adjoining Yarra River (Fig. 6b). This annual variation also occurred in other years at Station 1, with the magnitude of the nitrate concentration largely dependent upon river dilution (Fig. 7). At Station 5 in the centre of the Bay however, nitrate concentrations were always less than 10 ug. l. (Fig. 7) and the average annual concentration particularly from 1950 onwards was not significantly increased by the decreased chlorinity during this period (Fig. 2a).

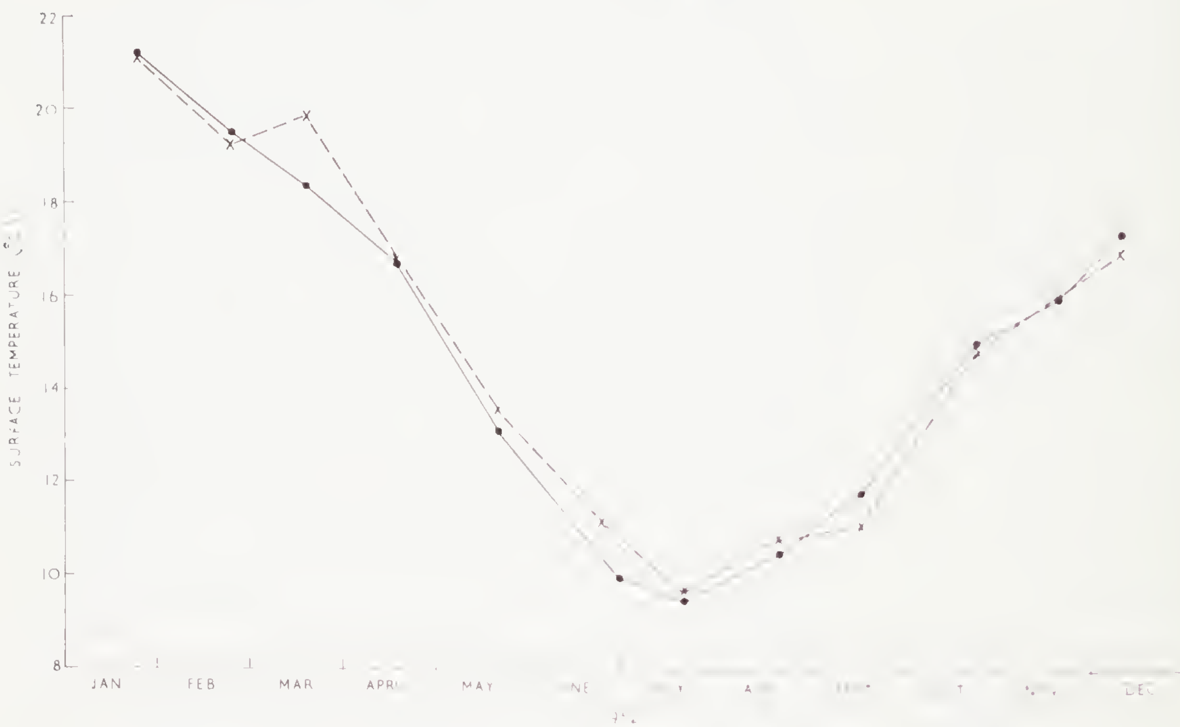

Fig. 4. The temperature changes in surface waters of Station 1 (·———·) and of Station 5 (x— —x) during 1952.

(d) Inorganic phosphates.

At Station 5 during 1947–1952 phosphate fluctuated between 0–15 ug./1. (Fig. 8). There was no year by year increase in the average phosphate concentration similar to nitrate paralleling the decrease in chlorinity at this station (Fig. 2a). In point of fact the average phosphate concentration decreased from 1947–1952. Since the high chlorinities in 1947 at Station 5 were caused by greater amounts of Bass Strait water (page 109) it is probable that Bass Strait and not river waters are more important for the phosphate economy of the Bay. This is also shown by the year by year change in phosphates at Station 1 (Fig. 8)

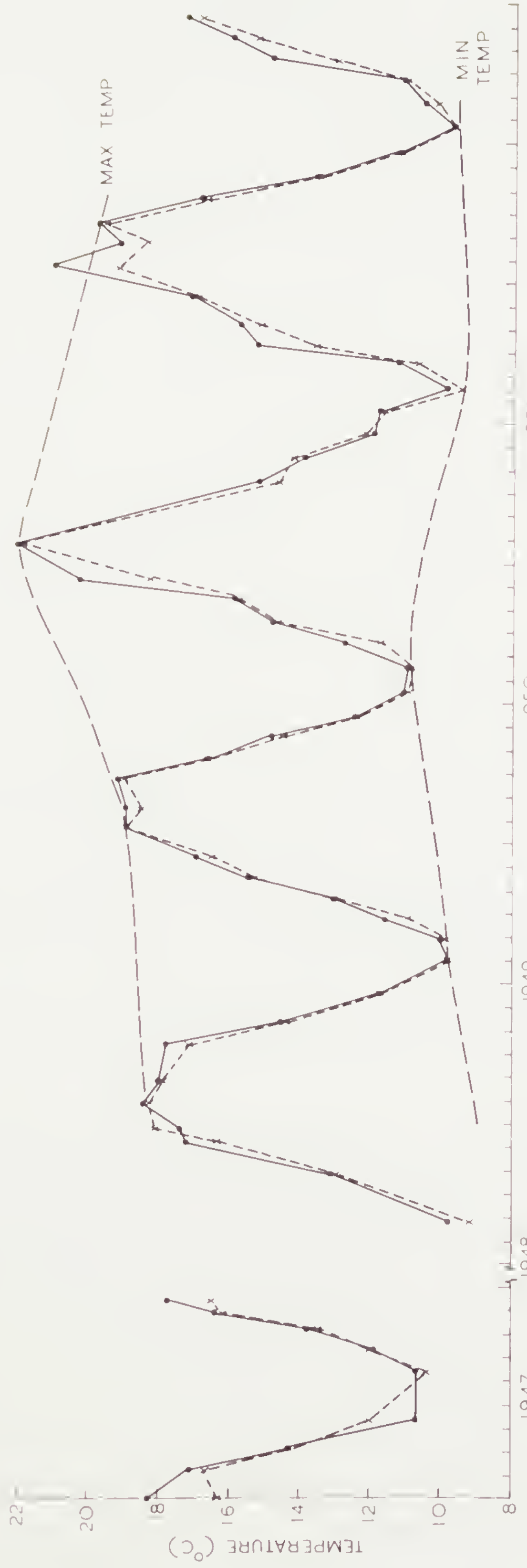

FIG. 5. The changes in temperatures of surface (·———·) and 20 mm. (x— — —x) waters at Station 5 during 1947–52.

which is strongly influenced by river discharge (page 109). Between 1949 and 1952 at this station the average phosphate concentration decreased (Fig. 8) despite large increases in river discharge as evidenced by the decrease in chlorinity (Fig. 3).

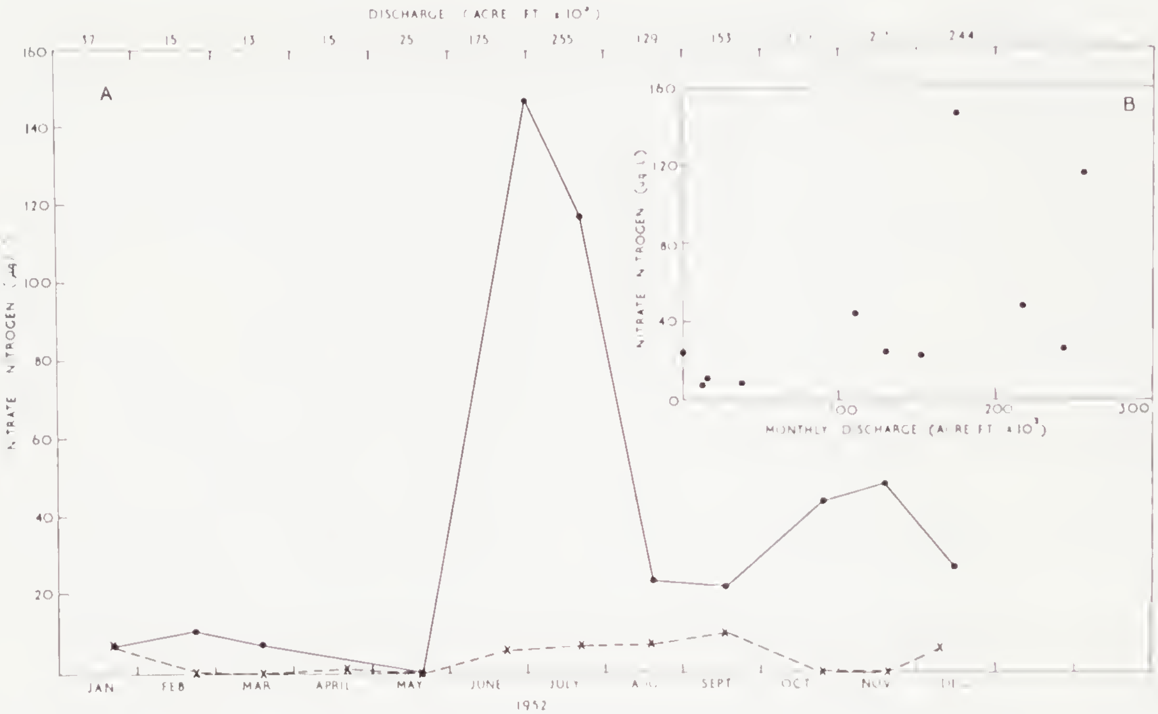

FIG. 6. A. Variations in nitrate concentration of surface waters at Station 1 (·———·) and Station 5 (x———x) during 1952. Figures along the top show the monthly discharge in acre ft. x 10³ of the Yarra River at Yering during 1952.

B. The monthly nitrate concentration of surface waters at Station 1 as a function of Yarra River discharge during 1952.

(e) Oxygen.

Oxygen at Station 5 fluctuated from high values in winter to low values in summer (Fig. 9). Throughout these fluctuations the water generally remained nearly saturated with oxygen (Fig. 9) showing that these seasonal changes are mainly an effect of physical factors probably temperature upon the oxygen retaining capacity of the water. However, in December 1949, January 1952 and December 1952 the bottom waters had an oxygen content of some 85 per cent. only of the saturation value and biological utilization must have occurred.

At Station 1 the monthly changes followed (Fig. 10) somewhat the same seasonal pattern as at Station 5 but with a much greater annual range. Chlorinity stratification at Station 1 was much greater at certain times than at Station 5 (page 109). In general it was during these periods of stratification that the oxygen content of bottom

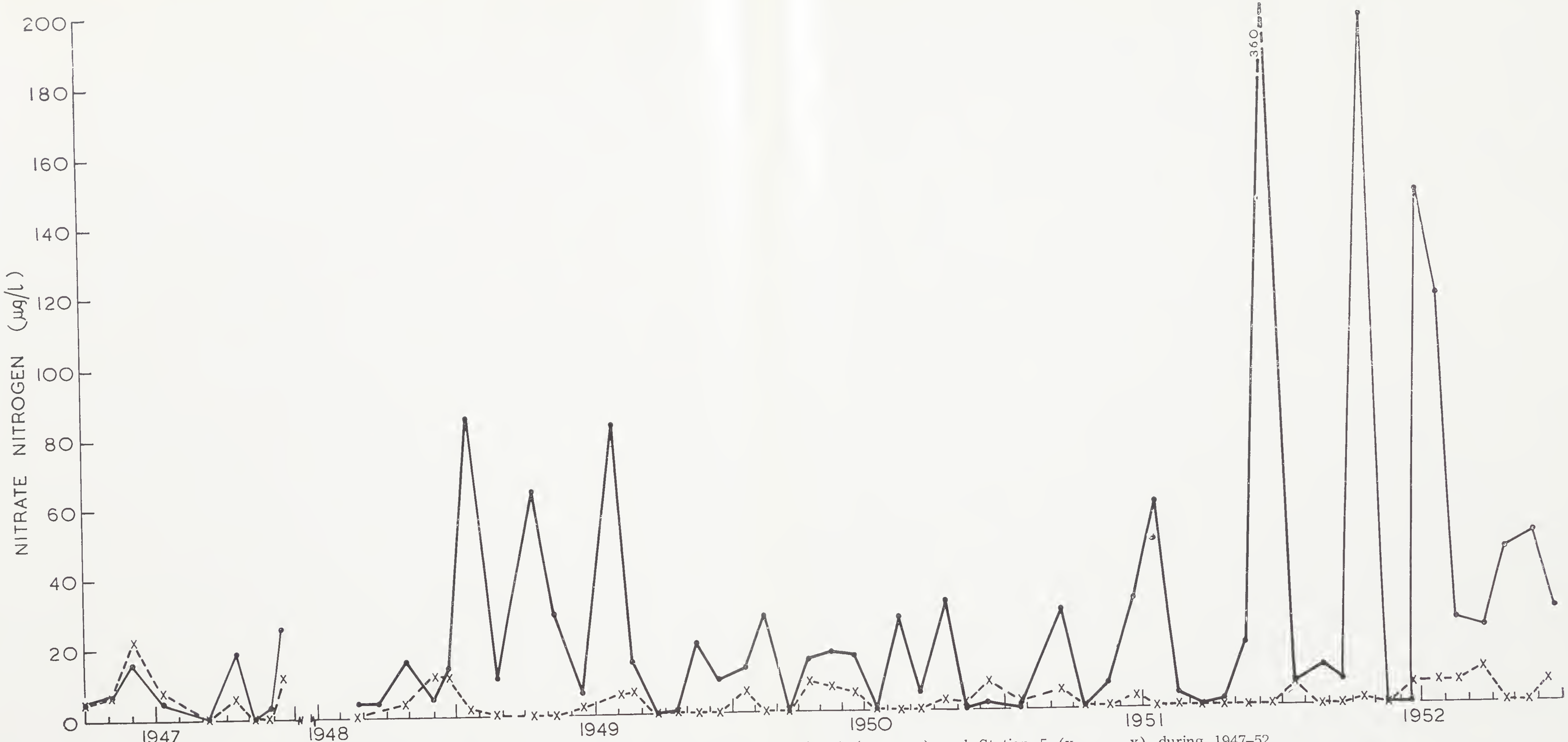

FIG. 7. Changes in nitrate concentration of surface waters at Station 1 (·———·) and Station 5 (x— — —x) during 1947–52.

FIG. 8. Changes in phosphate concentration of surface waters at Station 1 (·———·) and Station 5 (x— — —x) during 1947–52.

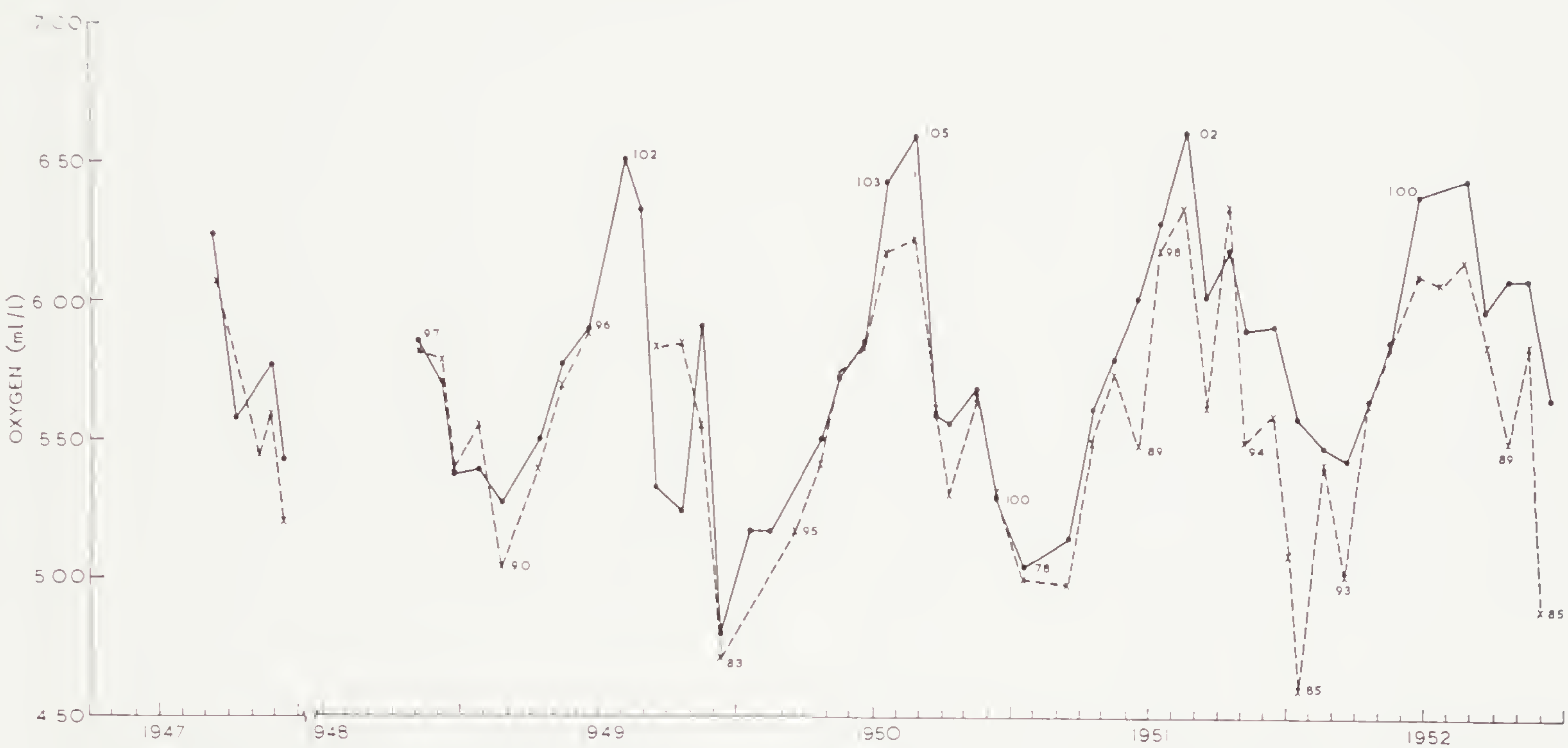

FIG. 9. Monthly changes in oxygen of surface (·———·) and 20 m. (x— — —x) waters at Station 5 during 1957–52.

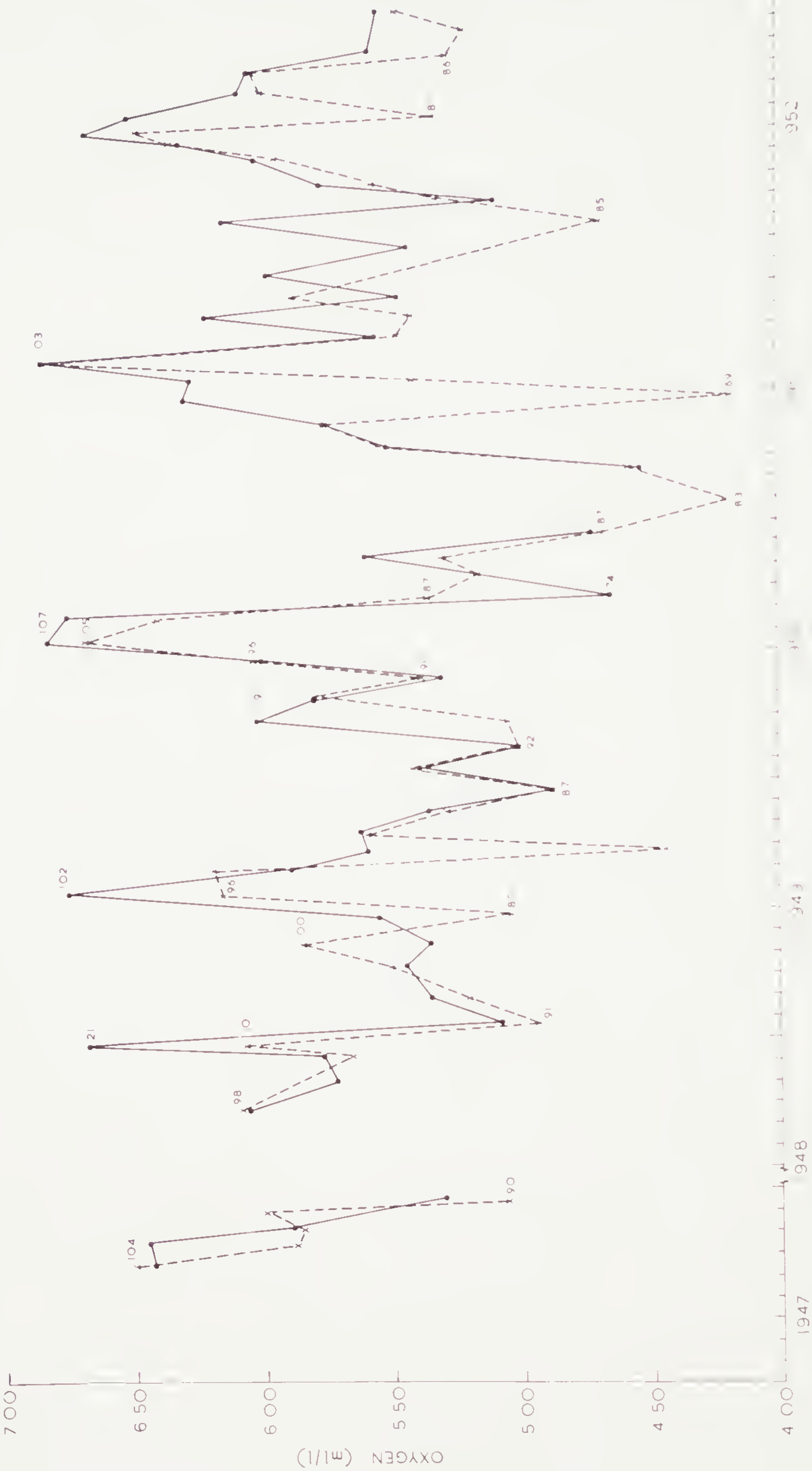

FIG. 10. Monthly changes in oxygen of surface (·———·) and 5 m. (x— — —x) waters at Station 1 during 1947–52. Figures indicate oxygen percentage saturation value.

waters at Station 1 attained their lowest values (Fig. 11). This deoxygenation cycle is a feature of those estuarine systems in Australia (Rochford 1951) in which the bottom sediments contain easily oxidized substances such as ferrous salts and presumably such sediments occur at Station 1.

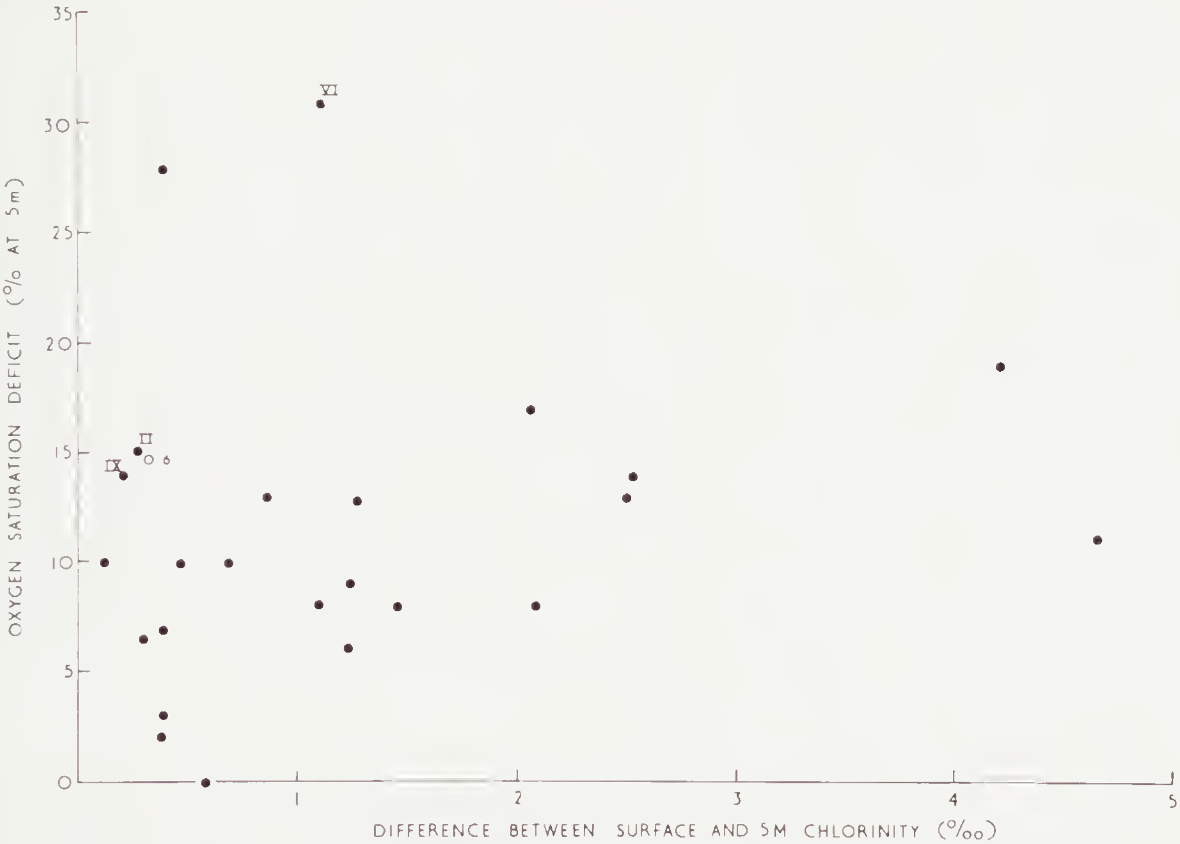

FIG. 11. Oxygen saturation deficit of 5 m. waters at Station 1 as a function of the difference in chlorinity at 0 and 5 m.

CONCLUSIONS.

(*a*) From 1947 to 1952 chlorinities of Port Phillip Bay decreased, because of increased river discharge, mainly during winter.

(*b*) After the winter dilution, some 4–6 months without further dilution is required to effect complete exchange of Bay and Bass Strait waters.

(*c*) The volume of water in the Bay is large enough relative to total river discharge to preclude any complete scouring of saline waters during floods.

(*d*) Concentration of nitrate nitrogen in Port Phillip Bay increases during periods of dilution.

(*e*) Inorganic phosphates in Port Phillip Bay decrease during periods of dilution.

(*f*) The seasonal changes in oxygen content of the Bay were largely caused by physical factors such as temperature, but at Station 1 in particular the oxygen of bottom waters was lowered by biological demand, whenever chlorinity stratification developed. However at no time did the oxygen fall below 60 per cent. of the saturation value.

ACKNOWLEDGMENTS.

The account of the Geological History was prepared by Dr. A. Beasley, to whom the author's thanks are extended.

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