Fisheries Research Bulletin No. 3

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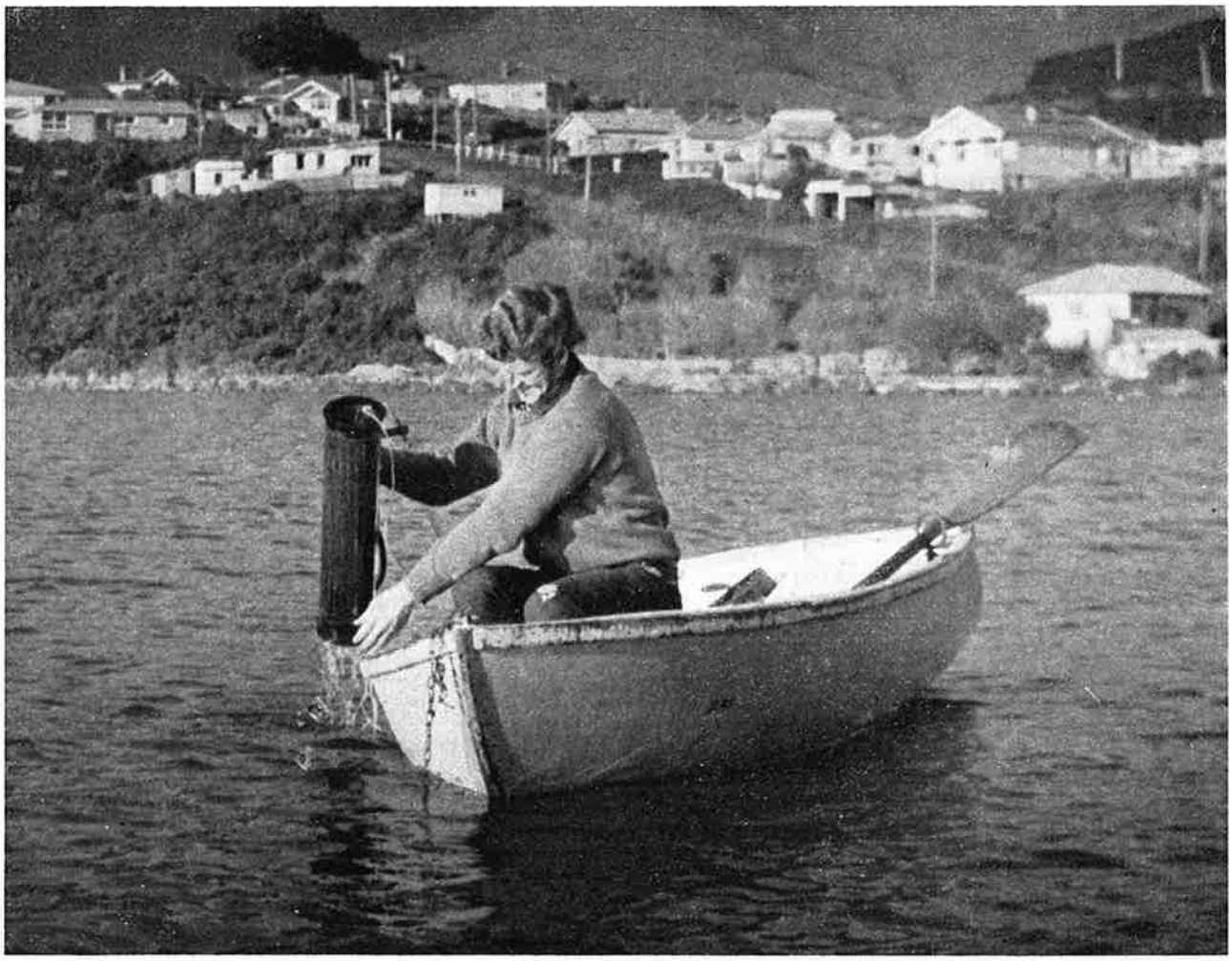

Frontispiece: Water samples being taken from Tomahawk Lagoon with a Van Dorn sampler on a calm winter's day.

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FOREWORD

THOSE of us interested in the proper use of our water resources are concerned with the effects of natural and induced changes on the productivity of the environment, yet relatively few fundamental observations have been made of primary production in fresh water in temperate regions. But such observations are essential if we are to be able to measure accurately the changes taking place.

In providing a critical appreciation of techniques and fundamental information on three South Island lakes Dr Mitchell has established a basis for those comparative studies which future workers will certainly desire to make. He has also indicated how variation of chemical and physical conditions may alter primary productivity, and his observations on the apparent mutual exclusion of phytoplankton and macrophytes must be of interest to those concerned with the aesthetic appearance, as well as the productivity, of our inland waters.

G. DUNCAN WAUGH,
Director, Fisheries Research Division.

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INTRODUCTION

Between July 1963 and January 1966 an experimental investigation of phytoplankton productivity was carried out on Tomahawk Lagoon No. 2, Lake Waipori, and Lake Mahinerangi, which all lie between latitude 45° 50′ and 46° S, in the Otago district of the South Island, New Zealand (fig. 1). Some observational data were gathered on macrophytic vegetation during this period, and observation of the phytoplankton and macrophytes was continued at irregular intervals until December 1966. The aims of the study were to establish the level of phytoplankton productivity and to investigate the influence of some environmental factors on phytoplankton productivity. Most studies of phytoplankton productivity have been made in tropical or continental regions, and this is one of the first in an area having an oceanic climate.

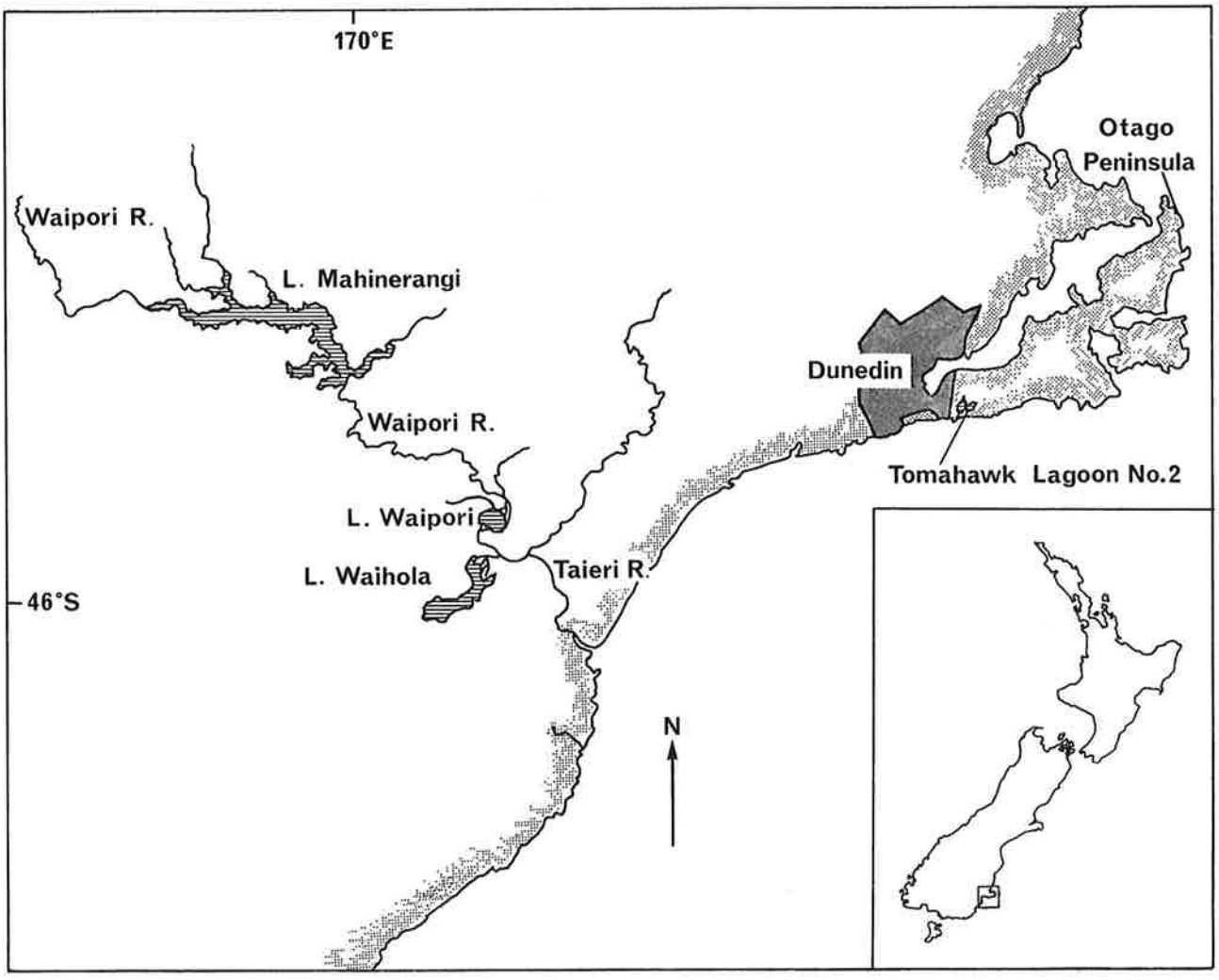

Fig. 1: The locations of the three lakes studied, Tomahawk Lagoon No. 2, Lake Waipori, and Lake Mahinerangi, in the Otago district.

DESCRIPTION OF THE LAKES

TOMAHAWK LAGOON NO. 2

The two Tomahawk Lagoons (fig. 2) are coastal lagoons lying on the southern side of the Otago Peninsula on the outskirts of the city of Dunedin. They have been formed in two small river valleys by the growth of a bar across their estuary, and a small stream runs through sandhills from No. 1 Lagoon to the sea. The two lagoons are separated by a natural spit which carries a road, but are linked under the road by a narrow channel. The direction of flow was always observed to be from No. 2 Lagoon to No. 1. Number 1 Lagoon is more saline ($Cl^- = 2{,}500$ mg/l) than No. 2 ($Cl^- =$ 278-580 mg/l).

Number 2 Lagoon is 400 m from the sea. It has an area of 9.6 hectares, a length of 600 m, and a maximum width of 300 m. Its depth is between 1.0 and 1.2 m over much of the basin, but this has been increased by dredging to between 2.0 and 2.6 m in an area of about 2,000 sq m near the centre of the basin. Dredging with a suction pump has been carried out since 1961 by a local organisation wishing to improve conditions for trout, and the spoil has been used to reclaim an area on the southern shore. There are small areas of swamp at the south-western and north-eastern ends of No. 2 Lagoon, but the northern and south-eastern shores slope steeply and there is only a narrow swamp zone between hill pasture and the lake. The lake sediment is 0.4-1.3 m thick in the centre of the basin and lies on a substratum of sand (Dr D. Scott, pers. comm.). It is black when wet, and a dried sample contained 8.55 percent of carbon and 0.83 percent of nitrogen.

The drainage basin has an area of 1.8 sq km, and the geological substratum is Basic Volcanic Rocks. The soils are Southern and Central Yellow-

[*Department of Lands and Survey photo.*

Fig. 2: Tomahawk Lagoons. Number 2 Lagoon is on the right. S: Sampling station.

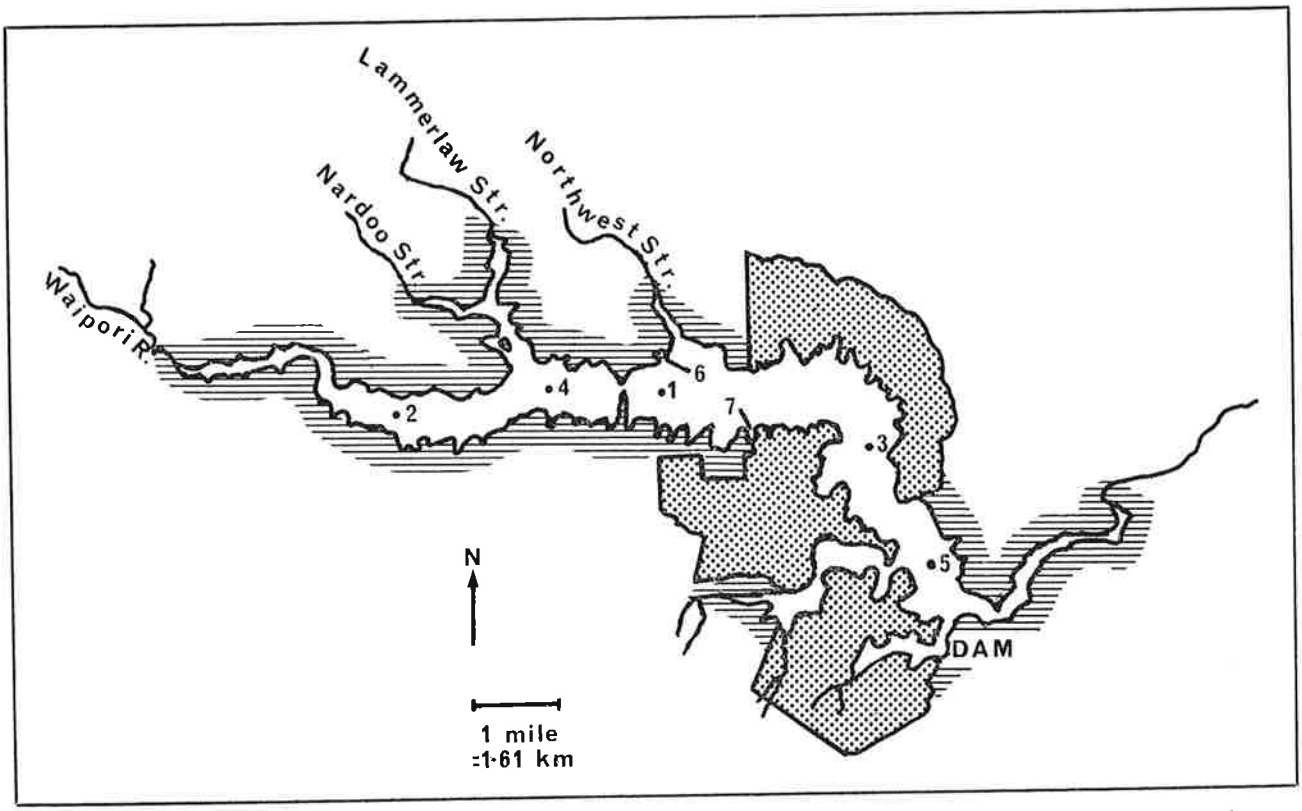

Fig. 3: Lake Mahinerangi. 1: Main sampling station. 2-7: Sampling Stations Nos. 2-7. Forest is indicated by stippling.

Brown Earths, and land utilisation is agricultural. There is one small permanent stream, with several temporary streams. It is unlikely that significant drainage or seepage is received from the small southern part of the basin, which consists of sand dunes with some urban development.

LAKE MAHINERANGI

Lake Mahinerangi (fig. 3) is an artificial lake formed by the damming of the Waipori River in 1923 for hydro-electric purposes; the dam was raised to its present level in 1946. Earlier reservoirs formed by the damming of tributaries to the Waipori River in 1907 and 1910 are now part of the lake. Gold was discovered on the site of the lake in 1862, and dredging and sluicing were carried out there until the lake was formed (Pairman 1951).

The lake is 390 m above sea level and is 30 km from the sea. It has an area of 19.7 sq km, a length of 14.5 km, and a maximum width of 1.6 km. The rate at which electricity is generated varies, and this causes the lake level to fluctuate. During the period of study the depth at the dam varied from 22.6 to 31.2 m (Dunedin City Corporation Electricity Department records). The corresponding range at the main sampling station (Station 1, fig. 3) was about 4.5 to 13 m. The long-term mean lake level (1949-64) was about 26 m at the dam, and at this level the volume of the lake is $1.22 \times 10^8 m^3$ (D.C.C. records). From these figures and the area the mean depth was calculated to be 6.2 m. The mean rate of outflow is 6.45 m^3/second, so that the mean retention time is about 8 months. There has been little shoreline erosion and much of the shore is hard clay covered with a thin layer of gravel. There are areas of bog along the lower reaches of the inflowing streams. The sediment is grey, and after being dried a sample contained 3.3 percent of carbon.

The drainage basin has an area of about 33 sq km. The lake is fed by the Waipori River and by a number of smaller streams, the largest of which are named in fig. 3. The basement rock of the catchment area is Chlorite Zone Schist and the soil is High Country Yellow-Brown Earth. There is a pine plantation of 18.5 sq km round the lower half of the lake. With the exception of an area of about 20 hectares on the southern side of the lake

[*Department of Lands and Survey photo.*

Fig. 4: Lake Waipori. P: Channel through which drainage is received. 1: Main sampling station. 2 and 3: Other sampling stations. The Waipori River flows in at top right and out at lower left.

opposite the main sampling station, which was sown with grass in 1964, the rest of the drainage basin was undeveloped tall tussock grassland until September-October 1965, when an area on the northern side of the lake was ploughed in preparation for subsequent development. By February 1967 the area under development was about 3.9 sq km.

LAKE WAIPORI

Lake Waipori (fig. 4), which also lies on the Waipori River system, has an area of 2.4 sq km. It is a natural lake on the low-lying Taieri Plain, which is protected from flooding by a stopbank built along two sides of the lake. The Waipori River enters it through three main channels in the north-eastern region and leaves by two main channels at the south-west. These rejoin and flow to the Taieri River after receiving drainage from nearby Lake Waihola. The margins of the lake, which is surrounded by willows, are swampy. Although it is 10 km from the sea, Lake Waipori is tidal. The depth over most of the basin is normally about 0.6 m at low tide and a little more than 1 m at high tide. There is no intrusion of saline water. The macrophyte *Anacharis canadensis*

(Michaux) Planchon usually covers much of the bottom of the lake from spring until late autumn. The bottom deposits consist mainly of sand mixed with fine silt.

After leaving Lake Mahinerangi the Waipori River receives only one large tributary—the Contour Channel, an artificial stream carrying drainage from the eastern face of (Mt.) Maungatua and entering the river just before it reaches Lake Waipori. The upper part of this catchment is fairly similar to the catchment of Lake Mahinerangi in geology, in soil, and, with the addition of some native forest, in vegetation. The smaller lower region, where the soil is alluvial, has been developed agriculturally. The Contour Channel has a higher concentration of salts than Lake Mahinerangi and this is likely to be largely the reason for differences in water chemistry between the two lakes.

The lake also receives drainage, which is collected by drains and is pumped into the lake intermittently, from a part of the Taieri Plain, a region of intensive farming. The plain has been inundated by the sea in geologically recent times, and this water has a very high ionic concentration. From the capacity of the pumps it was estimated that this contribution rarely exceeds about 1-2 percent of the volume of the lake in any one day. In addition, one small stream, the Meggat Burn, enters the northern side of the lake. The mean retention time for the lake water is about 76 hours. This figure is based on the mean rate of flow in the Waipori River and on the assumption that the mean depth of the lake is 0.75 m.

CLIMATE

The climate of the region is characterised by windy and variable conditions, without extremes of temperature, and with a moderate rainfall in all months. Monthly mean values for temperature, hours of bright sunshine, and rainfall for the years 1963-66 at the Musselburgh meteorological station, which is 1 km from Tomahawk Lagoon, are shown in fig. 5 with day length. Temperatures have been derived by taking monthly means of daily maxima and daily minima and taking a mean of the two.

At the Dunedin Airport meteorological station, which is 10 km from Lake Waipori, sunshine hours and rainfall are similar to those at Musselburgh, though temperatures are frequently 1 to 2°c lower. At the Lake Mahinerangi meteorological station, which is 7 km from the main sampling station on the lake, temperatures are generally a further 1-2° lower, and the rainfall is generally similar to that at Musselburgh. No sunshine records are available for this station.

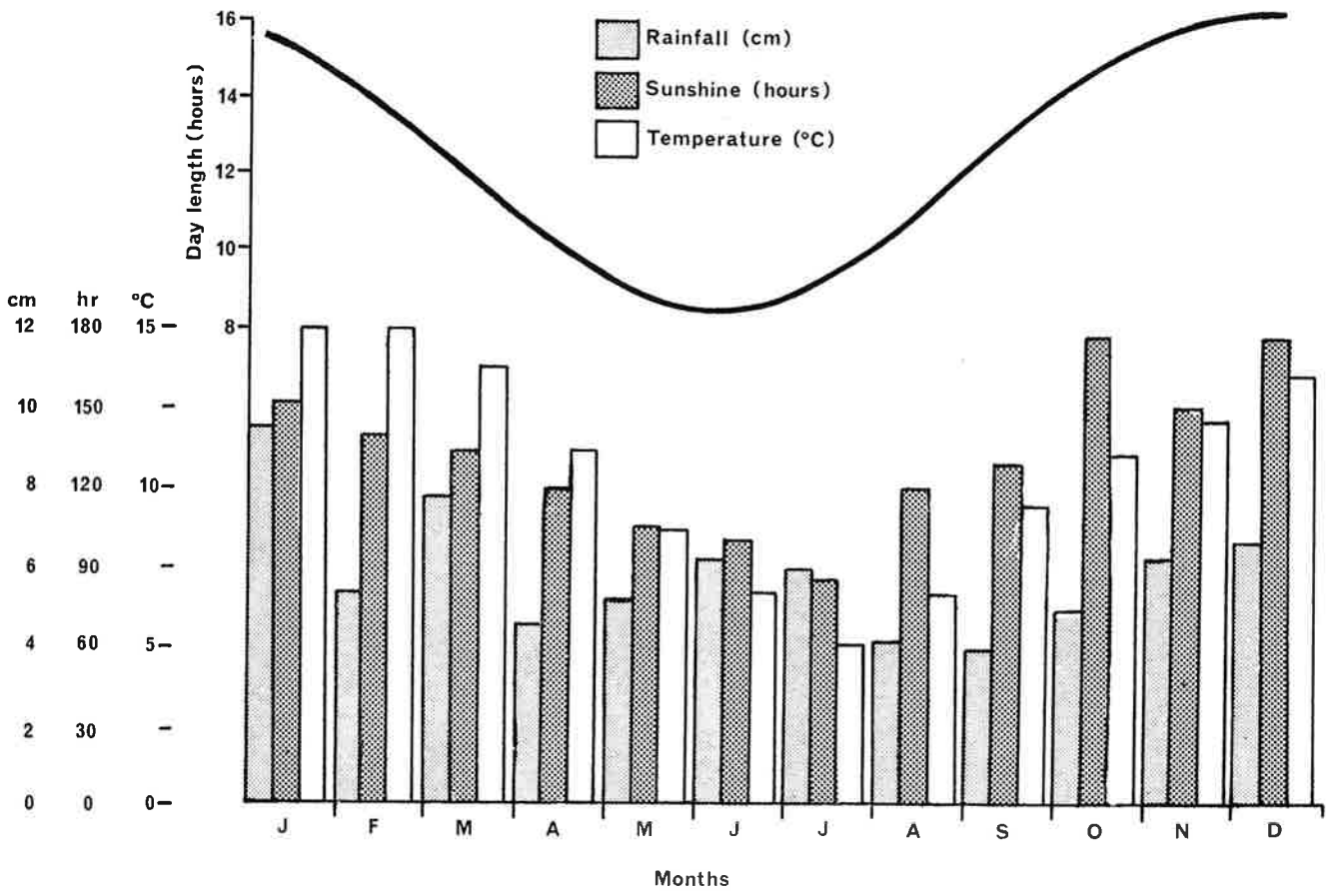

Fig. 5: Day length and meteorological conditions at the Musselburgh meteorological station (mean values for the years 1963-66).