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LAKE ELLESMERE, CANTERBURY, NEW ZEALAND

A review of the lake and its catchment

by

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Ecology Division, DSIR

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INVERTEBRATES

Amphipsalta sp.	cicada	D G
Anisolabis littorea	large earwig	S
Calliphora quadrimaculata	blowfly	S
Costelytra zealandica	grass grub	G
Latrodectus katipo	katipo	S
Locusta migratoria	locust	G
Lycaena boldernarum	purple butterfly	G D
L. salustrius	common copper butterfly	D G
Pericoptus truncatus	sand scarab	S
Phaulacridium marginale	grasshopper	G
Porcellio scaber	woodlouse	D I
Salius sp.	spider hunting wasp	D G
Sarcophaga milleri	flesh fly	G
Sigaus australis	grasshopper	G
Teleogryllus commodus	cricket	G
Various Diptera, Lepidoptera, Coleoptera, Arachnida, etc.		
Zizeeria otis	common blue butterfly	D G

"Aquatic" Animals

RHABDOCOELA	
Microstomum sp.	plankton
TRICLADIDA	
Procerodes sp.	southern edge (Mrs F. R. Allison, University of Canterbury)
NEMATODA	
species undetermined	among aquatic vegetation
POLYCHAETA	
Fam. Aricidae	bottom mud
Eumenia sp.?	among aquatic vegetation
OLIGOCHAETA	
Tubificidae	mud throughout
COPEPODA	
Boeckella hamata	plankton
Gladioferens subsalaria	plankton (reported by E. Percival)
OSTRACODA	
Two species, undetermined	among aquatic vegetation
MYSIDACEA	
Tenagomysis chiltoni	among aquatic vegetation
T. novae-zealandiae	among aquatic vegetation
AMPHIPODA	
Paracalliope fluviatilis	throughout
Paracorophium lucasi	throughout
ISOPODA	
Idotea marina	mud, open water area
ODONATA	
Xanthocnemis zealandica	among aquatic vegetation, northern side
TRICHOPTERA	
Pycnocentria sp.	northern side
Pycnocentrodes sp.	northern side
Paroxyethira sp.	northern side
Olinga sp.	northern side
LEPIDOPTERA	
Nymphula nitens	northern and western sides
HEMIPTERA	
Diaprepocoris zealandiae	northern and western sides
Sigara arguta	northern and western sides
DIPTERA	
Ephydra sp.	among aquatic vegetation
Chironomus zealandicus	throughout
GASTROPODA	
Potamopyrgus antipodum	throughout
P. corolla salleane (or *P. badia*)	among aquatic vegetation
P. spelaeus	reported by E. Percival
BIVALVIA	
Cyclomactra ovata	reported by E. Percival

Fish

(Excluding temporary visitors when the lake is open to the sea)

Aldrichetta forsteri	yellow-eyed mullet
Anguilla australis	short-finned eel
A. dieffenbachii	long-finned eel
Galaxias maculatus	whitebait
Gobiomorphus gobioides	giant bully
Gobiomorphus spp.	bullies
Maugeclupea antipodum	sprat
Oncorhynchus tshawytscha	Quinnat salmon
Retropinna retropinna	common smelt
Rhombosolea retiaria	black flounder
R. leporina	yellow-belly flounder
R. plebeia	sand flounder
Salmo trutta	brown trout

CHECKLIST OF ALGAE OF LAKE ELLESMERE

Data supplied by Dr E. A. Flint, Ecology Division, DSIR

Cyanophyta

Anabaena sp.
Gomphosphaeria lacustris Chod.
Merismopedia sp.
Nodularia spumigena Mertens

Chlorophyta

VOLVOCALES
Chlamydomonas sp.

CHLOROCOCCALES
Actinastrum Hantzschii Lagerh.
Ankistrodesmus spp.
Botryococcus Braunii Kutz.
Chlorella sp.
Coelosphaerium Keutzingianum Naeg.
Dictyosphaerium Ehrenbergianum Naeg.
D. pulchellum Wood
D. primarium Skuja
Franceia ovalis (Francé) Lemm.
Langerheimia quadriseta Lemm.
Nephrocytium sp.
Oocystis marsonii Lemm.
O. parva W. & G. S. West
Oocystis sp.
Scenedesmus obliquus (Turp.) Kutz.
S. quadricauda (Turp.) Bréb.

ULOTRICHALES
Planctonema lauterbornii Schmidle

Chrysophyta

BACILLARIOPHYCEAE
Campylodiscus sp.
Chaetoceros sp.
Coscinodiscus sp.
Cyclotella sp.
Hyalodiscus sp.
Melosira dubia Kutz.
Melosira sp.
Nitzschia acicularis W. Smith
N. closterium (Ehrenb.) W. Smith
Nitzschia sp.
Surirella sp.
Synedra ulna (Nitzsch) Ehrenb.
Synedra sp.

CHRYSOPHYCEAE
Ochromonas sp.

Pyrrophyta

DINOPHYCEAE
Gymnodinium sp.

Cryptophyta

Cryptomonas sp.

Euglenophyta

EUGLENOPHYCEAE
Euglena sp.

BRIEF CHECKLIST OF ANIMALS OF LAKE ELLESMERE*

"Terrestrial" Animals

S — shore, D — dune, G — annual grassland, M — salt meadow, L — lake, W — lake edge swamp, I — shingle beach ridges

MAMMALS

Bos taurus	domestic cattle	G W M
Erinaceus europaeus	hedgehog	D G
Lepus europaeus	hare	D G
Mus musculus	mouse	D G
Mustela erminea	stoat	D G
Oryctolagus cuniculus	rabbit	D G
Ovis aries	domestic sheep	D G W M

BIRDS

For a complete checklist see Tunnicliffe 1973 (98B).

Alauda arvensis	skylark	D G
Anas gibberifrons	grey teal	L
A. platyrhynchos	mallard	L
A. rhynchotis	shoveller	L
A. superciliosa	grey duck	L W
Anthus novaeseelandiae	pipit	D G M
Ardea novaehollandiae	white-faced heron	L W
Arenaria interpres	turnstone	W
Botaurus stellaris	Australian bittern	W
Branta canadensis	Canada goose	L W
Calidris acuminata	Siberian sandpiper	W
C. canutus	knot	W
C. melanotos	banded dotterel	S
Charadrius bicinctus	American sandpiper	W
Circus approximans	harrier	D G L W
Cygnus atratus	black swan	L
C. olor	mute swan	L
Egretta alba	white heron	L
Haematopus ostralegus	pied oystercatcher	L
Halcyon sancta	kingfisher	L W
Himantopus himantopus	pied stilt	L
Hirundo tahitica	welcome swallow	L
Larus dominicanus	black-backed gull	S L
L. novaehollandiae	red-billed gull	S L
Limosa lapponica	bar-tailed godwit	W
Phalacrocorax carbo	black shag	L
P. melanoleucos	little shag	L
Pluvialis dominica	Pacific golden plover	L
Porphyrio porphyrio	pukeko	W
Porzana pusilla	marsh crake	W
Sterna striata	white-fronted tern	S L
Sturnus vulgaris	starling	W
Tadorna variegata	paradise duck	L

REPTILES

Hoplodactylus sp.	gecko	I
Leiolopisma sp.	skink	D

*Determinations by G. A. Knox, University of Canterbury (Polychaeta, Aricidae), D. E. Hurley, N.Z. Oceanographic Institute, DSIR (Amphipoda), E. C. Young, University of Canterbury (Hemiptera), T. Gorman, University of Canterbury (fish), plus information obtained by Zoology Honours Part III students of the University of Canterbury. Information on aquatic animals compiled by Dr V. M. Stout, University of Canterbury.

FOREWORD

The Officials Committee on Eutrophication was set up in 1970. Its functions are to advise the Minister of Science on DSIR research on eutrophication in New Zealand freshwaters, consider the effects of different land management systems on eutrophication, review research associated with eutrophication and recommend new lines of research, and facilitate interchange of information with organisations responsible for freshwater management.

In 1972 concern over the apparently increasing eutrophication of Lake Ellesmere was brought to the notice of the Officials Committee on Eutrophication, and a general report on the lake was prepared by Ecology Division, DSIR. The Committee considered that the report would be of interest to a wider audience, so its publication was recommended.

The Ellesmere review discusses the effects of different types of land and water management, past and current research associated with the lake, and recommends corrective action and further research. The Officials Committee on Eutrophication hopes that this publication, by providing a background of information, will stimulate research on Lake Ellesmere; this will provide a sound basis for any future recommendations that may be necessary to prevent increasing eutrophication of the lake. It should also be a useful guide to the study of similar problems of other lakes.

I. L. BAUMGART, *Chairman,*
Officials Committee on Eutrophication

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(Lists compiled by Dr C. J. Burrows and Miss P. Carpenter for N.Z. Limnological Society Conference Field Day 1969 and by Dr E. A. Flint)

CHECKLIST OF PLANT SPECIES OF LAKE ELLESMERE
(Brief list only)

Beach, Dune Area, and Annual Grassland

S — shore, D — dune, A — area transitional from dunes to grassland, G — grassland, R — shingle beach ridge

SHRUBS AND SUB-SHRUBS		
Carmichaelia appressa	prostrate broom	D A
Clematis afoliata	leafless clematis	R
Coprosma crassifolia	thick-leaved coprosma	R
C. propinqua	miki miki	R
Discaria toumatou	matagouri	R
Hymenanthera sp.	porcupine bush	A R
Muehlenbeckia complexa	pohuehue	A R
M. ephedroides	leafless pohuehue	R
Pimelea prostrata	N.Z. daphne	D A
Rubus squarrosus	leafless lawyer	R
GRASSES AND GRASS-LIKE PLANTS		
Aira caryophyllea	hair grass	G R
Ammophila arenaria	marram grass	D
Bromus Gussonii	barren brome	D A G R
Carex pumila	sand sedge	S D
Desmoschoenus spiralis	pingao	D
Holcus lanatus	Yorkshire fog	R
Hypoxis pusilla	N.Z. narcissus	G
Lagurus ovatus	harestail grass	D A R
Notodanthonia sp.	danthonia	G R
Poa laevis	silver tussock	A G
Stipa variabilis	needlegrass	G R
Vulpia bromoides	hair-grass	G
Zoysia minima	pygmy twitch	A
OTHER HERBS AND SMALL PLANTS		
Acaena ovina	Australian sheep's burr	D A R
A. novae-zelandiae	piri-piri	A
Arenaria serpyllifolia	sandwort	D A G
Cakile edentula	sea rocket	
Calystegia soldanella	sand convolvulus	D A
Craspedia uniflora	woollyhead	A
Cyathodes fraseri	patotara	G
Dichondra repens	Mercury Bay weed	G
Erodium cicutarium	cranesbill	A G R
Galium perpusillum	pygmy bedstraw	D A G
Geranium sessiliflorum	N.Z. cranesbill	G R
Hypochoeris radicata	catsear	D A G
Leontodon taraxacoides	hawkweed	D A
Lepidium murale	dune cress	D R
Polycarpon tetraphyllum	allseed	G
Pterostylis mutica	green orchid	G
Raoulia australis	scabweed	D A
Rumex acetosella	sorrel	D A
Salsola kali	saltwort	S
Scleranthus uniflorus	kohukohu	A
Senecio glaucophyllus subsp. *basinudus*	shore groundsel	S D
Silene gallica	catchfly	D A G
Spergularia marginata	sand spurrey	D
Tillaea sieberiana	coastal tillaea	G R
Trifolium arvense	haresfoot trefoil	A G R
T. dubium	suckling clover	G R
T. fragiferum	strawberry clover	G
T. repens	white clover	G R
Verbascum thapsus	woolly mullein	R
Vicia sp.	vetch	R
Vittadinia australis		D G R
OTHER PLANTS		
Pteridium esculentum	bracken	D
Polytrichum juniperum	moss	G
Rhacomitrium crispulum	moss	
LICHENS		A G

Lake Edge

L — swamp plants and taller lake shore plants, U — floating or submerged plants, O — salt meadow plants

SHRUB		
Plagianthus divaricatus	shore ribbonwood	L
GRASSES AND GRASS-LIKE PLANTS		
Agrostis stolonifera	creeping bent	L O
Holcus lanatus	Yorkshire fog	L
Hordeum marinum	sea barley	O
Juncus gregiflorus	common rush	L
J. maritimus	sea rush	L
J. pallidus	giant rush	L
Leptocarpus simplex	jointed "rush"	L
Parapholis incurva	sickle grass	O
Polypogon sp.	beard grass	O
Puccinellia stricta	salt grass	O
Scirpus americanus	three square	L
S. caldwellii		L
S. nodosus	node sedge	L
Triglochin striatum var. *filifolium*	arrowgrass	O
OTHER HERBS		
Apium filiforme	slender celery	L O
Atriplex hastata	goosefoot	O
Chenopodium ambiguum	goosefoot	O
Cotula coronopifolia	bachelor's button	O
C. squalida	pincushion	O
Lemna minor	duckweed	U
Lepilaena bilocularis		U
Lilaeopsis novae-zelandiae	tape measure	O
Mimulus guttatus	monkey musk	L
M. repens	purple mimulus	O
Myosotis palustris	forget-me-not	L
Nasturtium sp.	water cress	L
Plantago coronopus	buckshorn plantain	O
Potamogeton pectinatus	narrow-leaved pondweed	U
Rumex obtusifolius	dock	L
Ruppia megacarpa	horses mane	U
Salicornia australis	glass wort	O
Samolus repens	sea primrose	O
Selliera radicans	remu-remu	O
Suaeda novae-zelandiae	sea-blite	O
Zannichellia palustris		U
OTHER PLANTS		
Azolla rubra	water fern	U

88 Rigg, H. H. 1955: Effect of herbicides on a series of aquatic plants. *Northeastern Weed Control Proceedings, New York 9*: 535-44.

*89 Snoad, J. B. 1970: Effluent discharge Leeston Creek. Evidence as Health Inspector before the Town and Country Planning Appeal Board, Christchurch.

90 Speight, R. 1930: The Lake Ellesmere Spit. *Transactions of the N.Z. Institute 61 (1)*: 147-69.

91 Spooner, B. W. 1973: The role of the National Water and Soil Conservation Authority and Regional Water Boards in the control of water pollution. Proceedings of the Pollution Research Conference, Wairakei, New Zealand. *DSIR Information Series 97*: 539-47.

92 Stokell, G. 1936: The nematode parasites of Lake Ellesmere trout. *Transactions of the Royal Society of N.Z. 66*: 80-96.

93 ——— 1938: The ill-conditioned trout present in the lower Selwyn during the spring of 1932. *Transactions of the Royal Society of N.Z. 68*: 380-9.

94 ——— 1966: Notes on Lake Ellesmere trout. *Transactions of the Royal Society of N.Z. (Zoology) 8*: 135-9.

95 Stout, V. M. 1969: Lakes in the mountain region of Canterbury. *Internationale Vereinigung fur Theoretische und Angewandte Limnologie 17*: 404-13.

95A ——— 1969: Life in lakes and ponds. *In* "The Natural History of Canterbury," Ed. G. A. Knox. A. H. & A. W. Reed.

*96 Stuart, R. C. 1956: Reclamation and irrigation of Lake Ellesmere Flat. N.Z. Department of Agriculture, Economics Division. Internal Report.

97 Todd, P. 1973 (Scientist, Fisheries Research Division, Ministry of Agriculture and Fisheries): Eels, Lake Ellesmere. Personal communication.

98 Tovey, E. 1970: Ellesmere – a dying lake? *Caclin* 30.9.70: 8-9 (Newspaper of Canterbury Agriculture College, Lincoln).

98A Town and Country Planning Appeal Board No. 1 1971: Decision No. 172/70. (*Town and Country Planning Appeals 3 (3 N.Z.T.C.P.A.)*: 329-31. Butterworths, 1972).

98B Tunnicliffe, G. A. 1973: The avifauna of the Lake Ellesmere area, Canterbury. *Mauri Ora 1*: 107-35.

99 Vollenweider, R. A. 1968: Scientific fundamentals of the eutrophication of lakes and flowing waters with particular reference to nitrogen and phosphorus as factors in eutrophication. Organisation for Economic Co-operation and Development, Directorate of Scientific Affairs, Paris. Report.

100 Ward, W. T. 1962: Soil type and land valuation in Ellesmere County, Canterbury. *N.Z. Geographer 18*: 170-83.

101 Ward, W. T.; Harris, C. S.; Schapper, H. P. 1964: Soils and Agriculture of Ellesmere County, Canterbury, N.Z. *DSIR Soil Bureau Bulletin 21*.

*102 White, E. 1973 (Scientist, Freshwater Section, Ecology Division, DSIR): Water analyses Lake Taupo catchment. Extracts from records.

*103 Wildlife Service, Department of Internal Affairs 1972: Black swan: Lake Ellesmere. Internal report.

104 ——— 1973: Personal communication.

105 Yeates, G. W. 1965: The benthos of Lake Ellesmere. Unpublished project for B.Sc. Hons., Zoology Department, University of Canterbury.

LAKE ELLESMERE, CANTERBURY, NEW ZEALAND

by *Helen R. Hughes, R. H. S. McColl, and D. J. Rawlence*

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ABSTRACT

Lake Ellesmere, New Zealand, and its agricultural catchment are described with special reference to the lake's biology and chemistry, and the interests of the management authority — the North Canterbury Catchment Board, farmers, commercial fishermen, sportsmen, and the general public. The lake, which is shallow and nutrient-rich, is periodically opened to the sea, allowing drainage and influx of sea water.

Problems giving concern are eutrophication of the lake, the appearance of blue-green algal blooms, the disappearance of aquatic weed beds supporting some of the water fowl, particularly black swan, the depredation of farmland by black swan and Canada geese (apparently as a result of reduced food supplies in the lake), the failure of the black swan to breed, deaths of commercial fish, and difficulties in controlling lake level. Problems in contributing drains and waterways are the control of water flow and quality, excessive aquatic weed growth, and the provision of sufficient water for irrigation while maintaining the trout fishery.

Recommendations are made of practical methods for minimising the deterioration of Lake Ellesmere and for further research to facilitate improved management.

INTRODUCTION

Over recent years increasing concern has been expressed about the condition of Lake Ellesmere, Canterbury. Not only has there been a decline in the local black swan (*Cygnus atratus*) population but an increase in eutrophication of lake and inflow waters is suspected. Problems of lake management are related to changes in the lake biology as well as to the diverse interests and requirements of the many organisations and individuals concerned with the lake and its environs. These have been the subject of many reports on Lake Ellesmere, the earliest in 1875 (7).

In 1970 available information on Lake Ellesmere was submitted to the Town and Country Planning Appeal Board, relating to a right sought by the Ellesmere County Council to discharge oxidation-pond effluent for part of the year into a tributary of Lake Ellesmere. Many expert witnesses stated in evidence that they thought such an action would cause the condition of Lake Ellesmere to deteriorate still further. The Board concluded that:

> "The Board is not satisfied on the evidence that it can be said with any degree of scientific certainty that Lake Ellesmere is in a critical condition as alleged by the appellant [North Canterbury Acclimatisation Society]; the position however is such that it calls for watchfulness and for continued urgent scientific investigation. The further nutrient enrichment of the lake may lead to conditions having far-reaching and disastrous consequences, but it cannot be said at the present time just when these conditions are likely to occur" (98A).

Although the Town and Country Planning Appeal Board subsequently upheld the "right" of the Ellesmere County Council to discharge wastes for limited periods into a tributary of Lake Ellesmere, the North Canterbury Acclimatisation Society has continued to press for further action on Lake Ellesmere and to enlist the support of other interested groups.

In 1972 the Officials Committee on Eutrophication* asked Ecology Division, DSIR, for a general report on the lake, and on receipt of this in 1973 recommended its distribution to various organisations to provide background information and encourage further research.

The present publication is based on the 1973 report (39); it summarises the available information about the lake and outlines the history of lake use and land development ajacent to the lake. It makes no attempt to evaluate the relative importance of any one activity or organisation associated with the lake. Any recommendations for major changes in management, land use, or lake use are considered to be outside its scope, and no attempt is made to assess the financial or political importance of research proposals.

*Composed of representatives from DSIR, N.Z. Electricity Dept., Dept. of Health, Dept. of Internal Affairs, Ministry of Works, Ministry of Agriculture and Fisheries, Dept. of Lands and Survey, N.Z. Forest Service, the N.Z. Limnological Society, and of the Minister of Science.

LAKE ELLESMERE

Physical description

Lake Ellesmere is a large area of shallow water, roughly triangular in shape, measuring 24 km (15 miles) from east to west, and 11 km (7 miles) from north to south (*figure 1*). When the level of lake water is *c.* 1.06 m (3.5 ft) above mean sea level (m.s.l.) the lake area is *c.* 20 250 ha (50 000 acres). If the level is low, 0.3 m (1 ft) above m.s.l., the area is *c.* 15 790 ha (39 000 acres). Mean lake depth when lake level is at m.s.l. is *c.* 2.1 m (7 ft).

Lake Ellesmere is normally separated from the sea by a large shingle spit, the Kaitorete or Lake Ellesmere spit. The lake is periodically opened to the sea by cutting a channel through the spit at Taumutu, allowing drainage and sea water influx (*figures 2 and 3*). Wave action quickly closes the cut in a southerly storm. At high tide with a heavy sea, waves may actually break over the spit near Taumutu.

Inflow and outflow

The lake level rises as water from inflowing rivers and drains accumulates. The catchment area of the lake consists of 777 km^2 (300 sq miles) of hills and 1 295 km^2 (500 sq miles) of plains. These are drained principally by the Selwyn River, Halswell River, L II River, Irwell River, Harts Creek, and by 32 other drains. Only the Selwyn River flows directly from the foothills of the Southern Alps. All the others rise within 19 km (12 miles) of the lake.

The average inflow to the lake has been calculated to be 9 m^3/sec (320 cusecs) (49).

During a low flow period in November 1970 the total inflow was 7.8 m^3/sec (280.12 cusecs) (71). Lake level at that time was 0.35 m (1.2 ft) above m.s.l. Discharge from the lake on 5 July 1972 when the lake level was 1 m (3.3 ft) above m.s.l. was gauged at 173.6 m^3/sec (6 200 cusecs) (72). Inflows during wet periods have been calculated to be 72.8 m^3/sec (2 600 cusecs), 168 m^3/sec (600 cusecs), and during a flood in 1941 476 m^3/sec (17 000 cusecs) (40). A maximum possible

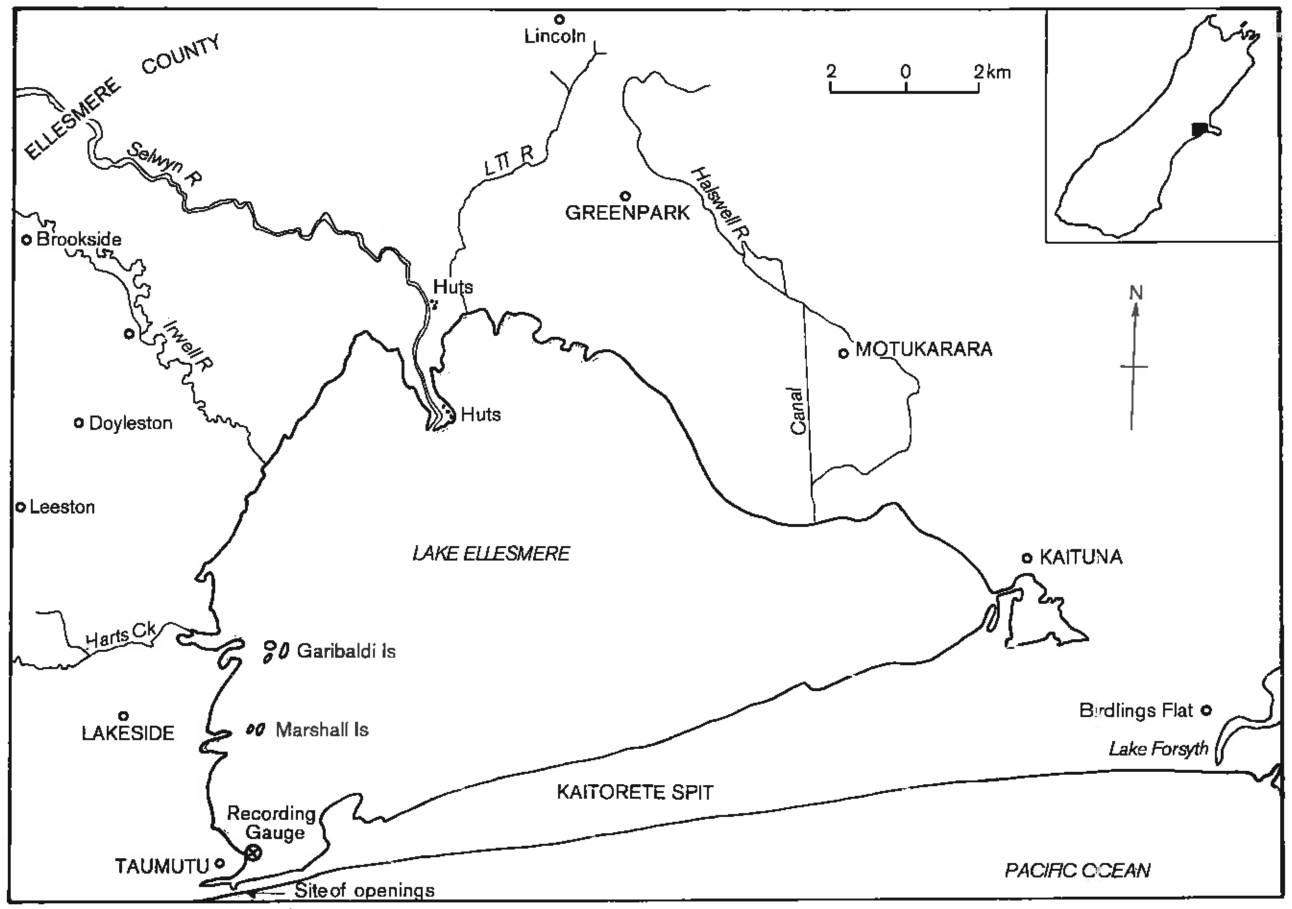

Figure 1 Locality map of Lake Ellesmere.

*38 Freshwater Section, Ecology Division, DSIR, 1973: Notes on use of weedicides in streams and drains relating to communications from North Canterbury Acclimatisation Soc. (see 67, 68). Internal report.

*39 ——— 1973: Lake Ellesmere. Report to N.Z. Officials Committee on Eutrophication. DSIR, Wellington.

*40 Grant, F. D. 1945 (Acting District Engineer): Lake Ellesmere – Drainage and reclamation proposals. Public Works Department. Internal Report.

41 Graynoth, E.; Skrzynski, W. 1973: The North Canterbury trout and salmon fishery. N.Z. Ministry of Agriculture and Fisheries, *Fisheries Technical Report 90.*

42 Graynoth, E. 1973 (Fisheries Officer, Fisheries Management Division, N.Z. Ministry of Agriculture and Fisheries): Personal communication.

*43 Hardy, C. J. 1973 (Technical Officer, Fisheries Management Division, N.Z. Ministry of Agriculture and Fisheries): Fish – Lake Ellesmere. Personal communication.

*44 Harris, C. S. 1948 (Senior Pedologist, Soil Survey Division, DSIR): Sand, silt and loam locations Lake Ellesmere bed. Letter to Botany Division, DSIR.

45 Hine, M. 1973 (Scientist, Fisheries Research Division. Ministry of Agriculture and Fisheries): Personal communication.

46 Hobbs, D. F. 1947: Migrating eels in Lake Ellesmere. *Report of the 6th N.Z. Science Congress, Transactions of the Royal Society of N.Z. 77 (5)*: 228-32.

*47 Hosking, G. 1965: Lake Ellesmere project. Unpublished student project. Zoology Department, University of Canterbury.

*48 Lambden, A. E. 1970: Effluent discharge Leeston Creek. Evidence as Chemist before the Town and Country Planning Appeal Board, Christchurch.

*49 Langbein, F. 1932: Lake Ellesmere. Public Works Department. Engineers Report.

*50 Lucas, D. 1973: An investigation into the death of commercial fish in Lake Ellesmere. Internal Report. Fisheries Management Division, Ministry of Agriculture and Fisheries.

51 McColl, R. H. S. 1972: Chemistry and trophic status of seven New Zealand lakes. *N.Z. Journal of Marine and Freshwater Research 6 (4)*: 399-447.

52 ——— in press. *In* "New Zealand Lakes". Ed. V. H. Jolly and J. M. A. Brown. Auckland University Press.

*53 MacFarlane, P. 1970: Effluent discharge Leeston Creek. Evidence as Chartered Engineer before the Town and Country Planning Appeal Board, Christchurch.

54 Marine Department. *Report on Fisheries* for the years 1965 to 1971. Published annually by the Government Printer, Wellington.

*55 Marshall, J. 1973 (Zoology honours student, University of Canterbury): Aquatic plants and salinity: Leeston Drain. Letter to Freshwater Section, Ecology Division, DSIR.

56 Marshall, P. 1933: Report on the basin of Lake Ellesmere with special reference to source of water and bottom deposits. *In* Aston, B. C. 1933: Lake Ellesmere submerged lands. *N.Z. Journal of Agriculture 46 (6)*: 317-20.

*57 Mason, R. 1946: Report on weed banks in Lake Ellesmere. Botany Division, DSIR Report prepared for the North Canterbury Acclimatisation Society.

*58 ——— 1951: Report on water weeds found in Lake Ellesmere. Botany Division, DSIR Internal Report.

*59 ——— 1973 (Scientist, Botany Division, DSIR): Lake Ellesmere. Letter to Freshwater Section, Ecology Division, DSIR.

60 Miers, K. H.; Williams, M. 1969: Nesting of the black swan at Lake Ellesmere, New Zealand. *Wildfowl 20*: 23-32.

*61 National Water and Soil Conservation Organisation 1969: Lake Ellesmere. Stabilisation of lake level. Report to Department of Lands and Survey.

62 N.Z. Gazette 15 Feb. 1973: North Canterbury Acclimatisation District. No. 10: 259. Government Printer.

63 N.Z. Limnological Society 1969: Excursion Guide to Lake Ellesmere and Lake Forsyth. *N.Z. Limnological Society Newsletter 4*: 6-11.

*64 N.Z. Ministry of Works 1953: Lake Ellesmere. Internal report.

*65 North Canterbury Acclimatisation Society 1970: Effluent discharge Leeston Drain. Submission by the Society as appellant to Town and Country Planning Appeal Board, Christchurch.

66 ——— 1971: *Annual Report.*

*67 ——— 1972: Lake Ellesmere. Letter to Commissioner for the Environment (see 38).

*68 ——— 1972: Lake Ellesmere. Submission to Committee on Noxious Weeds Administration, Ministry of Agriculture and Fisheries, Waimairi County (see 38).

*69 ——— 1973: Lake Ellesmere. Letter to Freshwater Section, Ecology Division, DSIR.

*70 North Canterbury Catchment Board 1968-1972: Lake level graphs Taumutu. Copies of water level recorder readings.

*71 ——— 1970: Inflow to Lake Ellesmere. November 1970: Gauging records.

*72 ——— 1972: Discharge of outlet from Lake Ellesmere 6/7/72. Memorandum to Chief Engineer.

*73 ——— 1972: Lake Ellesmere. Letter to Freshwater Section, Ecology Division, DSIR.

*74 ——— 1972: Extracts from water usage report. Internal report.

*75 ——— 1973: Lake Ellesmere – weed control in contributing waterways. Letter to Freshwater Section, Ecology Division, DSIR.

*76 Norton, A. C. 1963: Osborne's drain improvement scheme. North Canterbury Catchment Board Economic Report.

*77 ——— 1966: Report on the evaluation of benefits derived from the L II River improvement scheme 1946/47. North Canterbury Catchment Board Internal Report.

*78 Norton, A. C.; Jensen, R. C. 1968: An illustrative example of evaluation procedures. Agricultural Economic Research Unit Discussion Paper No. 4. Lincoln College, University of Canterbury.

79 Oborn, L. E. 1955: The hydrogeology of the Canterbury Plains between the Ashley and Rakaia Rivers. Unpublised M.Sc. Thesis, Otago University.

*80 ——— 1951: Ground water in Ellesmere County. DSIR, N.Z. Geological Survey, Water Resources Division, Hydrological Report No. 64.

*81 ——— 1953: Lake Ellesmere. Rapid rise in lake level, June 1953. DSIR, N.Z. Geological Survey Report.

*82 ——— 1957: Ground water investigations in the Lake Ellesmere project. DSIR, N.Z. Geological Survey Report.

83 ——— 1958: The incompetent and elastic nature of the Christchurch artesian system [including the effect of the changing water levels of Lake Ellesmere upon water levels in nearby artesian wells]. *N.Z. Journal of Geology and Geophysics 3 (1)*: 81-97.

*84 ——— 1958: Ground water studies at the saline soil reclamation trials. DSIR, N.Z. Geological Survey Report.

*85 ——— n.d. Ground water resources of Ellesmere County. DSIR, N.Z. Geological Survey Report.

86 Percival, E. 1937: Remarks on the brown trout stock in Lake Ellesmere. *Transactions of the Royal Society of N.Z. 67*: 341-51.

*87 Reid, H. M. 1953: Engineering report on Selwyn River improvement scheme. North Canterbury Catchment Board Engineers Report to the Board.

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REFERENCES

*Unpublished reports available for reference at the Freshwater Section, Ecology Division, Department of Scientific and Industrial Research, Lower Hutt.

1 ADAMS, J. S. 1971: Black swan at Lake Ellesmere. *Wildlife 1971 – A Review No. 3*: 23-5.
2 ANONYMOUS. 1946: Plant life in lake. *Ellesmere Guardian.* 11 May 1946.
3 ANONYMOUS. 1949: Food for wild duck. *Ellesmere Guardian.* 1 March 1949.
4 ARMON, J. W. (in press): Late quaternary shore line near Lake Ellesmere, Canterbury, New Zealand. *N.Z. Journal of Geology and Geophysics 17 (1).*
5 ASTON, B. C. 1933: Lake Ellesmere submerged lands. *N.Z. Journal of Agriculture 46 (6)*: 315-20.
*6 BEST, L. W. 1965: Lake Ellesmere. Zone of emergent vegetation. Unpublished student project. Zoology Department, University of Canterbury.
*7 BRAY, W. B. 1875: The drainage of Lake Ellesmere. By order of the Superintendent, Provincial Government of Canterbury. Report to the Public Works Department.
8 BUCKNELL, E. S. 1969: Black swan at Lake Ellesmere. *Wildlife 1969 — A Review No. 1*: 51-2.
*9 BURNET, A. M. R. n.d.: A preliminary report on investigation of feeding habits of eels and trout. Ministry of Agriculture and Fisheries Special Fisheries Report 20.
*10 ——— 1970: Effluent discharge Leeston Creek. Evidence as fisheries' scientist before the Town and Country Planning Appeal Board, Christchurch.
*11 ——— 1971: Data on chemistry of N.Z. lakes and rivers. Report to N.Z. Officials Committee on Eutrophication, DSIR, Wellington.
*12 ——— 1972: Lake Ellesmere. A preliminary report on chemical analyses 1971-72. Ministry of Agriculture and Fisheries, Fisheries Research Division. Internal report.
13 BURNET, A. M. R.; WALLACE, D. A. 1973: The relation between primary productivity, nutrients and the trout environment in some N.Z. lakes. Ministry of Agriculture and Fisheries, *Fisheries Research Bulletin 10.*
*14 BURROWS, C. J. 1969: "A Handbook of Background Material to the Ecology of the Lake Ellesmere Area." Botany Department, University of Canterbury.
15 ——— 1970: Flora and vegetation of the shores of Lake Ellesmere. *Canterbury Botanical Society Journal 3.*
*16 CANTERBURY PROGRESS LEAGUE INC. 1969: Improved drainage for Lake Ellesmere. Report prepared by Royds, Sutherland, Evans and McLeay, Consulting Engineers, Christchurch.
*17 CHEMISTRY DIVISION, DSIR 1970: Water analyses-Leeston Creek. From records held at Chemistry Division, DSIR, Christchurch.
*18 ——— 1971-3: Water analyses Lake Ellesmere and Ellesmere system. From records held at Chemistry Division, DSIR, Christchurch.
*19 COLLINS, B. W. 1953: Lake Ellesmere. Letter from the District Geologist to North Canterbury Catchment Board.
*20 ——— 1953: Notes on Christchurch rainfall. DSIR, N.Z. Geological Survey Report.
*21 ——— 1954: Geological and ground water aspects of proposal to reclaim part of bed of Lake Ellesmere in Greenpark District, DSIR, N.Z. Geological Survey unpublished report.
*22 ——— 1957: Ground water in the Greenpark District near Lake Ellesmere, DSIR, N.Z. Geological Survey Hydrological Report 133.
*23 COMMISSIONER OF CROWN LANDS, CHRISTCHURCH, 1954: Reclamation of bed of Lake Ellesmere. Internal Report. Department of Lands and Survey.
*24 DALMER, E. B. 1970: Lake Ellesmere. North Canterbury Catchment Board Chief Engineer's Report.
*25 ——— 1971: Halswell River – Water resource report. Letter from Chief Engineer, North Canterbury Catchment Board to National Water and Soil Conservation Organisation.
*26 DANN, R. A.; OBORN, L. E. 1954: Ground water near the shores of Lake Ellesmere. Greenpark – Motukarara District. DSIR, N.Z. Geological Survey Report.
*27 DEPARTMENT OF AGRICULTURE, ECONOMICS DIVISION, CHRISTCHURCH (now Ministry of Agriculture and Fisheries). Agricultural Returns. Personal communication.
28 DEPARTMENT OF STATISTICS 1971: *Agricultural Statistics 1969-70.*
*29 DICK, R. D.; NORTON, A. C. 1954: Report relating to questions asked by Soil Conservation and Rivers Control Council concerning Lake Ellesmere and adjacent lands. North Canterbury Catchment Board Report.
*30 DISTRICT INTERDEPARTMENTAL COMMITTEE ON IRRIGATION, CHRISTCHURCH 1956: Reclamation: Lake Ellesmere. (Departments involved were Lands and Survey, Agriculture, Ministry of Works, and Scientific and Industrial Research).
31 EVANS, L. T. 1953: The ecology of the halophytic vegetation at Lake Ellesmere, New Zealand. *Journal of Ecology 41*: 106-22.
32 FISH, G. R. 1969: Lakes: The value of recent research to measure eutrophication and to indicate possible causes. *N.Z. Journal of Hydrology 8*: 77-85.
*33 FLAY, A. H. 1950: Lake Ellesmere – The economics of its drainage. Unpublished report. Canterbury Agricultural College.
*34 FLINT, E. 1970: Effluent discharge Leeston Creek. Evidence as Botanist before the Town and Country Planning Appeal Board, Christchurch.
*35 ——— 1972 (Scientist, Freshwater Section, Ecology Division, DSIR): Algae. Lake Ellesmere. Personal communication.
*36 ——— 1973 (Scientist, Freshwater Section, Ecology Division, DSIR): Algae. Lake Ellesmere. Personal communication.
*37 FRESHWATER FISHERIES ADVISORY SERVICE, Marine Department 1967: Investigation into removal of water for irrigation from Halswell River. Investigation report Job No. 35.

Figure 2 Lake Ellesmere open to the sea, 10 August 1956. The outlet closed 15 days later. *Photo V. C. Browne*

Figure 3 Cutting the channel through the spit at dusk, 28 June 1972. *Photo W. G. Nealy, Ministry of Works*

flow with all waterways in flood has been calculated to be 840 m³/sec (30 000 cusecs) (49).

When the lake is open to the sea and the tributary streams flow normally, the lake level equilibrates at *c.* 0.45 m (1.5 ft) above m.s.l. (40). The rate of inflow of sea water at high tide is *c.* 560 m³/sec (20 000 cusecs) (*figure 4*) (72).

Wind effects

Wind may cause considerable differences in lake level. Storms can raise the lake level on the leeward shore by 0.5-0.68 m (1.75-2.25 ft) (24, 31, 33). This may cause flooding round the lake and also affect any lake opening. Due to wind action

Figure 4 Gauging the outflow of lake water 5 July 1972. *Photo North Canterbury Catchment Board*

on the shallow water column, the lake is permanently turbid (56, 57).

Lake openings

Lake Ellesmere is known to have been opened intermittently to the sea since 1852 (7). Prior to this it was opened by the Maoris when the lake level reached about 3 m (10 ft) above high water mark (7, 31). In 1947 lake levels were "stabilised" and the controlling authority, the North Canterbury Catchment Board, contracted with the Ellesmere Lands Drainage Board to open the lake when levels reached 1.05 m (3.45 ft) above m.s.l. from September to April, and 1.1 m (3.7 ft) above m.s.l. from May to August (24). In October 1947 the Catchment Board formally took over all the functions and works of the Drainage Board and has maintained the agreement (24). The number of times the lake is opened per year, and the duration of time the lake remains open to the sea have important effects on the lake environment, salinity, and sediment.

In *table 1* the recorded history of the lake has been divided into two main periods 1913 to 1947 and 1947 to 1972. During the latter period the number of lake openings per year has increased, while the length of time the lake remains open has decreased. This has resulted in a shorter residence time for lake water and a greater stability of levels. An average range of 1.06 m (3.5 ft) between low and high water levels has been reduced to 0.58 m (1.9 ft).

Lake salinity

Salinity levels of the lake depend on the volume of sea water present in the lake and the volume of freshwater inflow. The chloride level was 11 300 mg/l of chloride in January 1932 (49)

Table 1 Lake Ellesmere openings (data from Dalmer [24])

		1913-47	*1947-72*
Average no. of openings per year		1.59	3.17
Average length of an opening (days)		42.5	24.2
Average opening level above m.s.l.	(m)	1.53	1.16
	(ft)	5.02	3.82
Average closing level above m.s.l.	(m)	0.46	0.59
	(ft)	1.51	1.96

shortly after the lake was closed to the sea. This fell to 5 948 mg/l in August 1932 after the lake had been closed for 9 months. In July 1972 a level of 4 540 mg/l of chloride was recorded (18) after the lake had been closed for one week. Chloride values for the last 25 years have been lower than those recorded 40 years ago (*table 2*).

Lake and inflow nutrients

There are few chemical analyses of the lake and inflow waters (*tables 3 and 4*). Seasonal cycles, variation from year to year, and changes in nutrients as a result of sea water influxes are not understood and cannot be deduced from the available information; neither can reports of lake deterioration be substantiated chemically.

The mean concentration of soluble phosphorus (0.011 mg/l, *table 3*) lies between the mean concentrations for surface waters of eutrophic and mesotrophic Rotorua lakes (51). On most occasions total phosphorus in Lake Ellesmere waters lies within the range expected in mesotrophic to eutrophic waters (0.03-0.1 mg/l) (99). Nitrate concentration is considerably higher than that for Rotorua lakes. It can be concluded from the small amount of available data that Lake Ellesmere waters are fairly nutrient rich. In view of the high nitrogen content, increases in phosphorus input may raise

4 Nutrients in waterways from sewage may be reduced by disposing of oxidation pond effluent from sewage treatment works on to farmland.
5 Reduction of agricultural nutrients entering waterways may be achieved by spray-irrigating pig and dairy wastes back on to the land.
6 Beds of aquatic plants in Lake Ellesmere largely disappeared during the "Wahine" storm of 10 April 1968, as in the 1900s and 1940s.
7 The black swan population has declined since 1968.
8 The toxic blue-green alga *Nodularia spumigena* appeared in Lake Ellesmere in 1971 and "bloomed" in 1972. Blue-green algae were also reported in Lake Ellesmere during the 1930s.
9 The numbers of flounder caught in Lake Ellesmere have declined since 1967, but commercial eel fishing has increased.
10 The brown trout fishery appears stable.
11 The lake is eutrophic, may have been so for some considerable time, and there is insufficient data to establish the rate of trophic change.
12 Nitrate concentrations in both lake and inflow waters are considerably higher than those for Rotorua lakes, so control of phosphorus inputs may offer the best chance of reducing eutrophication.

Future of Lake Ellesmere

Lake Ellesmere can provide such recreational pursuits as brown trout fishing, shooting, and boating close to the city of Christchurch. Maintenance of the black swan breeding grounds is important for black swan populations over much of New Zealand, and Selwyn brown trout are used to stock other Canterbury rivers. Commercial fishing of flounder or eels can provide an important industry.

Provided macrophyte beds are re-established and the trophic status of the lake does not deteriorate, these interests should not be curtailed. Continued careful management by the North Canterbury Catchment Board will be necessary. The Board is to be commended on its management of the lake.

RECOMMENDATIONS

Based on present knowledge, eight practical steps might be successful in minimising further deterioration of Lake Ellesmere.

1 Farmers should be encouraged to dispose of farm wastes on the land, thus reducing pollution of contributing waterways.
2 The discharge of wastewater into waterways should be discouraged, and all wastewater discharged should at least receive secondary treatment.
3 Weed control schemes should be altered so that maximum control occurs at the end of summer when water levels are low and chemical sprays and cutting are most effective.
4 Chemical sprays should be used only at minimum concentrations.
5 The use of 2,4-D sprays should be restricted so that none drains into waterways.
6 Where practical, cut and decaying weed should be removed from waterways, possibly at collection points before it enters the lake.
7 Farmers should be encouraged to use the artesian system to reduce demands on waterways.
8 Build-up of algal blooms might be prevented by opening the lake during summer months. Such an opening is unlikely to affect the re-establishment of *Ruppia megacarpa* and *Potamogeton pectinatus* beds, but may conflict with recreational requirements.

Further research into the lake system will be necessary to provide information for improved management. Research on the lake should provide information on the following:

1 The chemistry and biology of lake waters and inflow waters.
2 The ecology and control of toxic algae.
3 The ecology of aquatic weeds and their control in contributing waterways.
4 The ecology of the black swan, eels, trout, and other important species.
5 The hydrology of the lake.

Any such research should have an integrated approach and all interested groups should be consulted.

CURRENT RESEARCH

Research on Lake Ellesmere and contributing waterways is limited and uncoordinated. In collaboration with Chemistry Division, DSIR, and the Department of Health, the North Canterbury Catchment Board has been collecting and analysing water samples from 4-8 locations at approximately 4-month intervals and now intends analysing 12 samples once a month. Further water analyses are being carried out by Dr V. M. Stout and students of the Zoology Department, University of Canterbury. This department is also studying bottom fauna, plankton, and eels. Research on eels by the Zoology Department, Victoria University of Wellington, has also involved Lake Ellesmere.

The Wildlife Service of the Department of Internal Affairs is continuing its study of black swan at Lake Ellesmere and the Fisheries Research Division of the Ministry of Agriculture and Fisheries has recently investigated fish mortalities and diseased eels in the lake.

Figure 13 Salvaging trout from the Selwyn River bed.

Figure 14 Trout spawning trap in the Selwyn River.

Photos C. J. Hardy, Fisheries Management Division, Ministry of Agriculture and Fisheries

were being disposed of via the storm water system. Sewage from a septic tank serving a community of 100 cottages at the Selwyn Huts drains into the Selwyn River without further treatment (69, 74).

Pig and dairy wastes are discharged into waterways chiefly in the Irwell River area (69, 74). Farmers in the L II catchment areas are being encouraged by the North Canterbury Catchment Board to spray-irrigate dairy waste back on to farmland. Following the 1967 Water and Soil Conservation Act and the classification of waters, regional water boards are responsible for maintaining water quality standards according to classification. Boards are imposing effluent conditions which will maintain the standards of the receiving water (91). This has resulted in farm effluent being discharged on to the land instead of into waterways.

PROBLEMS ASSOCIATED WITH LAKE ELLESMERE AND ITS CATCHMENT

The main problems associated with Lake Ellesmere are:

1 Eutrophication of waters.
2 The appearance of toxic blue-green algae in the lake.
3 Disappearance of the main weed beds (*Ruppia megacarpa* and *Potamogeton pectinatus*) from Lake Ellesmere.
4 Deaths of commercial fish (yellow-eyed mullet and flounder).
5 Depredation of farmland by black swan and Canada geese.
6 Failure of the black swan to breed.
7 Engineering problems related to draining the lake to the sea.
8 Flooding of farmland adjacent to the lake.
9 Maintenance of drains and waterways to provide
   (a) drainage of farmland,
   (b) water for irrigation to make up rainfall deficits, and
   (c) water to suppress high salinities in saline soils.
10 Control of aquatic plants in drains and waterways.
11 Maintaining minimum flows in waterways for fish and wildlife.
12 Pollution of waterways by urban and farm effluent.
13 Control of the lake level for boating and water skiing.

CONCLUSIONS

1 Over the last 25 years, Lake Ellesmere levels have been controlled within certain limits, the lake has been opened to the sea more frequently, and has remained open for shorter periods.
2 More water has been removed from contributing waterways for irrigation in latter years.
3 Growth of aquatic plants in contributing waterways has increased.

Table 2 Chloride concentrations for Lake Ellesmere and some mean values for other waters

Date	*Duration lake closed*	*Duration previous opening (days)*	*Lake level above m.s.l. m (ft)*	*Chloride mg/l*	*Authority*	*Comment*
Jan. 1932	35	81	0.36 (1.17)	11 300	Langbein (1932) (49)	Average of several lake samples
Aug. 1932	270	81	1.22 (4.0)	5 948	Langbein (1932) (49)	
Aug. 1949	270	?	1.19 (3.9)	3 460	Evans (1953) (31)	Average of several lake samples
Nov. 1949	30	?	1.16 (3.8)	4 840	Evans (1953) (31)	
Sept. 1954	240	?	1.28 (4.2)	4 100	Collins (1954) (21)	Kaituna end
June 1955	60	14	1.13 (3.7)	3 150	DSIR	
Nov. 1969	120	14	0.91 (3.0)	1 540	DSIR	Mid-lake
Jan. 1970	21	35	0.30 (1.0)	5 700	DSIR	
July 1970	180	42	1.07 (3.5)	3 420	DSIR	
Sept. 1970	30	10	0.76 (2.5)	2 560	DSIR	
Jan. 1972	180	28	0.82 (2.7)	4 240	DSIR	Mid-lake
June 1972	270	28	1.07 (3.5)	2 800	DSIR	Off Lakeside
July 1972	7	18	0.91 (3.0)	4 540	DSIR	Between Lakeside and Selwyn River
1932	Lake Ellesmere mean			8 624		
1949-55	Lake Ellesmere mean			3 970		
1969-72	Lake Ellesmere mean			3 540		
	Sea water mean			19 000		
1971	Lake Rotorua mean			24	McColl (1972) (51)	
1969	Canterbury mountain lakes mean			5	Stout (1969) (95)	

the trophic level. There is no chemical evidence, however, to show that the present condition is any worse than it was in earlier times, or to determine whether the lake has the ability to withstand further phosphorus loading without undergoing major trophic change.

The main inflows to Lake Ellesmere are generally lower in soluble phosphorus than those to either Lake Rotorua or Lake Taupo but are considerably higher in nitrate (*table 5*). Nitrate tended to be highest in the Selwyn River although the highest nitrate value was recorded on one occasion in the Irwell River (*table 4*). In view of the already high nitrate concentrations in the inflow waters it may be that control of phosphorus inputs offers the best chance of preventing the lake from becoming more eutrophic.

For further measurements of phosphorus and nitrogen to be of value they should cover a wide range of inflow and lake conditions and be supported by the following type of information:

(a) input flow rate,
(b) origin of input water,
(c) sediment discharge,
(d) lake level,
(e) lake salinity,
(f) composition of inflow sea water, and
(g) biological activity in input and lake waters.

Lake flora

A list of plant species occurring in and around Lake Ellesmere is included in the *Appendix*.

AQUATIC MACROPHYTES

Records of aquatic plants for Lake Ellesmere commenced in 1870. There appear to have been periods of abundance and scarcity of aquatic plants over the years. Plants were so scarce in the 1940s that the North Canterbury Acclimatisation Society requested research into the problem by Botany Division, DSIR, and Mason 1946 (57) reported that weed beds had disappeared periodically since 1904.

The dominant plants found in Lake Ellesmere have been *Ruppia megacarpa* and *Potamogeton pectinatus* (*figure 5*). Luxuriant weed stands were described as being so thick you could almost walk on them; individual plants were 1.8-2.4 m (6-8 ft) long and formed such dense beds that water within the beds was calm and still, even in strong winds (57). In the 1930s, weed beds 8 km (5 miles) long and 0.8 km (0.5 mile) wide occurred on the west side of the lake stretching from Taumutu to the mouth of the Selwyn River.

In 1960 when the main weed beds were mapped (*figure 6*) (60), the largest areas of weed lay between the mouths of the Selwyn and Halswell Rivers. This area was reported as having little

Table 3 Nutrient concentrations in Lake Ellesmere and mean values for Rotorua lakes

Date	*Lake level above m.s.l. m (ft)*	*Duration lake closed (days)*	*Soluble PO_4—P mg/l*	*Total PO_4—P mg/l*	*NO_2—N mg/l*	*NO_3—N mg/l*
3. 6.65	1.13 (3.7)	60	—	0.016	0.004	0.22
6.11.69	0.91 (3.0)	125	0.003	0.023	0.001	trace
26. 1.70	0.30 (1.0)	21	0.01	0.01	—	—
1. 7.70	1.07 (3.5)	180	0.003	0.003	—	0.04
14. 9.70	0.76 (2.5)	30	0.01	0.02	—	0.04
13. 1.72	0.82 (2.7)	180	0.01	0.25	0.001	0.30
8. 6.72	1.07 (3.5)	275	0.03	0.06	—	0.30
24. 7.72	0.91 (3.0)	7	0.01	0.02	0.003	0.10
Lake Ellesmere mean			0.011	0:022		0.144
Rotorua lakes mean*			0.008	0.045		0.004

Analyses by Chemistry Division, DSIR, and *McColl (1972) (51), (in press) (52)

Table 4 Nutrient inflows to Lake Ellesmere

River	*Date*	*Soluble PO_4—P mg/l*	*Total PO_4—P mg/l*	*NO_2—N mg/l*	*NO_3—N mg/l*
Halswell	1962	—	0.007	0.0035	1.6
	1969	—	0.003-0.033	Nil	1.6
	25. 6.70	0.008*	—	—	0.13-0.64*
	15. 9.71	0.02	0.03	0.028	2.0
	1972	0.025*	—	0.0289	0.9571*
	26. 6.72	0.01	0.03	0.02	0.1
	19. 7.72	0.01	0.10	0.04	2.0
	23. 1.73	—	—	0.032	1.25
Selwyn	29. 5.67	0.006	—	—	—
	3. 8.69	0.005-0.06	0.082	0.004-0.04	0.4-1.0
	1970	0.003	0.003	0.012	0.5
	15. 7.71	0.01	0.01	0.004	3.5
	15. 9.71	0.005*	—	0.0171*	1.579*
	12.10.71	0.01	0.01	0.008	3.2
	1972	0.01	0.02	0.012	3.6
L II	22. 6.70	0.009*	—	—	0.86-1.15*
	15. 9.71	0.01	0.02	0.009	1.4
	1972	0.007-0.011*	—	0.0396*	1.772*
Leeston Creek	1.12.69	—	0.09	—	0.8
Irwell	25. 6.70	0.022*	—	—	0.64
	3. 8.70	—	—	0.014*	4.39*
	15. 9.71	0.01	0.01	0.006	2.1
	1972	0.43	—	0.017	1.35
Harts Creek	22. 6.70	0.007*	—	0.009*	1.3-1.79*
	15. 9.71	0.01	0.03	0.001	1.6
	3. 8.72	0.012*	—	0.0118*	1.903*

Analyses by DSIR and *Fisheries Research Division, Ministry of Agriculture and Fisheries, Christchurch.

Table 5 Comparison of nutrient inflows to Lakes Ellesmere, Rotorua, and Taupo

	Soluble PO_4—P mg/l	*NO_3—N mg/l*
Mean Ellesmere inflow	0.014	1.55
Range	0.003-0.06	0.013-4.39
Mean Rotorua inflow	0.065	0.236
Range	0.006-0.122	0.027-0.54
Mean Taupo inflow	0.033	0.203
Range	0.009-0.093	0.056-0.694

Rotorua values from Fish (1969) (32), excluding sewage inflow
Taupo values from White (pers. comm.) (102)

weed prior to 1946 (57). In 1969 a continuous belt of weed extended south from the mouth of the Selwyn River along the west shore to Marshall Island, but weed was absent from Marshall Island to Taumutu.

Disappearance of weed beds in the past has been attributed to the base of the plant rotting during anaerobic conditions. This was associated with the vigorous growth of plants and the consequent stagnation of water (58). Reports of a "foul smell like sulphuretted hydrogen" when weed had broken loose and piled upon other weed beds tended to confirm this. It was suggested that the products of such anaerobic decay would not only kill the

Table 8 Ellesmere County agricultural statistics for 1969-70 (28)

Total cultivated area ha (acres)	*Total area topdressed ha (acres)*	*Fertiliser applied tonnes/year (tons/year)*	*Total no. of beef cattle*	*Total no. of pigs*	*Total no. of sheep*
84 953 (209 761)	37 893 (93 564)	22 086 (21 653)	27 000	23 000	429 000

reduced by controlling the lake level and by stop-banking. Stop-banking can prevent the flooding caused by wind lash. Various proposals for control have considered lowering the lake level still further and the construction of a permanent outlet. These are summarised in a North Canterbury Catchment Board report (24) which concluded that such an outlet was not feasible, and that the present method of lake opening and control was the most satisfactory.

Commercial fishing

Commercial fishing interest in Lake Ellesmere has varied in recent years. Registered fishing vessels for Ellesmere have declined from 44 vessels in 1965 to 28 in 1971. In 1965/66 the main catch in the Ellesmere District was flounder (101 818 kg) [2 000 cwt] valued at $17 000) but in 1971 the quantity landed was only 10 182 kg (200 cwt). Since 1969, interest in eels has increased dramatically because of the incentive of a healthy export market. The quantity landed for Ellesmere in 1971 was 286 720 kg (5 632 cwt) with a value of $46 459.

Before the development of the eel industry, commercial fishing interests had requested the construction of a permanent outlet to the lake (16). They claimed that reduction in the duration of lake opening contributed to the decline in the flounder catch.

Recreation

The North Canterbury Acclimatisation Society manages the wildlife of the area. The black swan population has provided sport for shooters since 1875. In order to restrict hatching of cygnets to 20 000 per year, the society collects excess swan eggs. These are used locally by commercial bakers (8). The adult population is kept down by organised shooting drives. Because of breeding failure after the "Wahine" storm on 10 April 1968, there have been no organised shooting drives, the shooting season has been kept at three months, and a daily bag limit of two was imposed (66). In 1973 the bag limit was increased to five (62).

During the season, duck, pukeko, and Canada geese are shot at Lake Ellesmere (62). A bag limit of 15 is imposed for duck whereas no limit is set for Canada geese which also damage surrounding farmland (104). The number of shooters is estimated at 2 500 (69).

The Society also manages the brown trout fishery for anglers. This fishery, chiefly in the Selwyn River, provides 25% of the fishing in North Canterbury (41). It is regarded as the most important in Canterbury (10) and fish bred in the Selwyn River are used to stock other Canterbury rivers. A characteristic of this river is that over several miles of its bed in the middle reaches, there is no surface flow for much of the year (*figure 13*). Since 1966, low water conditions in the Selwyn River have prevented trout moving up to spawn. Because of this, spawning fish are trapped by the Acclimatisation Society and, according to the length of suitable spawning waters available, either placed upstream of the trap or transferred to other waters (66) (*figure 14*).

In North Canterbury the popularity of freshwater angling has rapidly increased. The total district catch is approximately 90 000 fish and the total angling effort is 210 000 days per year (41) by an estimated 15 000 fishermen (69). The total expenditure on fishing is about $1 000 000 per year. A quarter of this expenditure is on the Selwyn fishery (41).

There is no doubt that the success of the Selwyn River as a fishery depends on Lake Ellesmere remaining in reasonable condition. A major change in the trophic state of the lake may seriously affect the trout fishery (41).

Lake Ellesmere is used for boating and water skiing (14, 64). Clubs have recently requested the maintenance of a high lake level during the summer months (74).

Effluent disposal

The streams and waterways contributing to Lake Ellesmere drain agricultural land and are used for the discharge of sewage effluent and agricultural waste. Sewage from the Lincoln College and Lincoln township is discharged into the L II River after treatment in a Passveer oxidation ditch. This effluent has a total phosphorus level of 2.0-5.6 mg/l and a soluble phosphorus level of 1.8-4.6 mg/l. In the Leeston sewage scheme using oxidation ponds, effluent is disposed of by land irrigation except during the wetter months of May to August when it may be discharged into the Leeston Stream, a tributary of Harts Creek. Evidence in 1971 (89) indicated that septic tank effluent in Leeston discharged into water-bearing strata as well as finding its way into surface drains. Water analyses from the Leeston Stream at this time indicated that considerable quantities of sullage wastes plus septic tank effluent

Potamogeton cheesmanii were recorded in Harts Creek 10 years later (59). *Ruppia polycarpa* and *Zannichellia palustris* are reported in the L II River and *Potamogeton pectinatus* is now reported as flourisring in the lower reaches of the rivers. Currently, the severest infestation of waterways is by *E. canadensis* with medium infestation by *Nitella hookeri, M. guttatus,* and algal slimes (75).

The North Canterbury Catchment Board uses the following methods of aquatic weed control:

1 Dragline or mechanical excavator. Accumulated weed, mud, and silt is removed every one to three years, in the autumn.
2 Weed cutting by boats on navigable waterways (27 km or 17 miles), usually in the spring, autumn, and early winter. Summer water levels are too low for navigation. River stretches may be cut three times a year. Cut weed drifts down to the lake.
3 Hand cutting where waterways are not navigable.
4 Chemical sprays and injections. These are used at any time of the year and sometimes three or four times a year. Paraquat is injected in solution to produce a concentration of 10 mg/l for 30 minutes. Spraying of side banks is done by boat and uses a mixture of 2,2-DPA, 2,4-D, and paraquat.

The increase of aquatic plants has made maintenance of waterways increasingly difficult over the years. Drainage waters from fertile farm land can be expected to contain more than adequate levels of nutrients for aquatic plant growth. The increase in weed may be related to increase in nutrient levels from such waters.

Weed cutting in the spring may enlarge weed areas by stimulating growth *in situ* and establishing new beds downstream. Nutrients released from weed sprayed in early summer may encourage other weed growth. Growth of *Elodea canadensis* may be stimulated by dilute spray mixtures containing 2,4-D (88).

MANAGEMENT, LAND USE, AND LAKE USE

Management

The chief controlling authority for Lake Ellesmere is the North Canterbury Catchment Board. This board is responsible for water levels within the lake, for opening the lake to the sea, and for the maintenance of drainage canals and irrigation ditches in the surrounding counties. Contributing rivers, such as the L II, Halswell, and Selwyn Rivers are also the responsibility of the Board. The allocation of water rights, including the right to discharge effluent into waterways, is under the direct control of the North Canterbury Catchment Board.

Two other boards, the Wairewa and Ellesmere County Councils, also share responsibility for the maintenance of waterways.

Farming

The farmers have a large interest in Lake Ellesmere. Land surrounding the lake and extending back into the Ellesmere and Springs Counties was once swamp. Drainage has enabled the development of 100 000 ha (250 000 acres) of productive farm land above the 9 ft (2.7 m) contour, valued at $1 235-2 223 per ha ($500-900 per acre) in 1972.

The water table and salt content of an additional 4 534 ha (11 200 acres) of drained land adjacent to the lake between the 5.0/6.0 ft and 9 ft (1.5/1.8 and 2.7 m) contours, is directly affected by the lake level. In 1972 land values (27) ranged from $247-370 per ha ($100-150 per acre) on sandy soils to $494-740 per ha ($200-300 per acre) on Motukarara soils. Land between the 2.5 ft and 5.0/6.0 ft (0.76-1.5/1.8 m) contour is irregularly flooded for variable periods by saline lake waters and comprises 5 790 ha (14 300 acres). This land is valued at $62-124 per ha ($25-50 per acre). In the past various schemes (7, 16, 21, 23, 29, 30, 33, 40) have proposed lowering the lake level to bring this land into year-round production.

Because of the low rainfall and high evapotranspiration rates, irrigation is essential for successful farming. Water is drawn from the contributing waterways of the lake and ground water supplies. Highly saline soils adjacent to the lake regularly require large volumes of water to effect desalting (84).

AGRICULTURAL STATISTICS 1969-70 (28)

Statistics are available only for Ellesmere County, the largest in the lake catchment area (*table 8*). Lime and artificial fertiliser are applied at a mean rate of 0.58 tonnes/ha/yr (0.23 tons/acre/yr).

Even a small percentage loss of fertiliser applied to the land together with nutrients leached from animal wastes would seriously affect nutrient levels in waterways and the trophic status of Lake Ellesmere.

AGRICULTURAL RETURNS (27)

Gross income from the Lake Ellesmere Catchment in 1971/72 ranged from as low as $50 per ha ($20 per acre) on saline soils near Kaituna to as high as $395 per ha ($160 per acre) where the land was used for town milk supply herds and intensive cropping. Despite lower land values in the belt below the 9 ft (2.7 m) contour total gross income from the 10 326 ha was still over $1 million.

Successful farming in the Lake Ellesmere Catchment is related to efficient drainage, irrigation, and flood prevention. The flooding of farmland can be

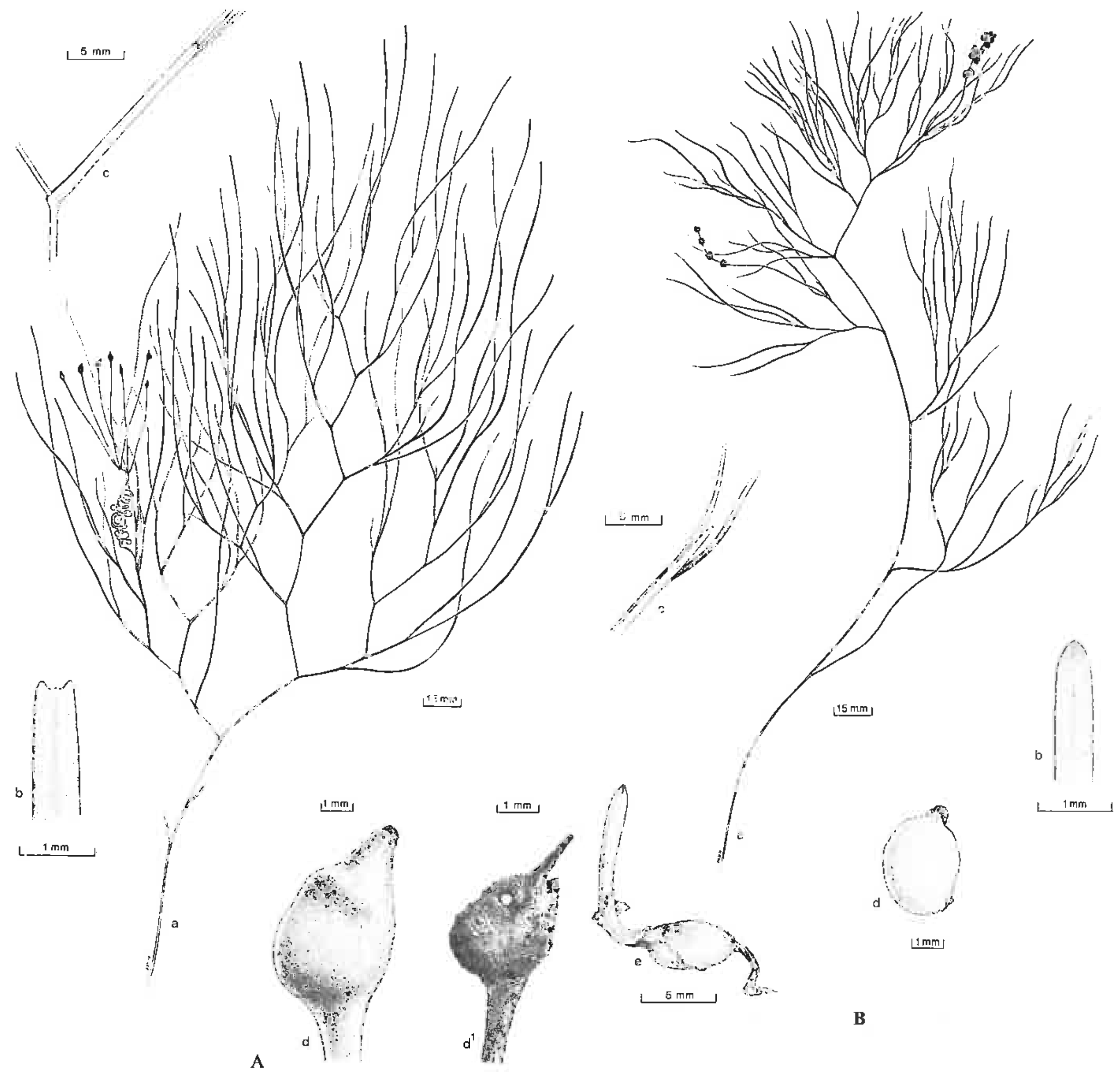

Figure 5 The dominant water weeds of Lake Ellesmere. (*Drawings by K. R. West, Botany Division, DSIR*) **A** *Ruppia megacarpa* (a) habit (b) leaf tip (c) leaf sheath (d) fruit (d[1]) "nut". **B** *Potomogeton pectinatus* (a) habit (b) leaf tip (c) leaf sheath (d) fruit (e) tuber

base of the plants but would prevent recolonisation. The removal of the finer bottom deposits by wave action after the destruction of a weed bed was considered likely to have a more lasting effect in preventing regrowth (57).

Weed beds reappeared in the 1950s but were scoured out by the "Wahine" storm of 10 April 1968. So far they have failed to reappear in their former luxuriance. Regeneration of the weed may be affected by such factors as the trophic state of the lake water, the removal of silt on which the weed grows, and the use of herbicides in contributing waterways. The North Canterbury Acclimatisation Society has expressed concern over the use of herbicides and the trophic state of the water. It cannot be stated with certainty that the reappearance of weed beds is prevented by the trophic state of the lake water. Past reports (57, 58) indicate that once weed beds are scoured out, their re-establishment takes several years. These reports also indicate that obnoxious conditions of weed and algae have existed before, suggesting highly eutrophic conditions.

ALGAE

Little is known about the algae of Lake Ellesmere. The earliest records appear to be those of Percival who simply noted that green and blue-green algae

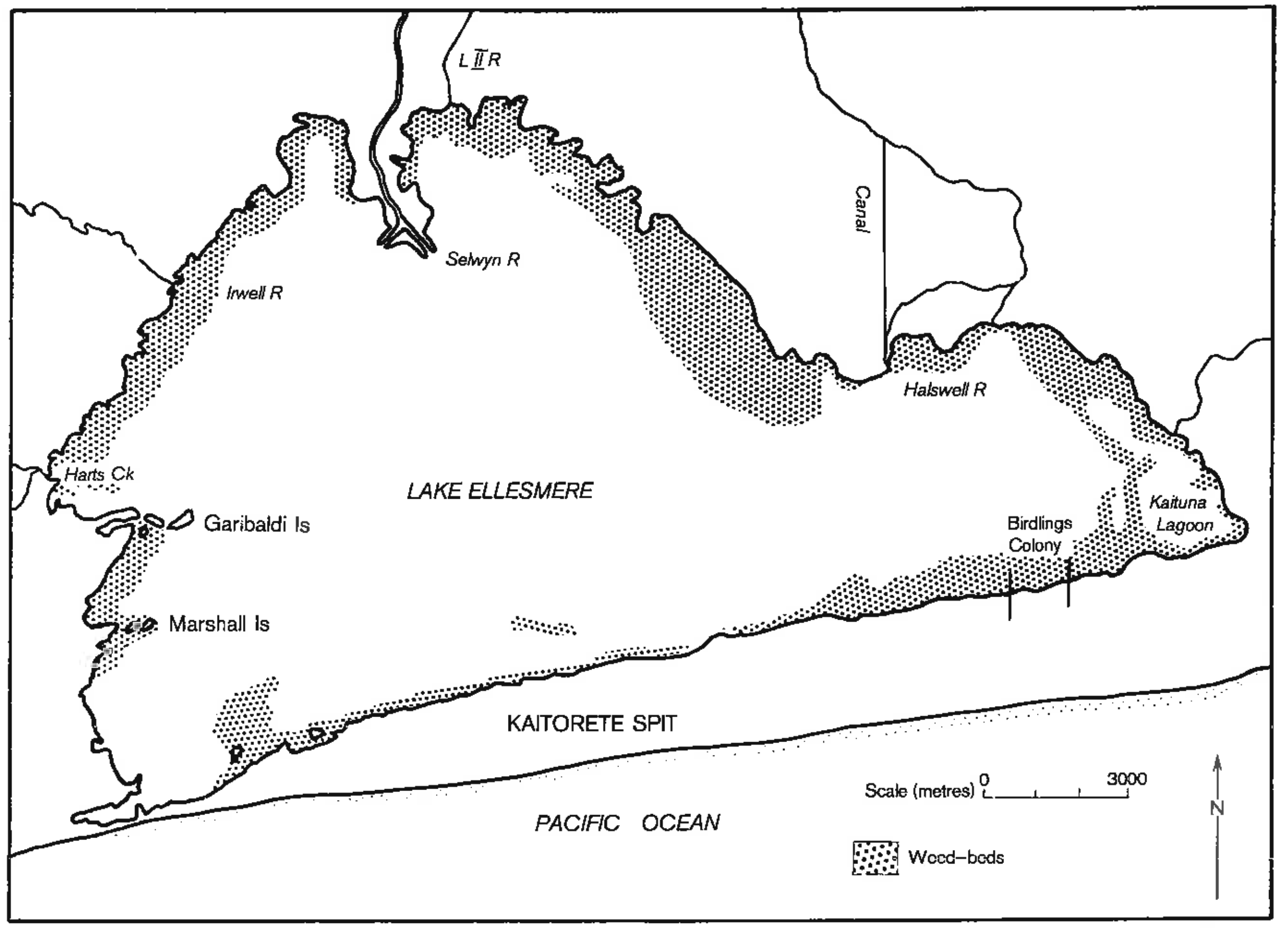

Figure 6 Distribution of aquatic weed in Lake Ellesmere, 1960. (*Reprinted from Miers and Williams 1969* [60])

were abundant in the weed beds during the 1930s (57). The only attempt to investigate the phytoplankton was by Flint (35, 36) who has examined samples supplied irregularly to the DSIR since 1969 (see *Appendix*).

She found that, until recently, the phytoplankton was dominated by green algae, particularly *Dictyosphaerium primarium* and species of *Oocystis* and *Ankistrodesmus.* The blue-green algae *Coelosphaerium Keutzingianum* and *Merismopedia* sp. were present in 1970. *Nodularia spumigena,* a blue-green alga capable of "blooming" in warm brackish water, appeared in April 1971. In nearby Lake Forsyth death of sheep and dogs was attributed to a toxin produced by this alga. *N. spumigena* was abundant again in Ellesmere during March and April 1972 and in January 1973. The lake flora is considered eutrophic, being dominated by members of the Chlorococcales and occasionally by masses of blue-green algae (35, 36).

Some estimates of photosynthesis expressed as the maximum rate of carbon utilisation (P max) are available (12), and these figures for Lake Ellesmere are compared in *table 6* with mean P max values for other New Zealand lakes (13). The drought summers of 1971-1973 may have hastened the development of a eutrophic algal flora by concentrating an increasing supply of nutrients by evaporation. Increasing P max values (12) suggest such a trend, and the high value of 406 µg/l/hr corresponds with a *N. spumigena* bloom. The complexity of the situation is illustrated by the fact that there was no bloom of this alga in the summer of 1973 (36).

Wildlife

A list of animal species occurring in or around Lake Ellesmere is included in the *Appendix.*

WATERFOWL

Lake Ellesmere and its margins are rich in bird life. The bird fauna includes black swan *Cygnus atratus* (*figure 7*), Canada goose *Branta canadensis* (*figure 8*), grey duck *Anas superciliosa,* mallard *A. platyrhynchos,* shoveller *A. rhynchotis,* and paradise duck *Tadorna variegata* together with pukeko *Porphyrio porphyrio* and wading birds such as pied stilt *Himantopus himantopus,* oystercatcher *Haematopus ostralegus,* and white-faced heron *Ardea novaehollandiae.* The swans, geese, and ducks feed on the aquatic weed beds and many breed around the lake edge. In summer the lake is visited by northern hemisphere migrants such as knot *Calidris canutus,* sandpipers *Calidris* spp., and bar-tailed godwit *Limosa lapponica* (14, 64).

Black swan (1, 8, 60, 103) Black swans have been present in large numbers (*figure 7*) on the

which discharge into Lake Ellesmere and also through four culverts direct to the sea.

A rise in lake level raises the base level of drainage and thus may raise the water table. However, ground water levels appear much more closely related to local rainfall and have been high after periods of heavy rain, even though lake levels were low (21).

There is an artesian belt 7.2 km (45 miles) wide bordering Lake Ellesmere (83) (*figure 12*). The depth to the aquifers in this belt varies from 15 to 120 m (50 to 400 ft). Water levels in artesian wells fluctuate with lake levels. This is probably a pressure effect due to the lake water loading the artesian aquifer (83) rather than proof of any direct connection between the lake and aquifer (21).

Contributing waterways

The North Canterbury Catchment Board has carried out engineering works on many of the contributing waterways. The Halswell River, the L II River and Osborne's Drain (flowing into the Halswell River) have all been improved. The L II scheme lowered the water table level along the whole length of the river and increased the volume of water in the river. No further flooding occurred and the L II River was less influenced by changes in Lake Ellesmere levels. It was estimated (76) that 1 000 ha (2 500 acres) directly benefited from the L II improvement scheme and a 12% return on all monies invested resulted. This was derived from the increased annual income of the farmers relative to land development costs. Similar results were obtained on other waterways. No major improvements have been carried out on the Selwyn River.

The North Canterbury Catchment Board allocates water rights and has, for example, set a minimum flow of 0.28 m^3/sec (10 cusecs) in the Halswell River acts as a wtaer supply and drain, that the trout fishery has enough water during spawning when fish migrate upriver from Lake Ellesmere, and also allows the Board to carry out weed cutting and cleaning operations by boat. The Halswell River acts as a water supply and drain, making farming possible over 7 300 ha (18 000 acres) of very fertile land. Water rights are granted so that 0.028 m^3/sec (1 cusecs) irrigates 60 ha (150 acres) of land (25). This is based on the prospect of a 310 mm (12.2 in.) rainfall deficit occurring once every 7 years.

AQUATIC WEEDS

The North Canterbury Catchment Board controls aquatic weed growth in the waterways. In the Halswell Drainage District the Board maintains 35 km (22 miles) of rivers and 113 km (70 miles) of contributing drains (75). Most aquatic weed control is carried out in this district.

Twenty years ago only the water buttercup *Ranunculus fluitans* was recorded in the Selwyn River, where it is still present as a light infestation. Canadian pond weed *Elodea canadensis,* monkey musk *Mimulus guttatus,* and pond weed

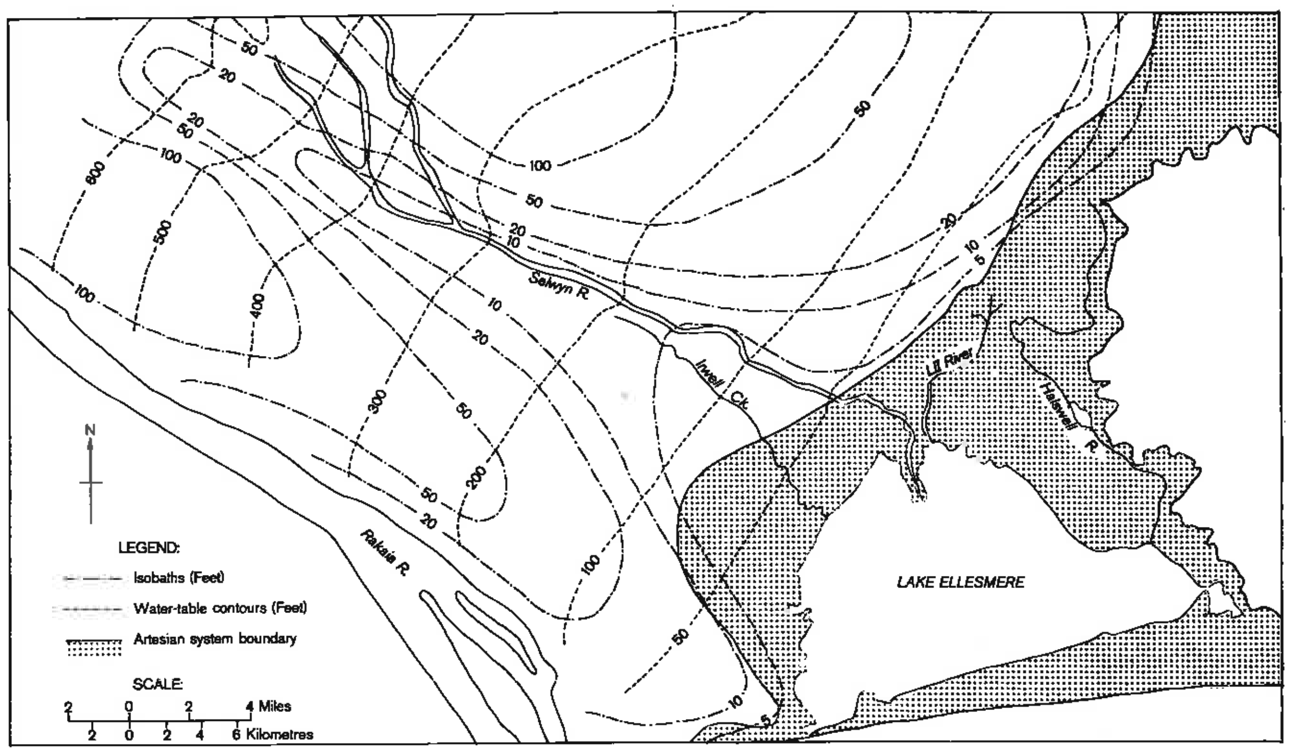

Figure 12 Ground water contours and artesian system of the Lake Ellesmere catchment. (*Redrawn from Oborn 1955* [79])

Table 7 Climatic data from Lincoln (43° 39′ S, 172° 28′ E)

Year	*Sunshine hours*	*Estimated open water evaporation mm*	*Rainfall mm*	*Max. height of lake m (ft)*	*Number of times lake opened*
1968	2 161	951	813	1.22 (4)	5
1969	1 884	936	453	1.22 (4)	6
1970	1 938	908	651	1.22 (4)	2
1971	1 947	859	442	1.06 (3.5)	1
1972	2 139	885	499	1.22 (4)	3
Mean	2 000	908	650	1.16 (3.82)	3.17

From N.Z. Meteorological Service, Meteorological Observations for 1968, 1969, 1970, 1971, and 1972

selves in depth, texture, moisture content, and fertility (29, 44, 101). Almost the entire catchment is farmed (*figure 11*). The fertile soils around Southbridge, Leeston, Brookside, and Irwell are well suited to intensive farming and support a wide variety of crops, although production is limited by low rainfall. Land nearer the lake is used for dairy farming. Sheep farming occurs on the less fertile soils and on the hills to the east of the lake.

Chemical analyses of soils and lake sediments (5) generally show them to be rich in available phosphate, potassium, magnesium, and calcium but low in nitrogen. When soil moisture is adequate, crop and pasture yields are high. Production is low on the saline soils near Lake Ellesmere but can be increased if the salts are removed (84). These soils require careful management, irrigation to reduce salt levels, and drainage to reduce water table levels. This land is used almost wholly for grazing by sheep, dairy and beef cattle (101).

Ground water

Because of low rainfall, ground water supplies are important in this region. Most ground water moves laterally in the direction of slope of the water table towards Lake Ellesmere (80). The slope of the water table is approximately 3.75 m/km (20 ft/mile). The rate of flow is a few metres per day but the phreatic wave (water table peak) may travel at 50 60 m/day (170-200 ft/day).

There are great differences between depths to the water table in the counties surrounding the lake (*figure 12*). It is necessary to supply water artificially in some areas and remove it in others. The depth to the water table may be only 0.3 m-0.9 m (1-3 ft), or greater than 15 m (50 ft). Water is supplied to one area of 19 845 ha (49 000 acres) by 258 km (160 miles) of open races drawing from the Rakaia and Selwyn Rivers. Areas of high water table are drained by 105 km (65 miles) of drains

Figure 11 Aerial photograph of Lake Ellesmere, 25 October 1966. *Photo RNZAF, Wigram*

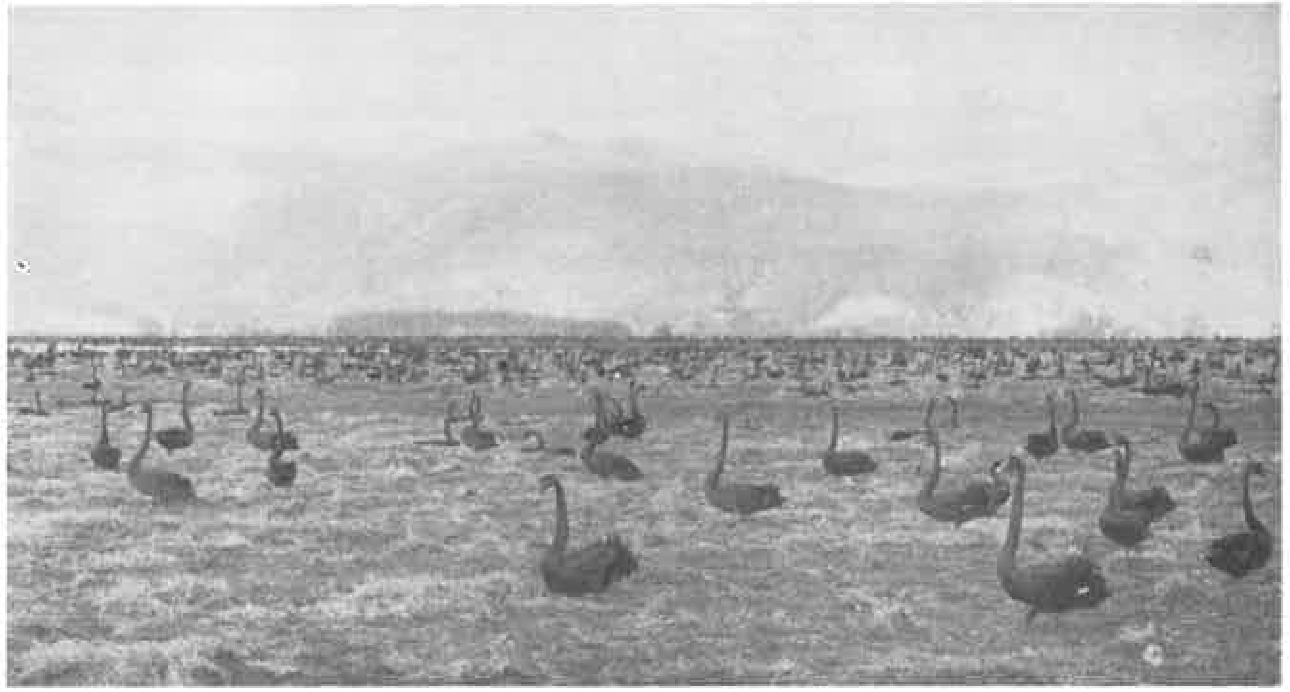

Figure 7 Black swans on pasture land, Lake Ellesmere. *Photo P. Morrison, Wildlife Service, Department of Internal Affairs*

Figure 8 Canada geese at Lake Ellesmere. *Photo P. Morrison, Wildlife Service, Department of Internal Affairs*

Table 6 Photosynthetic activity in Lake Ellesmere

Date	Lake level above m.s.l. m (ft)	Duration lake closed (days)	P max µg/l/hr
6.11.69	0.9 (3)	180	110
26. 2.70	0.3 (1)	90	116
1. 7.70	1.1 (3.5)	180	101
24.11.70	0.4 (1.25)	10	206
5. 4.72	0.7 (2.5)	240	406

Mean values of P max for Lake Ellesmere compared with other New Zealand lakes:

Lake	P max	Trophic status	Authority
Lake Forsyth	463.9	eutrophic	Flint (1970) (34)
Lake Ellesmere	134.6	eutrophic	Flint (pers. comm.) (36)
Lake Rotorua	58.9	eutrophic	Flint (1970) (34)
Lake Taupo	6.3	mesotrophic	Flint (1970) (34)
Lake Coleridge	1.0	probably oligotrophic	

All P max values from Burnet & Wallace (1973) (13)
P max = maximum rate of carbon utilisation

lake at least since 1867. Damage to surrounding farmland by the swans was first reported in the early 1900s. In 1915 the North Canterbury Acclimatisation Society were given statutory authority to control the swan numbers by collecting eggs. Since then the policy of the society has been to limit the number of cygnets hatching to 20 000 per year (60). In 1960 a population of 80 000 was estimated.

Some of the swans which breed at Lake Ellesmere, chiefly on Birlings Flat (*figure 9*), have later been recorded in other South Island regions, and in the North Island south of the Waikato. Occupation of the breeding ground starts in late July after the high winter lake levels. Egg laying is markedly seasonal, starting in the first week of August, reaching a peak in early September, with a second peak (mainly renesters) in early October (60).

Lake level appears to be one of the most important factors in the ecology of black swan at Lake

Figure 9 Black swans nesting on Birdlings Flat, Lake Ellesmere. *Photo P. Morrison, Wildlife Service, Department of Internal Affairs*

Ellesmere, affecting not only the food supply but also the length and duration of the nesting season, availability of nesting ground, nest spacings, nest destruction, and the number of birds likely to renest (60).

High lake levels in October during 1969, 1970, and 1972 reduced the second peak of egg laying. In the "Wahine" storm of 10 April 1968 not only were the food sources (weed beds) destroyed but 5 000 black swan died (8). Since 1968 the weed beds have not redeveloped and the black swans have failed to breed successfully. In 1971 only 4 000 cygnets were raised (1).

When food is scarce, as in the 1900s, the 1940s, and since 1969, black swans have caused considerable damage to crops and surrounding pasture land. This can be correlated with the disappearance of the lake weed beds (3, 8, 103). The Wildlife Service of the Department of Internal Affairs (103) considers that the control of this situation can only be achieved by strict management relating swan populations to the available weed. Lack of food may also be responsible for the failure of the black swan to breed (1, 8).

FISH

Fish which have occurred in abundance in Lake Ellesmere are flounders *Rhombosolea retiaria, R. leporina,* and *R. plebeia;* yellow-eyed mullet *Aldrichetta forsteri;* and eels *Anguilla australis* and *A. dieffenbachii.* Whitebait *Galaxias maculatus,* bullies *Gobiomorphus* spp., smelt *Retropinna retropinna,* and sprat *Maugeclupea antipodum* have also been recorded (14, 64). Other sea fish have been known to enter the lake for short periods when the lake is open to the sea.

A fishery of brown trout *Salmo trutta* exists in the lake and occasionally rainbow trout and perch are caught. When a lake opening coincides with a run of Quinnat salmon *Oncorhynchus tshawytscha,* these have been known to enter the lake and spawn in the Selwyn River (41).

Brown trout Lake Ellesmere and its tributary streams support the most important brown trout sport fishery in Canterbury (10). Lake trout move

upstream to spawn, beginning in December and reaching a peak in June and July. Records from 1916 onwards indicate that the average size of spawning trout in the Selwyn River has remained 48.0 cm long and 1 335 g in weight (43, 86). However, a recent report (41) suggests that the average size of fish caught by anglers in the Selwyn River appears to have decreased slightly in the last 10 years whereas the size of Lake Ellesmere fish has fluctuated.

Sea fish Sea fish caught in Lake Ellesmere are principally flounders (*Rhombosolea* spp.) and yellow-eyed mullet (*Aldrichetta forsteri*) (54, 64). Deaths of fish, mainly yellow-eyed mullet and flounder, were reported in June, July, and August 1972. Arsenic from sheep dip was suspected but evidence from analyses of fish, water, and weeds proved inconclusive (50). It is not known whether toxins from the blue-green algal bloom in March/April 1972 were related to the fish mortality.

Eels Eels migrate in the autumn from the tributary streams to Lake Ellesmere and attempt to reach the open sea (46) (*figure 10*). Two species are involved, *Anguilla australis* and *A. dieffenbachii.* Hobbs (46) estimated there were 977 000 migrants of *A. australis* in 1942, and 3 850 female migrants of *A. dieffenbachii.* He concluded that when the lake is closed the eels finally abandon attempts to escape, and hibernate. However, there was some evidence that *A. australis* may escape the following spring if the lake is open.

A. australis males spend an average of 14 years and females 22 years in fresh water before migration to the sea (97). Closure of the lake does not appear to affect the inward migration of elvers which are able to enter the lake through or over the shingle pit (42).

Some local fishermen report that eels caught in parts of the lake are in poor condition with large heads and poor bodies. Attenuated specimens known as "stock whip" eels were also reported

Figure 10 A catch of large eels on the gravel spit near Taumutu. *Photo National Publicity Studio, Tourist and Publicity Department*

in 1942 (46). Thirty eels from Lake Ellesmere have been examined thoroughly by the Fisheries Research Division of the Ministry of Agriculture and Fisheries over the last 2 years. Compared with eels from other parts of New Zealand they were heavily infected with the bacterium *Aeromonas liquifasciens* and the protozoan *Myxidium* sp. The bacterial pathogen is world wide in distribution and does not adversely affect the fish unless they are damaged or in poor condition (45). It is not known how representative these 30 eels were of the whole population. If the eel industry is to continue on a sound footing a major research effort may be required.

BOTTOM FAUNA

So far only a few marine and freshwater species of aquatic invertebrates have been recorded. Two species of mysids (a marine group) *Tenagomysis chiltoni* and *T. novaezealandiae,* often occur in large numbers in the water at the lake edge (14, 95A).

The amphipod *Paracalliope fluviatilus,* chironomid midge larvae, polychaete worms, and the snail *Potamopyrgus antipodum* have been recorded from bottom samples taken near the centre of Lake Ellesmere (95A, 105). Near the mouth of the Selwyn River the numbers of organisms were higher, with the exception of *Potamopyrgus* sp. Other organisms found near the river mouth and not in mid-lake were the isopod *Idotea marina,* Trichoptera (caddis) larvae, and larvae of the moth *Nymphula nitens.*

Invertebrates associated with the aquatic weed beds include an amphipod *Paracorophium lucasi,* several species of caddis fly larvae, the water boatman *Sigara arguta,* and Zygoptera (damselfly) larvae.

Zooplankton include the calanoid copepods (*Gladioferens pectinatus* and *Boeckella hamata* (64, 95A).

LAKE ELLESMERE CATCHMENT

Climate (*table 7*)

Average rainfall for the region is 650 mm. The wettest months are May to July and the driest are September to November. Free surface evaporation is high, being twice the rainfall in a low rainfall year. Sunshine averages 2 000 hours per year and mean air temperatures range from 6.1° c in July to 16.7° c in January. During the three summers of 1970-73, drought conditions have prevailed in Canterbury.

Soils and agriculture

To the north and west of Lake Ellesmere the land surface is flat or gently undulating. The soils of the surrounding counties are mostly derived from alluvial material but differ greatly among them-