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The Biology of Six South Island Ponds

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Abstract

General descriptions are given of six ponds, between latitudes 42° and 44° S, from seasonal visits between 1969 and 1971. All the ponds were permanent with rooted macrophytes. They had a wide range of physical and chemical conditions, and associated variations of flora and fauna. Special attention was given to fauna in the areas of aquatic macrophytes.

Introduction

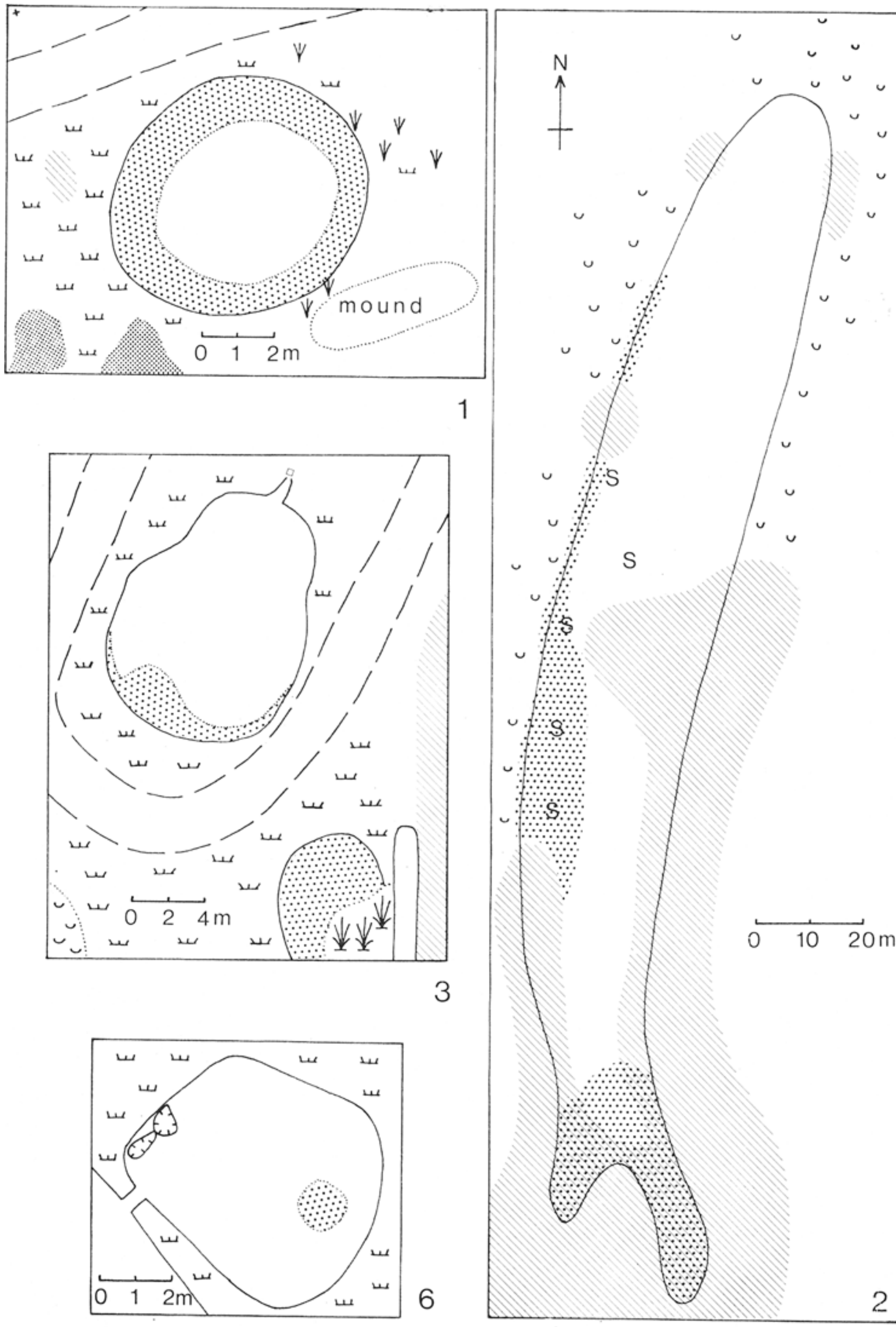
Previous studies of New Zealand freshwater ponds include those by Barclay (1966) on some temporary ponds near Auckland; Byars (1960) on the ecology of Saddle Hill Pond near Dunedin; and Stout (1964) on some temporary ponds on Marley's Hill, Christchurch. Stout (1969) published a description of a kettle hole pond near Lake Coleridge, in the Canterbury high country, and summarized and compared the information in these four pond studies (Stout 1975). Unpublished student projects from the University of Canterbury include a more detailed study of Marley's ponds by Johnson (1969); two studies on ponds at Isaac's, near Harewood, Christchurch, by Teirney (1971) and Field-Dodgson (1972); a study of two ponds on the Waimakariri river bed near Christchurch (Brouwer 1972); and comparisons of two farm ponds near Geraldine (Woods 1973), and of two adjacent small lakes near Lake Coleridge (Livingstone 1970).

This study was undertaken as part of a research project comparing the ecology of *Xanthocnemis zealandica* and *Austrolestes colensonis* (Odonata, Zygoptera). A survey of a variety of zygopteran habitats in Canterbury and Westland was made. Six ponds were selected for study, and are described here. All are permanent ponds with rooted vegetation which included species in which the Zygoptera oviposit (Crumpton 1975). The six ponds were visited during the period 1969 to 1972. Woodend Pond, Shipley's Large Pond, and Welshman's Mill Pond were visited more often and studied in more detail than the other ponds. Notes from the initial zygopteran habitat survey will be published elsewhere.

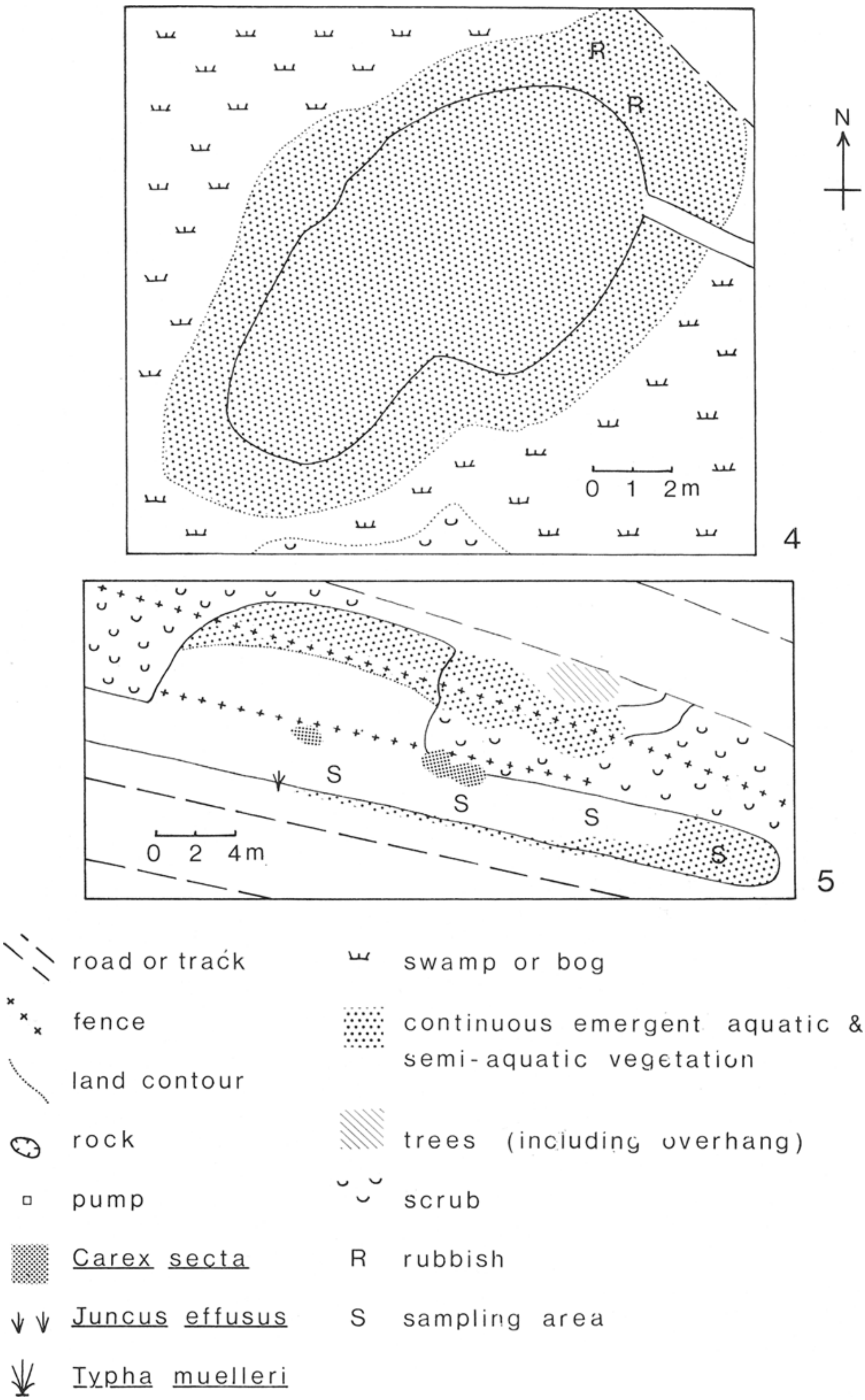
General Descriptions of the Ponds

Woodend Pond (Fig. 1)

Woodend Pond is situated at Woodend, about 20 km north of Christchurch, at the end of Gladstone Road, which turns off State Highway 1. It is on government Wildlife Reserve property which is leased for farmland. The pond was dug in 1965 to provide a watering place for cattle. It is approximately circular, with a diameter of 8-10 m. The maximum area is 39 m². Figure 1 shows the pond and its surrounding vegetation as mapped by compass survey



FIGS. 1-6. Maps of the ponds showing surrounding vegetation. All maps have the same north-south orientation. Samples of aquatic fauna were taken from all parts of the ponds, except where a sampling area (S) is marked. Grid references are from New Zealand Map Series 1 maps, published by the New Zealand Department of Lands and Survey. 1 — Woodend Pond (grid reference S76/065819). 2 — Shipley's Large Pond (S76/931644). 3 — Welshman's Mill Pond (S50 + 51/745769). 4 — Kumara Straight Pond (S50 + 51/688693). 5 — Hukarere Pond (S38/178134). 6 — Arthur's Pass Tarn (S59/052325).


R
R
N
0 1 2m
4
S
S
S
S
0 2 4m
5
road or track
swamp or bog
fence
continuous emergent aquatic & semi-aquatic vegetation
land contour
rock
trees (including overhang)
pump
scrub
Carex secta
R rubbish
Juncus effusus
S sampling area
Typha muelleri

on 9 December 1970. There is a central area which has no rooted aquatic vegetation, and a surrounding weedbed of aquatic and semi-aquatic plants. On the south side, this weedbed merges into a swampy area dominated by "pussy-willow" trees (*Salix caprea*). The pond is thus sheltered from cold southerly winds. At the edge of the swamp, patches of *Carex secta* are interspersed with pasture grasses and rushes. Rough pastures with drainage ditches surround the remainder of the pond, leaving it exposed to prevailing easterly and northwesterly winds. Approximately 90 m to the east of the pond are sand dunes flanking Woodend Beach.

The bottom of the pond is covered with up to 0.7 m of fine organic mud, consisting mostly of particles with a diameter smaller than 150 μm. The maximum depth of mud in the weedbed is 0.1 m. Underneath is fine, grey sand, similar to the beach sand on Woodend Beach. This sand is derived from greywacke alluvium carried by the Ashley River into Pegasus Bay.

Thirty visits were made to this pond between November, 1969, and March, 1972. During this period there was a regular annual rise in water level in the pond and surrounding swamp during late aututmn and winter, corresponding with the months of maximum rainfall (Table 1). The maximum depth recorded in the main pond was 1.5 m and in the weedbed, 0.75 m, on 6 September 1971. The mean depth of the weedbed was 30 cm between 28 April and 27 November 1970. The weedbed and swamp were very shallow, or dry during the warmer months of both years. The minimum depth of the main pond was 0.5 m on 24 February 1971, when the weedbed was dry; it was also dry in February 1970. Minimum rainfall occurred in February of both years (Table 1).

The area immediately surrounding the pond was not disturbed by stock during the study period, as there was an electric fence around it. On most visits, ducks (*Anas superciliosa* and *A. platyrhynchos*) and pukekos (*Porphyrio melanotus*) were seen at the pond. In October and November 1970, pukekos nested in *Juncus effusus* beside the pond. The water was fouled by their droppings during this period, and also in February, 1971. Canada geese (*Branta canadensis*) and the white faced herons (*Notophoyx novaehollandiae*) were each seen at the pond on two occasions.
chosen for detailed studies (Fig. 2).

Shipley's Large Pond is a cut-off section of a stream which previously formed part of the south branch of the Waimakariri river system. It is on Island Farm, Harewood, near the outskirts of Christchurch. Nineteen visits were made to this pond from May, 1969, to April, 1971.

The pond (Fig. 2) has an area of approximately 775 m^2 and a maximum depth of 1.0 m. The long axis lies approximately north to south. It is in a field of rough pasture and surrounding it are willow trees (*Salix* sp.) and gorse bushes (*Ulex europeaus*). The central section of the pond, 78 m long, was chosen for detailed studies (Fig. 2).

The bottom of the pond has a 0.05-0.20 m layer of fine sand and silt covering greywacke riverbed shingle. From March to June, the surface of the water in the areas overhung by trees was thickly covered with fallen willow leaves. Many of these sink to the botttom, adding to the silt layer.

There were no regular seasonal depth changes, but there was a slow depth increase from 0.60-0.85 m in the clear sampling region, and from 0.25-0.35 m in the tree overhung sampling region, between June, 1969, and January, 1971. Water levels in this pond are not directly related to rainfall, but are more affected by fluctuations in the water level of the nearby Waimakariri River (L. J. Brown, pers. comm.). The pond is fed by continuous seepage from underground water. The rainfall in this area was similar to that for Woodend Pond (Table 1).

The field by the pond was stocked with cattle and sheep during most of the study period; usually ducks and pukekos were present.

Welshman's Mill Pond (Fig. 3)

Welshman's Mill Pond is 12.9 km from Greymouth by the route through Paroa. It is situated beside Stratford and Blair's sawmill at Welshman's. The pond (Fig. 3), is approximately oval (14 by 10 m); area c. 115 m^2. It lies in a small, swampy clearing in native mixed podocarp-broadleaf forest, and is separated from the road on the west side, and the forest on the east by two parallel drainage ditches, 30 m apart, and about 1.0 m deep. Small trees and shrubs, including gorse and blackberry (*Rubus fruticosus*), surround each ditch. A logging truck road skirts the pond except at its north end, where there is a small drainage outlet. There are two small pools of permanent water in the same clearing; one of which has raupo (*Typha muelleri*) growing in it. After heavy rain, the whole of the clearing becomes covered with water, coalescing pond and pools.

Ten visits were made to this pond, between April, 1969, and April, 1971. Its depth varied very little as it was maintained by seepage and rainfall. The rainfall of this and other Westland areas (Table 1) was considerably higher than that for the Canterbury regions. The pond was deepest on 11 July 1970, when the entire clearing was under water (0.8 m in the middle; 0.45 m near the edge). The lowest water (0.65 m) was recorded on 14 March 1971, after a particularly dry February.

The bottom of this pond consisted of 0.10-0.12 m of mud overlying coarse limestone gravel.

There was little human interference until 26 October 1970, when the mill began working again, after being idle for several years. On 25 January 1971, the road end of the pond had been enlarged by a bulldozer. The mill remained working until the end of the study period. No water-fowl were seen at the pond.

Kumara Straight Pond (Fig. 4)

Kumara Straight Pond is situated approximately 19.3 km south of Greymouth, on the south side of State Highway 73, near Kumara. It is a bog pond, formed in the 1960s as part of a drainage system to convert the surrounding pakihi bog into farmland. The pond was visited five times. It is roughly oval (Fig. 4), 13 by 8 m; area c. 60 m^2. At the northeast end, an outlet (c. 0.5 m wide) joins a drainage ditch 7.5 m from the pond.

Although originally covered in native forest, no trees remain near the pond, and it is open on all sides to prevailing winds. The surrounding vegetation consists mainly of rushes (*Cladium glomeratum* and *Juncus* spp.) and grasses, with patches of taller vegetation consisting of flax (*Phormium tenax*), *Coprosma tenuicaulis*, and gorse. A small quantity of organic rubbish and scrap corrugated iron had been dumped close to the edge of the pond.

The bottom of the pond and outlet consist of rounded greywacke shingle overlain by a thin layer of fine silt. The sides show the typical soil-profile for the peaty loam soils of the Okarito and Kumara areas (Cutler 1968).

Depths were approx. c. 1.0 m at the south end, and 1.5-2 m at the north end at all visits. The water in the outlet was deepest on 26 January 1971 (0.03 m) and shallowest on 25 October 1970 (a trickle). As at Welshman's Mill Pond, there was very little seasonal variation in depth.

Hukarere Pond (Fig. 5)

This pond forms part of a drainage system on a dairy farm at Hukarere, about 25.4 km south of Reefton, on State Highway 7. The area of the pond is 116 m^2. There are two outlets (Fig. 5); one in the northeast to a culvert which runs into another pond draining banks of shingle gold dredge tailings;

TABLE 1. — Rainfall and air temperature, 1969-71.

Pond	Woodend	Shipley's	Welshman's	Kumara	Hukarere	A. Pass
Estimated altitude (m)	0	27	61	61	113	924
Climatological Station	Rangiora	Harewood	Greymouth		Totara Flat	A. Pass
Altitude (m)	45.7	29.6	4.3		77.4	738
Direct Distance from pond (km)	9	3	7.5	15	9	4
Rainfall (mm)						
Annual total 1969		382				3826
1970	601	589	2401		1983	4259
1971	522	445	2437			2881
Maximum monthly 1969		64 (May)				972 (Sept.)
1970	96 (June)	89 (Mar.)	385 (Sept.)		337 (Sept.)	883 (Sept.)
1971	116 (July)	79 (July)	373 (Oct.)			689 (Oct.)
Minimum monthly 1969		8 (Mar.)				87 (Nov.)
1970	15 (Feb.)	15 (Feb.)	81 (Feb.)		52 (Feb.)	59 (May)
1971	10 (Feb.)	11 (Mar.)	104 (July)			86 (Jan.)
Air temperatures (°C)						
Maximum daily mean 1969		22.3 (Dec.)				
1970	18.1 (Jan.)	18.0 (Jan.)	21.7 (Jan.)		23.5 (Jan.)	
1971	16.2 (Jan.)	22.2 (Feb.)	21.8 (Jan.)			
Minimum daily mean 1969		—0.4 (June)				
1970	6.8 (July)	6.9 (July)	5.3 (July)		0.7 (May)	
1971	7.5 (Aug.)	1.2 (July)	1.5 (July)			

the other a ditch (4.5 m wide) which runs into pastures from the southwest corner of the pond. The pond is sheltered from prevailing winds in the north by high banks of tailings, and a few willow (*Salix* sp.) trees. Gorse and blackberry grow nearby.

This pond was visited in January, March, and July, 1970. It had a flat bottom, and was 0.8 to 1.0 m deep on all visits. The bottom was covered with submerged dead tree branches. There was a layer of sand 0.1 m thick overlying greywacke gravel.

The only waterfowl seen near the pond were pukekos, but these did not foul the water as at Woodend Pond as it was too deep for them to wade in.

Arthur's Pass Tarn (Fig. 6)

Arthur's Pass Tarn is one of several small bog pools near the summit of Arthur's Pass, on State Highway 73. The tarn (Fig. 6) is approximately circular; diameter 6.0 m, and area 35 m^2. It has a small wooden trough for an outlet, which leads into another small pool. The vegetation of this area and other similar alpine cushion bog areas has been described by Burrows (1969).

The tarn was visited in May 1969, January 1970, and October 1971. The substrate consisted of particles of dark humus, mostly about 150 μm in diameter. A few large greywacke boulders projected from the water. The tarn was 0.2-0.4 m deep on all visits. The pools become connected by a sheet of water after periods of exceptionally heavy rain, and they are covered by ice and snows for most of the winter. This pond is within the high rainfall area of Westland (Table 1).

PHYSICO-CHEMICAL CONDITIONS

Temperatures

Air, and water (0.15-0.20 m below the surface) temperatures were taken at each pond visit, using a centigrade mercury thermometer. All visits were made during daylight hours, though the time of day varied considerably. At Woodend Pond from 20 October 1970 until 3 April 1971, a Foxboro continuous temperature recorder was set up beside the pond, with one probe in the weedbed water, and the other in the air. The water probe stopped working on 6 February 1971. At Welshman's Mill Pond a maximum-minimum thermometer was set up by the pond in March 1970. A local resident took readings from this thermometer and also air and water temperature readings periodically between 19 April and 26 October 1970.

Table 1 shows monthly mean daily maximum and minimum air temperatures for climatological stations near each pond. There was no marked difference in these temperatures between the Canterbury and Westland regions. Mean temperatures for Arthur's Pass were not available, but these would have been lower than for the other localities, because of the higher altitude. A comparison of absolute maximum and minimum air temperatures beside Woodend Pond (Canterbury) and Welshman's Mill Pond (Westland) (Table 2) indicates that much higher temperatures were reached at Woodend. These higher temperatures occurred during periods when warm northwesterly (föhn) winds prevailed (de Lisle 1969).

The overall recorded range of water temperatures for the ponds (Table 2) was from 5°C to 28°C. This is slightly less than the temperature range measured in other New Zealand ponds (Stout 1975). The smaller ponds, particularly Woodend and Welshman's, became very warm in summer. This may be related to their small volumes (Macan 1963) and to their sunny positions, sheltered from prevailing winds. Winter temperatures at Woodend Pond were by contrast, very low. No indication of minimum winter water temperatures in Welshman's Mill Pond is available. Kumara Straight Pond, which is deeper and is exposed

TABLE 2. — Minimum and maximum air temperatures and water temperatures 0.15-0.20 m below surface (°C).

	Woodend Pond			Shipley's	Welshman's Mill			Kumara	Hukarere	A. Pass
	Air		Water	Water	Air		Water	Water	Water	Water
1969 June				5*						*
July										
Aug.										
Sept.										
Oct.							23			
Nov.			25							
Dec.								24		
1970 Jan.							28			
Feb.			21							
Mar.							24	20	19	
April			14		3	27	11-14			
May					-2	23	8-13			
June					-8	17				
July			7*		0	15	10	11	10	
Aug.						11				
Sept.			14			25				
Oct.	2	37	11-18	14	-1	21	19	22		
Nov.	1	37	11-22	18	4	28				
Dec.	3	29	14-23	18			27			
1971 Jan.	4	29	14-26	17	7	31	28	25		
Feb.	2	36	15-24	22	6	31				
Mar.	0	36	19	15			26			
April	0	33	14	17			18			
May			11							
June			9							
July			6							
Aug.			9							
Sept.			12-18							
Oct.			12-13							14
Nov.										
Dec.			24							

* ice on surface

to prevailing winds, showed a smaller temperature range. Only one temperature reading was available from Arthur's Pass Tarn, but the tarn probably shows a wide range of temperature variation because of its small volume and exposed position. Holmes (1973) obtained temperatures ranging from 0 to 17.5°C in Lake Blimit, which is a small, shallow lake, also in the Arthur's Pass National Park, at altitude 1733 m.

The temperatures of Shipley's Large Pond were generally lower than those of Woodend and Welshman's ponds over summer because of its larger volume, shading of the water by trees, and inflow of cool spring seepage water. Both Teirney (1971) and Field-Dodgson (1972) recorded surface water temperatures ranging from 9-18°C during March and April for two ponds which have the same water source, on Isaac's property nearby. Similarly, Hukarere Pond would probably never become very warm, as it has a large volume and a continuous source of cool stream water.

Differences occurred in surface to bottom temperatures in all ponds (Table 3) except the shallow Arthur's Pass Tarn for which only one reading is available. All temperatures were taken on relatively calm days when there was little mixing of the water by wind. Marked stratification occurred around mid-day in the warmer months at Woodend, Welshman's and Kumara Straight Ponds.

TABLE 3. — Surface to bottom variations in temperature (°C).

Pond	Details	Wind direction	Date	Time (hours)	Temperatures (°C) Air	Surface	Bottom
Woodend	main pond	south	4 Nov. 1969	1200	16.0	26.5	18.0
,,	,,	northwest	4 Feb. 1970	1300	23.0	24.5	21.0
,,	,, (ice over weedbed)	east	31 July 1970	1200	11.5	6.7	7.0
Shipley's Large	open area	east	13 Jan. 1971	1100	19.0	19.0	17.0
,,	,,	east	8 Feb. 1971	1500	26.0	22.5	20.0
Welshman's Mill		west	27 Mar. 1970	1300	23.0	25.5	19.0
,,		east	26 Oct. 1970	1450	21.5	19.0	17.7
Kumara		—	12 July 1970	1350	14.0	10.5	11.0
Straight							
,,		south	25 Oct. 1970	1500	17.0	23.0	14.7
Hukarere	south side	west	7 July 1970	1400	14.0	9.0	10.5
Arthur's Pass			31 Oct. 1971		15.0	14.0	14.0

At Woodend, on 4 November 1969, the air temperature was considerably lower than the surface water temperature because there had been a sudden air temperature drop within the previous hour when the wind had changed direction from northwesterly to southerly. The surface water would have warmed up during the morning, leaving the bottom water cool, as there was very little wind. When the air temperature changed, the surface water would remain warm, as water retains its heat longer than air. Such sudden air temperature changes are frequent in Canterbury. Barclay (1966) described thermal stratification in the Ardmore pond on similar calm, clear days. She found that dense vegetation also facilitates stratification. This may partly explain the extent of differences between surface and bottom temperatures at Welshman's Mill Pond between 27 March 1970, when there was a dense growth of filamentous algae over the pond surface, and a 6.5°C difference between surface and bottom temperatures, and 26 October 1970, when there was very little algal growth and only 1.3°C difference between surface and bottom. Weather conditions and air temperatures were similar on both days. At Kumara Straight Pond the marked stratification on 25 October 1970 could also be explained by the presence of dense aquatic vegetation in this pond.

Slight temperature inversions occurred at Woodend Pond, Kumara Straight Pond, and Hukarere Pond during winter. There were probably caused by overnight cooling and heat generated during decomposition at the bottom, in Woodend and Kumara Straight Ponds, where there was little water movement to mix surface and bottom waters. At Hukarere Pond, inflow of stream water near the surface could make it cooler than the bottom standing water.

Chemical Conditions: Water Samples

Conductivity at 25°C and pH were determined by appropriate meters immediately after collection. Bicarbonate alkalinity was determined by the titration method described in Mackereth (1963). Sodium and potassium ions were determined using flame photometry and calcium and magnesium using titration methods (Mackereth 1963). Table 4 shows the results of these analyses. In addition, one water sample from each habitat was analysed in more detail by the Chemistry Division, DSIR (Table 5). These samples were mostly taken after the main sampling period, and at different times of the year. Calcium and magnesium ions were measured as calcium carbonate by the DSIR and converted to compare with the author's calcium and magnesium results. Alkalinities were taken to slightly different end-point pH values according to the methods used:

Sample		Carbonate	Bicarbonate Alkalinity
Table 4;	all results	—	to pH = 4.5
Table 5;	Woodend Pond	to pH = 8.0-9.8	to pH = 3.1-4.4
Table 5;	other ponds	to pH = 8.3	to pH = 4.8

The DSIR originally used titration with phenolphthalein and methyl orange (Woodend Pond) and later used a pH meter to determine alkalinity. Using information from Tables 4 and 5 on conductivity (a measure of the total concentration of ions in solution), pH, bicarbonate alkalinity, and total hardness (EDTA), the ponds can be grouped into hard water ponds, including Woodend Pond and Welshman's Mill Pond; intermediate, Shipley's Large Pond; and soft water ponds, Kumara Straight Pond, Hukarere Pond, and Arthur's Pass Tarn. Hard water is uncommon in the lakes of Canterbury and Westland (Stout 1975), although all the New Zealand ponds studied so far have had medium to hard waters.

TABLE 4. — Water analysis data.

Date	Notes	pH	Cond. *	Alk (HCO_3^-) g/m³	Na^+ g/m³	K^+ g/m³	Ca^{++} g/m³	Mg^{++} g/m³
Woodend Pond								
4 Nov. 1969		7.6	55.2					
4 Feb. 1970	Fouled, opaque, brownish-yellow	9.0	56.8	161.5	2.74	0.04	36.4	10.21
28 April 1970	Bubbles rising	7.0	63.2	177.5	2.44	0.04	42.16	11.47
31 July 1970	Dark brown	6.7	58.0	135.5				
11 Sept. 1970		7.8	52.0	131.0				
27 Nov. 1970	Brown	7.7		126.0				
5 Jan. 1971	Dark brown	7.8	31.1	145.0				
Shipley's Large Pond								
11 June 1969		6.4	4.5					
24 March 1970	Clear, greenish-brown	6.1	9.6	31.0	1.0	0.006	8.64	1.14
13 Jan. 1971		6.7	9.9	32.0				
Welshman's Mill Pond								
5 April 1969			18.0	118.0				
15 Oct. 1969		8.5	40.0					
27 Mar. 1970	Blackish-brown	8.4	40.0	122.0	1.35	0.009	43.32	0.80
11 July 1970		6.5	13.6	58.0				
26 Oct. 1970	Brown	7.5	26.6	138.0				
25 Jan. 1971		6.9	30.9	125.0				
Kumara Straight Pond								
22 Dec. 1969		5.1	7.0	4.0	1.0	0.048	1.84	0.73
29 Mar. 1970	Reddish-brown	6.4	5.5	4.0	1.31	0.004	1.76	0.32
12 July 1970	Blackish-brown	5.3	5.6	3.5				
25 Oct. 1970		6.0	3.9	4.0				
26 Jan. 1971		6.6	4.1	4.5				
Hukarere Pond								
11 Jan. 1970	Yellow-brown, clear to bottom	6.7						
26 Mar. 1970		6.1	7.2	11.0	1.31	0.006	2.0	1.0
7 July 1970		5.5	6.8	9.5				
Arthur's Pass Tarn								
All visits clear to bottom					no data			

* Millisiemens/cm

TABLE 5. — Water chemistry (analysed by Chemistry Division, DSIR, Christchurch).

Sampling date	Woodend Pond 4 Apr. 1971	Shipley's Large Pond 12 Mar. 1974	Welshman's Mill Pond 6 Oct. 1973	Kumara St. Pond 6 Oct. 1973	Hukarere Pond 15 Nov. 1973	Arthur's Pass Tarn 29 Jan. 1974
Colour (A.P.H.A. Hazen Units)	125		40	150	35	
pH	7.9	6.8	8.8	5.6	6.3	
Grams per cubic metre:						
Nitrate nitrogen	0.1	0.05	<0.05	<0.05	0	
Nitrite nitrogen	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ammoniacal nitrogen	<0.005	0	<0.02	<0.02	<0.005	
Albuminoid nitrogen	0.72	0	0.02	0.16	0.25	
Total organic nitrogen	2.5	0	0.6	9.4	0.7	
Oxygen absorbed*	39	0	9.6	18.4	9.8	
Carbonate alkalinity	0	0	10	0		
Bicarbonate alkalinity	153	35	132	4	9	
Hardness total (EDTA)**	142	31	131	6	11	4
Calcium	38.0	11.0	52.0	2.0	3.2	1.2
Magnesium	11.28	1.0	0.5	0.5	0.72	0.2
Free CO_2 (calculated)	4	0		15	9	
Total dissolved solids	350	65	195	65	150	
Total suspended solids	High	0	0	0	0	
Chloride	269	1	7	6	3	<1
Sulphate	0	7	0	0	0	
Iron (as Fe)	0.08	<0.04	<0.04	0.28	0.6	<0.04
Reactive Silica (as SiO_2)	38	12	4	2	4	3
Manganese	<0.1	0	0	0	0	
Total phosphorus	0.12	0	0	0	0	
Soluble phosphorus	<0.01	0	0	0	0	

* Woodend Pond (4 hours at 27°C) x 3
Other Ponds 30′ at 100°C

** as $CaCO_3$

About one-third of the hardness of Woodend Pond was due to magnesium ions (Tables 4 and 5). This high magnesium content probably results from the pond's proximity to the sea, as does the fact that chloride, sodium and potassium ions are also higher at Woodend Pond than in any other ponds.

The amount of reactive silica at the ponds is related to the presence or absence of greywacke in their sand and gravel substrates. The Woodend Pond substrate is sand consisting of greywacke and quartzite particles (Knox 1969). This pond has the highest reactive silica content. Similarly, Shipley's Large Pond is on greywacke shingle and is also high in reactive silica.

Woodend Pond, although usually alkaline, showed wide fluctuations in pH and alkalinity throughout the year. These fluctuations could be expected in such a small body of water. Alkalinity was low in winter when water level was high, and higher in late summer and autumn when water level was low and amounts of algae and rooted vegetation were maximal. The pH of 9.0 on 4 February 1970 was probably caused by the fouling of the water by pukeko droppings. On this date, dissolved oxygen measured by the Winkler technique was very low (7.62% saturation).

On 4 April 1971, when the water level was still low, and conditions were similar to those in April, 1970, total organic nitrogen was 2.5 g/m^3, and total phosphorus 0.12 g/m^3 (Table 5). These results indicate that the pond was eutrophic at this time and are similar to those obtained for South Block Pond, Geraldine, by Woods (1973). Albuminoid nitrogen was highest at Woodend Pond (Table 5), and the value recorded compares with those found by Barclay (1966), Livingstone (1970) and Woods (1973). All these ponds are highly productive.

On 29 March 1971, the amount of organic matter in the mud at Woodend pond was estimated as 21.5% (loss on ignition technique: Metson 1956). This high value indicates (as was evident from the smell) much decomposing organic matter in the mud. Nitrate nitrogen a month later was 0.1 g/m^3 (Table 5), a similar value to that found by Livingstone (1970) in Spectacles Lakes. The amount of oxygen absorbed was also very high. Both these measurements further indicate that there was much decomposition occurring in Woodend Pond in autumn, 1971.

Welshman's Mill Pond, although comparable to Woodend Pond in total mineral content (Tables 4 and 5), was much less productive and much less decomposition occurred in it. The very high calcium content of this pond in analyses was related to its substrate of limestone gravel. As at Woodend Pond, alkalinity decreased markedly in winter.

In March, 1974, Shipley's Large Pond had some nitrate nitrogen detectable in the water, probably resulting from decomposition of the dissolved solids. This pond is poor in nutrients at this time of the year, although rich in minerals. It is similar in this respect to the nearby Isaac's ponds (Field-Dodgson 1972; Teirney 1971).

Of the soft water ponds, Kumara Straight Pond, at the time of sampling, had the highest total organic nitrogen value recorded in any of the ponds. Table 5 also shows that this pond had the most colour (A.P.H.A. Hazen Units) of any of the six ponds. The dark brown colour probably indicates that the water is high in organic matter, as Tucker (1958) found that a correlation could be made between the brownness of pond water and its dissolved organic matter content. The combination of high organic matter, relatively low productivity (as indicated by albuminoid nitrogen), and acid pH characterizes this pond as a dystrophic habitat. The organic rubbish which was dumped at the roadside, partly in the pond would have increased the input of decomposing organic matter, and may partly account for its high oxygen absorbed value.

TABLE 6. — Algae present in samples showing relative abundance where estimated.

Pond Sampling Date	Woodend 3 Feb. 1971	Shipley's (a)	 (b)	 (c)*	Welshman's 27 Mar. 1970	Kumara 12 July 1970	Hukarere 7 July 1970
Euglenophyceae:							
Euglena	r					r	
Phacus	r						
Trachelomonas	r						
Chlorophyceae:							
Volvocales:							
Chlamydomonas		p				r	
Chlorogonium	r						
Chlorococcales:							
Dictyosphaerium	r					r	
Pediastrum	f	p		p			p
Ankistrodesmus	f			p			
Oocystis	r			p			
Tetraedron	c						
Crucigenia	r						
Scenedesmus	r						
Actinastrum hantzshii	a						
Tetrastrum	r						
Ulotrichales:							
Microspora		p				r	
Cylindrocapsa		p					
Geminella		p				r	
Gleotila						r	
Siphonocladales:							
Rhizoclonium		p					
Oedogoniales:							
Oedogonium	p	p		p		r	
Bulbochaete		c	a	p		r	
Conjugales:							
Cylindrocystis				p		r	
Netrium						r	
Mougeotia				p		f	f
Hyalotheca						r	
Spirogyra		p		p	a		
Zygnema			f	p	a		
Zygogonium						c	
Closterium	r			p	p	r	p
Cosmarium		p		p		r	p
Desmidium						r	
Micrasterias				p			p
Euastrum						r	

Pleurotaenium		p				r	
Spondylosium		p					p
Cosmocladium		p					
Staurodesmus		p					
Staurastrum						r	
Triploceras		p				r	
Nitella hookeri		p	p	p			
Dinophycae:							
Gymnodiniales:					p		
Gymnodinium						r	
Perediniales:							
Peridinium						r	
Xanthophyceae:							
Heterochloridales:							
Botryococcus			f				
Heterococcales:							
Centritractus	r						
Heterotrichales:							
Tribonema						a	
Chrysophyceae:						f	
Synura						r	
Bacillariophyceae:							
Fragilaria							c
Tabellaria				p		r	c
Rhoicosphenia		p	f	p			
Epithemia		c	c	p			
Gomphonema	p						
Navicula		c	c	p			c
Nitzschia acicularis	r						
Pinnularia			c				
Myxophyceae:							
Chrococcales:							
Anacystis		p		p			p
Chrococcus				p			
Coccochloris				p			
Nostocales:							
Oscillatoria		c	f				
Anabaena				p			
Nostoc				p			
Calothrix		p					
Tolypothrix				p			
Stigonematales:							
Stigonema						r	
Nodularia			r				
Cryptophyceae:							
Cyptomonas						r	

* (a) 24 March 1970
(b) 18 June 1970
(c) 8 February 1971

Abundance: a = abundant
c = common
f = few
r = rare

Woods (1973) found that a dead cow at one end of South Block Pond had a profound effect on the water chemistry of this pond.

Hukarere Pond, as well as having a low mineral content, was (at the time of sampling) also poor in nutrients, although the albuminoid nitrogen is higher than in Kumara Straight Pond. This could be partly because the sample was taken a month later in the spring. Organic matter and decomposition, as indicated by total organic nitrogen, oxygen absorbed, and colour, were considerably less at Hukarere than at Kumara Straight Pond. Hukarere and Kumara Straight ponds had the highest iron contents of all the ponds, which is to be expected in soft waters which are very low in bicarbonate (Wetzel 1975), and is often found in Westland lakes (Stout 1975).

Finally, Arthur's Pass Tarn had the purest water of all the ponds, which was to be expected, as it was constantly replenished by rainwater, and melting snows.

Rain and snow should be free of industrial pollutants in this remote area. Its water chemistry is similar to that of Lake Blimit (Holmes 1973).

VEGETATION

The macrophytic flora in and surrounding the ponds was noted on each visit. Algae were examined at irregular intervals from weed samples from Woodend Pond weedbed, Shipley's Large Pond, Welshman's Mill Pond and Hukarere Pond. In addition, water samples from Woodend Pond, Kumara Straight Pond and Arthur's Pass Tarn were examined by Dr E. A. Flint, to identify free-floating algae.

Woodend Pond

Myriophyllum propinquum was the dominant plant in the inner circle of rooted vegetation in the weedbed area of Woodend Pond (Fig. 1), except during the winter months of 1971, when it was codominant with *Rorippa microphylla* and *Agrostis stolonifera*. *Rorippa microphylla* was only present from July until December, 1971. Other plants which were present throughout the study period, but were less abundant around the weedbed in the outer circle and swampy verge, were: *Mimulus guttatus, Myosotis caespitosa, Ranunculus sceleratus, R. sardons, Rumex crispus* and *R. conglomeratus*. These plants flowered over the summer months. *Veronica anagallis-aquatica* was present in April, 1970, *Callitriche stagnalis* until October, 1970, and *Azolla rubra* was present in November, 1970, and May, 1971, only. *Cotula coronopifolia* was present throughout the study period, and it formed a large mat on the mound side of the pond during January, February, and March, 1971, while the water level was low. *Eleocharis acuta* was very abundant in the outer weedbed on the swamp side of the pond. *Juncus articulatus* was also found there, but was less abundant.

Table 6 lists the free-floating algae which were present in a sample of Woodend Pond water collected on 3 February 1971, when the community was dominated by Chlorococcales. The sparseness of Conjugales and absence of Myxophyceae is an indication that the water is alkaline, probably rich in calcium and magnesium. The large number of genera such as *Tetraedron* and *Euglena,* usually associated with pollution, further indicates that the water was rich in nitrates and phosphates. Water analysis results given in Table 5 correlate well with these algal indicators.

A sample of algae from the weedbed was examined on 19 July, 1971, when the growth of filamentous algae amongst the rooted vegetation and in pools in the surrounding swamp was at its height. The following algae were found:

Chlorophyceae	
Oedogoniales	*Oedogonium* sp.
Bacillariophyceae	
	Eunotia sp.
	Gomphonema sp.
Xanthophyceae	
Heterosiphonales	*Vaucheria* sp. (Abundant)
Heterotrichales	*Tribonema* sp.

There were many epiphytic diatoms on the filaments of *Oedogonium, Vaucheria,* and *Tribonema* spp.

Shipley's Large Pond

In the clear sampling region (Fig. 2) rooted vegetation consisted of *Myriophyllum propinquum* growing over the bottom, and *Potamogeton cheesemanii* and *Juncus articulatus* growing only near the waters' edges. Amongst the *Juncus* and *Potamogeton* leaves which reached the surface were the floating plants *Azolla rubra, Lemna minor, Spirodela oligorrhiza,* and *Wolffia arrhiza.* In November and December, 1970, patches of *Rorippa microphylla* and *Myosotis caespitosa* also appeared at the pond's edge.

The tree-overhung sampling region was shallow enough for all the rooted vegetation to reach the surface. The same plants were present, *Juncus, Potamogeton* and the floating plants were not confined to the edge (Fig. 2). *Myosotis* was present here throughout the sampling period, also *Mimulus guttatus* and *Gratiola sexdentata.* In the clear sampling region 20 to 50% of the water surface was covered by vegetation, and in the tree overhung region, 80 to 100% of the surface was covered. Maximum surface cover occurred in summer and autumn 1970 and 1971.

During early summer 1970, and autumn of 1970 and 1971, filamentous algae were abundant amongst the rooted vegetation. These were examined on three occasions (Table 6). In the two late summer samples, a wide variety of genera were present, including a large number of Chlorophyceae, especially Conjugales. This abundance of Conjugales indicates that the pond is oligotrophic, and the presence of *Rhizoclonium* sp. (Cladophoracea) on 24 March 1970 could indicate that the pond was well aerated (Chapman 1962).

In the winter (June) sample, diatoms were dominant, although *Bulbochaete* was also abundant. Diatoms favour cooler conditions than do green algae. Teirney (1971), recorded a change in dominance from green algae to diatoms in nearby Play Pond, between March and May, 1971.

Welshman's Mill Pond

Two rooted plants were present in Welshman's Mill Pond: *Potamogeton cheesemanii* and *Eleocharis acuta. Potamogeton* occurred sporadically all over the bottom, and was present throughout the sampling period (April 1969—April 1971). In summer, its leaves covered up to 80% of the surface. *Eleocharis* was found only at the mill end of the pond. The following plants grew around the pond: *Carex virgata, Agrostis stolonifera, Juncus articulatus, J. gregiflorus, Eleocharis acuta, Scirpus prolifer, Plantago media, Lotus major, Acaena anserinifolia, Ranunculus repens, Myosotis caespitosa, Rumex conglomeratus,* and *Prunella vulgaris.*

Small patches of filamentous algae, consisting mainly of *Spirogyra* and *Zygnema* spp., were present at all times of the year. From October 1969 until March 1970 this algal growth was very dense, covering half the surface of the pond, and on 30 December 1969 oxygen bubbles were present among the algae. By July, 1970, only 20% of the surface was covered with algae, which were mostly dying. The growth began to build up again by October, 1970, until in January, 1971, 40% of the surface was covered. A cursory examination of this algal growth was made on 27 March 1970 (Table 6).

Kumara Straight Pond

Agrostis stolonifera, Scirpus inundatus, Juncus bulbosus and *J. canadensis* grew in the water at Kumara Straight Pond. *Juncus canadensis* formed the basis for floating mats of vegetation which covered 80% of the surface of the pond, except on 29 March 1970, when only half the surface was covered. Immediately around the pond were the following plants, *Scirpus inundatus, Juncus canadensis, Agrostis stolonifera, Holcus lanatus, Anthoxanthum odoratum, Lotus pedunculatus, Baumea rubiginosa, Taraxacum* sp., *Coprosma tenuicaulis, Centella uniflora, Pratia ungulata,* and *Hypochaeris radicata. Sphagnum falcatulum, Blechnum* sp. and *Lotus pedunculatus* were present around the outlet.

Patches of filamentous and epiphytic algae were present around the *Juncus* and *Scirpus* stems in the pond at the time of all collections. A sample collected with a pond net (mesh 142 μm) was examined by Dr Flint (Table 6). There were a large number of species and individuals present including littoral diatoms, which are not shown in the table, and Chrysophyceae, which were epiphytic on the filamentous algae. The only genera which were common or abundant were *Tribonema* and *Zygogonium.*

Hukarere Pond

Between 10 and 20% of the surface of Hukarere Pond was covered with vegetation throughout the year. This consisted of floating patches of *Potamogeton cheesemanii,* and, in the ditch area (Fig. 5), an undescribed angiosperm. The following plants grew around the edges and into the water: *Carex secta, Juncus effusus, J. canadensis, J. bulbosus, J. acuminatus,* and *Myosotis caespitosa.*

On 11 January and 26 March 1970, there were masses of filamentous and epiphytic algae growing around the stems of the *Juncus* spp. Smaller patches were present on 7 July 1970 and were examined in the laboratory (Table 6). Most of this algal mass consisted of Conjugales and Bacillariophyceae, and *Oscillatoria* sp. was also common.

Arthur's Pass Tarn

Rooted vegetation in this tarn consisted of a *Juncus* sp., stems of which projected over the entire surface. Small patches of filamentous algae were seen on all three visits. A water sample examined from the 14 January 1970 collection contained *Navicula* sp. and *Closterium compactum.*

FAUNA

Faunal collections were made during all visits to the ponds. On 11 June 1969, several sampling methods were tried at Shipley's Large Pond. From these, three methods were selected:

1. Pond net sampling using a 0.2 m diameter net (mesh aperture 142 μm).
2. Sampling rooted vegetation using a Wisconsin trap with jaws enclosing 0.02 m^2 (Welch 1948).
3. Core sampling for bottom fauna using the saw-toothed cylinder sampler described by Macan (1964). This sampler was used for qualitative sampling only. In addition, an ordinary drag plankton net, 0.15 m in diameter (mesh aperture 84 μm) was used at Woodend Pond on 10 August 1971.

Samples were always taken amongst vegetation, using the pond net. There was considerable variation in the quantity of material collected on different collection dates, as well as in the total numbers of collections at each pond. Samples from open water and of bottom sediments were taken seasonally. Relative abundances of species were usually estimated as abundant, common, few, or rare (Byars 1960).

At Woodend Pond, on 10 August 1971, quantitative samples were taken by means of standard sweeps of the pond net covering 1.0 m^2, from the open water, various parts of the weedbed, the mud at the bottom, and pools in the swamp surrounding the pond. Samples were preserved in formalin and sieved through 1.0 mm, then 0.4 mm meshes. The three fractions of the sample thus obtained were processed separately. Animals were counted directly from the portion which did not pass through either sieve. The two sieved portions were each made up to 250 ml and subsampled using a 2.5 ml plankton sampler. Numbers of animals in 15 ml were counted under the binocular microscope in perspex counting squares and converted to numbers per 250 ml. Numbers of each species in the three portions of the sample were then added together.

Rotifers were noted in all the ponds except Hukarere and Arthur's Pass in at least one collection. Gastrotrichs were seen in Woodend and Shipley's Large Ponds. Aquatic nematodes were present in all ponds except Arthur's Pass.

The freshwater coelenterate *Chlorohydra viridissima* was seen at Shipley's Large Pond in February 1971, and at Kumara Straight Pond, where it was present in small numbers in all collections.

All the ponds contained oligochaetes of the Family Tubificidae in the bottom sediments. *Chaetogaster* sp. (Naididae) was seen in February and March 1971 in Shipley's Large Pond. Lumbriculidae species were also present in most collections from Woodend, Shipley's, Welshman's and Hukarere ponds. These were found amongst vegetation as well as in bottom samples.

The frequency and seasonal distribution of Turbellaria and Mollusca at the ponds is summarized in Table 7. The number of species of these two groups present is greatest in Woodend, Welshman's Mill, Shipley's Large, and Hukarere ponds. These ponds have the highest hardness and calcium concentrations (Table 5). Although Hukarere Pond is a soft-water pond, it has a large amount of dissolved solids. Macan (1963) recognized the Turbellaria and Mollusca in fresh waters as groups to which the presence of abundant dissolved calcium in the water is favourable. Tucker (1958) studied these groups in a series of ponds in Britain. He found that the numbers and diversity of species in a habitat became greater as the hardness of the water increased. Numbers were also greater where there was a large amount of dissolved organic matter, as at Hukarere Pond. There are no Turbellaria or Mollusca at Kumara Straight Pond, which has an acid pH and low calcium content. Only one mollusc species was found at Arthur's Pass Tarn.

The triclad turbellarian *Cura pinguis* was present at Shipley's Large, Welshman's Mill and Hukarere ponds (Table 7). It is common throughout New Zealand in the littoral zone of lakes and in streams and ponds, living on stones and in rooted vegetation. The rhabdocoele *Phaenocora* sp. was present at Woodend and Welshman's Mill Ponds. There were four species of rhabdocoele at Woodend Pond, including *Mesostoma ehrenbergii,* which was recorded by Stout (1953) from a lagoon in the Wairarapa district. On 10 August 1971, *Mesostoma ehrenbergii* and two unidentified species of black rhabdocoele were found only in the shallowest part of the weedbed, whereas *Phaenocora* sp. was present in the mud sample taken at the inner edge of the weedbed.

All the Mollusca listed in Table 7 are widely distributed throughout New Zealand (Winterbourn 1973). *Potamopyrgus antipodarum* was common or abundant at all ponds except Kumara Straight and Arthur's Pass.

Sphaeriidae were also present, in the bottom sediments, of all except Kumara Straight and Hukarere ponds. *Gyraulis corinna* was present in the three hardest water ponds, but was never common. *Lymnaea tomentosa* was found only at Hukarere Pond. The distribution of *Physa* sp. and *Physastra variabilis* follows that described by Winterbourn (1973). The two species are not usually found

TABLE 7. — Turbellaria, Mollusca, Crustacea, and Hydracarina collected in the ponds. A summary, from all samples, of range of abundance and seasonal distributions.

	Woodend	Shipley's	Welshman's	Kumara	Hukarere	Arthur's Pass
Turbellaria						
Rhabdocoela						
Phaenocora sp.	r-c Y		c A, V			
Mesostoma ehrenbergii	r V					
Rhabdocoele spp. 1 and 2	f Y					
Tricladida						
Cura pinguis		r-f Y	f Y		c Y	
Mollusca						
Potamopyrgus antipodarum	f-c Y	f-c Y	f-a Y		a	
Lymnaea tomentosa					c	
Gyraulis corinna	r-c Y	f Y	f			
Physastra variabilis					c	
Physa sp.	c-a Y	f-c Y				
Sphaeriidae	f	f	f Y			p
Crustacea						
Cladocera						
Simocephalus vetulus elizabethae	c V	f-c Y				
S. obtusatus				f	c Y	
Biapertura affinis		f Y			c Y	
Ceriodaphnia sp.		f S				
Chydorus sphaericus	c Y	f A	f			
C. barroisi				c		
Chydorus sp.						f
Copepoda						
Acanthocyclops robustus	f-c Y					
Acanthocyclops sp.		f-c Y	f-c	f	a Y	
Tropocyclops prasinus					a Y	
Tropocyclops sp.			f-c	f		
Eucyclops sp.		f-c Y				
Unidentified cyclopoid						f
" calanoid				r		

Ostracoda										
Herpetocypris pascheri	f	Y	f	Y	c-a	Y				
Ilyodromus sp.							f			
Cypricercus sanguineus	f-c	Y								
Cypris kaiapoiensis	c-a	Y								
Newnhamia fenestrata	c-a	Y								
Cypretta sp.			c							
Unidentified ostracod									r	
Hydracarina										
Eylais waikawae	f	Y								
Hydrachna maramauensis	f	Y	f	Y	r					
Arrenurus rotoensis	r		f	Y	f-c	Y	f		r	r
Hydryphantes sp.							c	Y		
Oribatidei			f	W						

Abundance as in Table 6.

Y = present most to all of year
W = present in winter
S = present in summer
V = present in spring (vernal)
A = present in autumn
P = present

together; *Physa* sp. is common in the two habitats near Christchurch, and *Physastra* at Hukarere Pond, which is in an area more remote from large centres of population.

The differential habitat samples from Woodend Pond on 10 August 1971 showed that *Potamopyrgus* and *Physa* were most abundant on or near the bottom of the pond and *Gyraulis* was most abundant clinging to vegetation. Only a few specimens of Sphaeriidae were found, all in the bottom mud.

The occurrence of Crustacea in all the ponds is also summarized in Table 7. All habitats had at least one cladoceran and one copepod species. All the habitats except Arthur's Pass had two copepod genera: a large *Acanthocyclops* and a smaller *Eucyclops* or *Tropocyclops*. At Woodend Pond an unidentified small cyclopoid was present in September 1970 and 1971. *Tropocyclops prasinus* and *Eucyclops* may be found in New Zealand lake plankton (Chapman, Green, Jolly 1975), but they are more common in the littoral zone of lakes.

The cladoceran species listed in Table 7 are commonly found in ponds and sheltered areas of lakes. Shipley's Large Pond was unusual in having four Cladocera, but *Ceriodaphnia* sp. was only present in midsummer.

Acanthocyclops robustus, Simocephalus vetulus elizabethae, and *Chydorus sphaericus* were present in Woodend Pond for most of the year (Table 8). All were most abundant in the samples taken between June and November, when the water level in the weedbed was high. *Chydorus sphaericus* became most abundant in early spring as at Saddle Hill Pond (Byars 1960). On 10 August 1971, *Simocephalus* was more abundant than *Chydorus* in the open water and the deeper parts of the weedbed, while *Chydorus* was more abundant in the shallow weedbed and in pools in the swamp. This difference in abundance between shallow and deeper waters is a reflection of the size of these two species; the small *Chydorus* forms part of the "aufwuchs" of the littoral zone of lakes (Winterbourn and Lewis 1975) and can inhabit places where the larger *Simocephalus* is limited by space.

Herpetocypris pascheri was the only ostracod present at more than one habitat. It is a bottom-dwelling species (Chapman 1963) and was found at Woodend, Shipley's and Welshman's ponds. *Ilyodromus* sp., another bottom-dwelling ostracod, was present at Kumara Straight Pond. All these habitats had soft sediments in which these bottom dwelling ostracods could live and feed. Table 9 shows the percentages of each of the four species of ostracod in different samples from Woodend Pond on 10 August 1971. *Herpetocypris* was common only in the bottom mud sample. The plankton net and Wisconsin trap samples contained similar percentages of each of the four ostracod species in the weedbed. *Newnhamia fenestrata* was the most common in these samples, probably because it is a good swimmer, tending to swim upside down just under the surface film (Winterbourn and Lewis 1975).

From a quantitative comparison of ostracods at the Ardmore pond, Barclay (1966) concluded that *Cypris kaiapoiensis* and *Cypricercus sanguineus* are competitors. Both species are moderate swimmers (Chapman 1963). In the present samples there were more *Cypris* than *Cypricercus* in the deeper weedbed sample, and more *Cypricercus* in the shallower weedbed. In the pools, however, percentages were similar. Table 8 shows that both *Cypris* and *Cypricercus* were present in the winter, spring and summer months, and most abundant in spring. *Cypris* was always the more abundant species and appeared earlier in April and May 1971 than *Cypricercus*.

Hydracarina were represented at all six habitats (Table 7), although only *Arrenurus rotoensis* was found at all habitats. Larvae of this species were seen on final instar larvae and adults of *Xanthocnemis zealandica*. Both *Eylais waikawae*

TABLE 8. — Relative seasonal abudance of Crustacea in Woodend Pond 1970-1971.

Collection date	*Acanthocyclops robustus*	*Simocephalus vetulus elizabethae*	*Chydorus sphaericus*	*Cypris kaiapoiensis*	*Herpetocypris pascheri*	*Cypricercus sanguineus*	*Newnhamia fenestrata*
April 1970	c	0	r	a	f	c	a
July "	f	c	c	c	r	f	a
Sept. "	f	c	f	f	c	f	a
Oct. "	0	a	f	c	f	r	a
Nov. "	f	c	f	f	c	0	a
Dec. "	—	—	—	f	f	0	a
Jan. 1971	f	0	f	c	r	0	a
Feb. "	—	—	—	0	c	0	a
Mar. "	—	—	—	0	f	0	f
April "	—	—	—	r	f	0	c
May "	f	r	r	c	f	0	c
June "	c	c	0	c	f	f	a
July "	f	c	p	a	0	f	a
Aug. "	c	c	c	a	r	a	c
Sept. "	p	a	c	a	0	a	c
Oct. "	c	a	a	a	0	a	a

Abundance as in Table 6.
0 = none in samples
— = no sample

TABLE 9. — Woodend Pond Ostracoda collection on 10 August, 1971. (% in sample)

Sampling Method	Plankton Net	Wisconsin Trap	Pond Net (1 m²)		Pond Net	
Sampling Area			Shallow weedbed	Deep weedbed	Mud	Pools by pond
Cypris kaiapoiensis	17.58	20.39	9.89	51.82	23.72	36.89
Herpetocypris pascheri	0	5.49	0.06	0	75.64	3.60
Cypricercus sanguineus	3.39	10.19	73.64	4.64	0.64	39.46
Newnhamia fenestrata	79.03	63.92	16.41	43.54	0	20.05

TABLE 10. — Occurrence and maximum abund ance of Insecta in the ponds, from all samples.

	Woodend	Shipley's	Welshman's	Kumara	Hukarere	Arthur's Pass
Odonata						
Xanthocnemis zealandica	a	a	c	c	c	f
Austrolestes colensonis	c	c	f	c	f	
Procordulia grayi	r	r	r	r		
P. smithii					r	
Aeshna brevistyla		p	r	f	f	
Diplacodes bipunctata			(adult seen)	r		
Trichoptera						
Triplectides cephalotes	c	f			f	a
T. obsoleta			a			
Leptoceridae				r		
Oxyethira sp.	f	r			r	
Paroxyethira sp.	f	f	c		c	
Hydroptilidae				r		
Hemiptera						
Microvelia macgregori	a	c	c	a	a	
Diaprepocoris zealandiae		c		r	r	
Sigara sp.	a		f	r		c
Anisops sp.	a		f		r	
A. assimilus		c				
Lepidoptera						
Nymphula nitens		r	f		r	
Lepidoptera	c					
Coleoptera						
Antiporus strigosulus		r	r			
Homoeodytes hookeri	f					
Liodessus deflectus	c	f	p			
Rhantus pulverosus	f					
Diptera						
Anatopynia antarctica	p	c	c	a	a	f
Tanypodinae		c				
Orthocladiinae	c	a	c	a	a	
Tanytarsini				a	a	
Chironomus zealandicus	c	a	c		f	c
Culicidae	c	f	p	f		f
Dixidae			f			
Ceratopogonidae	f	f	f	f	f	
Stratiomyiidae	c	c	f	f		
Muscidae						r
Syrphidae	p					
Ephydridae	t	r				
Tipulidae		p				
Paralimnophila skuzei			r			

Abundance as in Table 6.

and *Hydrachna maramauensis* have as their hosts *Sigara* and *Anisops* spp. (Stout 1953). Larvae were in fact found only on *Anisops* spp. in these habitats. This may explain why *Hydrachna* adults were found at Woodend, Shipley's and Welshman's ponds, where *Anisops* were reasonably common (Table 10). *Eylais* was found only at Woodend Pond. An undescribed *Hydryphantes* species was common at Kumara Straight Pond. No parasitic stages were seen.

Unidentified specimens of free-living Oribatidei were found feeding on alga at Shipley's Large Pond on 18 June 1970.

The insect fauna of the ponds is shown in Table 10. Total numbers of insect species reflect the age, size and overall trophic nature of the ponds. Thus Woodend Pond, which contains more nutrients and had algae which indicated its eutrophic nature, had a total number of 43 species of animals including 21 insect species. Similarly, Shipley's Large Pond had the greatest number of species (45), and insect species (22). Shipley's is a larger, older and more varied habitat than Woodend, although it is less eutrophic (compare Table 2). The Westland ponds had totals of 35 (Welshman's), 27 (Kumara), and 28 (Hukarere) species and 20, 16 and 16 insect species respectively. Arthur's Pass Tarn, the smallest and more oligotrophic habitat, had a total of only 13 species, including 7 species of insects.

The distribution of Dytiscidae (Coleoptera) in the habitats reflects the water chemistry. Ordish (1967) noted that alkaline conditions favour this group. In these habitats, there are no dytiscids in the three acid, soft-water ponds, and two or three species in the ponds which tend to be alkaline: Woodend, Shipley's and Welshman's (Table 4). Similarly at Coleridge Kettle Hole (Stout 1969), which is highly alkaline, there are at least five species of dytiscid beetles.

Most of the insect species in these ponds live in areas of aquatic weeds. The Zygoptera *Xanthocnemis zealandica* and *Austrolestes colensonis* rely on plants for oviposition sites, and the Leptoceridae (including *Triplectides cephalotes* and *T. obsoleta*), need plant material for case building. *Aeshna brevistyla* is an anisopteran whose larva clings to weed while it awaits its prey. All the Trichoptera, *Nymphula nitens,* and the dipteran groups Tanypodinae (including *Anatopynia antarctica*), Orthocladiinae, and Tanytarsini, live and feed amongst the weed. They are also typical of macrophyte zones in New Zealand lakes (Winterbourn and Lewis 1975). Stratiomyid and ephydrid larvae and pupae were also found amongst weed.

The pond skater, *Microvelia macgregori,* was present at all habitats except Arthur's Pass. All habitats had at least one corixid, *Sigara* or *Diaprepocoris,* and usually *Anisops* as well. *Diaprepocoris zealandiae,* which is limited to more stable water bodies because it has no flying form (Young 1962), was found only at the larger, more permanent ponds.

Sediment dwellers in the ponds included the two *Procordulia* species, and Ceratopogonidae larvae. Both of these groups were absent at Arthur's Pass Tarn, where there was very little bottom sediment. *Procordulia smithii* larvae, which are usually flowing-water dwellers (Penniket 1966), were found at Hukarere Pond, where there was water movement through the pond. This movement may also explain the absence of Culicidae larvae at Hukarere, as Culicidae usually breed in still waters. They were present in all the other habitats. Several other dipteran groups (the Dixidae, Muscidae, Syrphidae and Tipulidae) were only represented occasionally. These groups are mostly semiaquatic. *Paralimnophila skuzei* is always sparsely distributed, and is never numerous (P. Johns, pers. comm.).

Bullies (*Gobiomorphus breviceps*: Eleotridae) were present in Shipley's Large Pond and Kumara Straight Pond. *Anguilla australis,* the short-finned eel, were seen in Woodend Pond in August and October 1971. On 1 October 1971, an electric fishing machine (Burnet 1959) was used in this pond. Three small eels were seen. Eels could easily reach Woodend Pond during the winter through the swamp and numerous drainage ditches surrounding the pond, and possibly from nearby Woodend lagoon, which is close to the sea.

Tadpoles were present at Woodend, Shipley's and Welshman's ponds over the spring, summer, and autumn months. Green frog (*Hyla aurea*) tadpoles were found in all three ponds, and whistling frog (*Litoria ewingii*) tadpoles in Welshman's Mill Pond only. This latter species was originally widely distributed in Westland, spreading to other parts of the country in recent years (Robb 1973).

DISCUSSION

Although the six ponds described in this paper were all selected for their permanency and the presence of aquatic macrophytes in which *Xanthocnemis zealandica* and *Austrolestes colensonis* live, they covered a wider range of physical and chemical conditions than those in the other New Zealand pond studies quoted. There was a correspondingly large variation in numbers and diversity of the flora and fauna of the ponds. Only three invertebrate species were present in all six ponds: *Xanthocnemis zealandica, Anatopynia antarctica,* and *Arrenurus rotoensis*. Of these, the two insect species both belong to groups which are found in a wide variety of aquatic habitats (Roback 1974) and which contain species tolerating a wide range of chemical and physical conditions. The larval stage of *Arrenurus rotoensis* was found to parasitize *Xanthocnemis*.

Hardness of the water was perhaps the most important single factor relating to this biological diverstiy. Both Macan (1957 and 1963) and Tucker (1958) have related species and diversity of fauna in a large number of British ponds to the pond waters' hardness and calcium ion concentrations. The overall range of hardness in these British ponds was comparable with that in New Zealand ponds, but there were more invertebrate species in British ponds with calcium concentrations over about 10 g/m^3 than in the New Zealand ponds. This is probably because many invertebrate groups, such as the Hirudinea and Mollusca, are poorly represented in New Zealand. However, the New Zealand ponds did have a comparable number of turbellarian species.

Within New Zealand, Woodend Pond may be compared with Saddle Hill, Marley's, and Ardmore ponds (Stout 1975), in that it is small, rich in nutrients, and has a high chloride content because it is close to the sea. Like Ardmore Pond (Barclay 1966), it has a rich ostracod fauna, especially in the winter and spring months when the encircling weedbed and swamp are filled with water. Rhabdocoeles were also abundant at Woodend Pond, which had four species, three of which are undescribed.

Shipley's Large Pond, which had the same groundwater source as the nearby Isaac's Play Pond (Teirney 1971), and Swan Lake (Field-Dodgson 1972), was similar in physical and chemical parameters to these ponds. However, it had a greater diversity and abundance of flora and fauna than either of the Isaac's ponds probably mainly because it is longer established.

The ponds in the high rainfall areas of Westland were acid, with soft waters, except for Welshman's Mill Pond which was alkaline because of its limestone substrate. Arthur's Pass Tarn, like Lake Blimit (Holmes 1973), would experience more extreme seasonal temperature variations than the other ponds because of its high altitude.

Kumara Straight, the first bog pond to be described in New Zealand, was found to be dystrophic. Its flora and fauna were distinctive; there were several species of invertebrates present which were not found in other ponds, including an undescribed species of *Hydryphantes,* a hydrachnid which has not previously been recorded from New Zealand. The abundance of Odonata and Hydracarina and the absence of Mollusca in this pond were noticeable.

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