ECOLOGY OF THE COPLAND RIVER WARM SPRINGS, SOUTH ISLAND, NEW ZEALAND

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SUMMARY: An ecological study of the alkaline Copland River warm springs in the South Island of New Zealand was made in January 1972. Maximum water temperature was 57°C and the upper limit of the dominant alga *Mastigocladus laminosus* was 50°C. Other important species of blue-green algae present were *Synechocystis minuscula* and *Oscillatoria terebriformis*. Fifteen species of invertebrates were found between 26 and 38°C including the thermophile *Ephydrella thermarum*, which is often abundant in North Island warm springs, and the common mosquito *Culex pervigilans* which previously had not been recorded breeding in thermal waters. Observations made on warm springs at four other South Island localities are also recorded.

INTRODUCTION

In recent years the biology of thermal waters in the North Island of New Zealand has been extensively studied and the nature of the flora and fauna, and its distribution in relation to temperature, has been well documented (Brock and Brock 1970, 1971; Dumbleton 1969; Winterbourn 1968, 1969; Winterbourn and Brown 1967). In contrast, no biological studies have been made on South Island warm springs, most of which are located in relatively inaccessible valleys on the western flank of the Southern Alps (see map in Ellis and Mahon 1964). Major faulting and uparching of old rocks has occurred in this zone, and the warm waters are thought to be associated with these rock movements and a high geothermal gradient (Ellis and Mahon 1964). This paper presents the results of an ecological study of the warm springs at Welcome Flat on the Copland River, south Westland, and also records observations made at four other South Island springs. Because they are geographically isolated from other warm springs and over 700 km from the main North Island thermal area, it is of considerable interest to compare the biota of the Copland Springs with that found elsewhere in New Zealand.

LOCATION AND DESCRIPTION

The Copland Springs are the southernmost warm springs on the west coast of the South Island. They are located within Westland National Park 19 km southeast of Fox Glacier township at an altitude of 550 m and are reached by a 19 km walk from the west coast highway.

Three upwellings of warm water constitute the springs. The main spring is almost circular in outline (2 m diameter) and a flow gauging weir has been built in its outflow channel. In January 1972, water flowing from the main spring had a temperature of 57°C, and values between 56 and 57°C were recorded in a series of seven readings made over four days in April 1967 (Westland National Park Board, upublished records). No information on discharge rate is available. The outflow channel from the main spring leads into a series of three man-made bathing pools before dispersing over a broad, gently sloping terrace. Spring B, located four metres from the main spring, is small (30 x 15 cm) with a temperature of 52°C and water from it flows into the main spring. Spring C is circular (3 m diameter), has a temperature of 33°C and is the source of a stony stream which flows into the Copland River. The floors of the springs and the upper sections of their outflow channels are coated with an orange mineral deposit similar to that produced by alkaline springs at Waimangu near Rotorua. The Waimangu deposit consists mainly of silica (80 percent) and iron oxide (10 percent) (Brock and Brock 1970). A layer of sinter covers most of the ground within the thermal region which has an area of about 3,000m^2.

METHODS

Field work was carried out at the Copland Springs on 26-27 January 1972 and a sample for water analysis was collected on 1 June 1972. Water temperatures were measured to the nearest 1°C with a mercury thermometer. Invertebrates were collected by hand, with a fine-meshed net, and in clumps of algae, and were preserved in four percent formalin for subsequent examination. Standing crops of benthic algae were estimated by measuring the chlorophyll *a* content of core samples taken with an 11 mm diameter cork borer, and preserved immediately in four percent formalin. Tests made on living and preserved algae in conjunction with this study showed that preservation did not result in chlorophyll degradation. This is in agreement with the findings of Brock and Brock (1967). Core samples were drained, ground up and extracted with 5 ml of acetone at 4°C for up to 24 hours. Acetone extracts were centrifuged and optical densities read at 665, 430 and 410nm on a "Unicam SP 600" Series 2 spectrophotometer with a 1-cm light path (red filter at 665 nm) in 5 ml cuvettes. A corrective reading was made at 750 nm. The ratio chlorophyll *a* to pheophytin *a*, and quantitative estimation of these pigments on a weight basis, was determined by the graphical method of Moss (1967a, 1967b). Samples of living and preserved algae were also taken for microscopic examination and identification. Because the identification of thermal blue-green algae is frequently difficult and confusing, particularly in the case of narrow diameter *Phormidium* species (Castenholz 1969, Kullberg 1971), I have adopted a conservative approach to their identification and have included some descriptive information in addition to formal names. Algae other than Cyanophyta were identified to genera. Water analyses were made by the Chemistry Division of the New Zealand Department of Scientific and Industrial Research.

Examinations of other South Island warm springs were made as follows: Pool at Fox Glacier and Waiho River springs, Franz Joseph, January 1972; Maruia Springs, May 1971; Hanmer Springs, September 1970, July 1971.

OBSERVATIONS AND EXPERIMENTAL RESULTS

COPLAND RIVER SPRINGS

1. *Water Chemistry*

Results of chemical analyses made on water samples taken from the main Copland spring are given in Table 1. The spring may be classified as a strongly alkaline, mixed bicarbonate-chloride water with sodium the major cation and lesser amounts of calcium. Comparison with the results of a partial analysis made in 1907 (Table 1) suggests that the spring water is quite stable chemically.

TABLE 1. *The chemical composition of water from the main Copland River warm spring in 1972 and 1907. (All except temperature and pH expressed as mg/l — = not measured; * approximate; ** calculated from $CaCO_3$ value. The* 1907 *figures are taken from Henderson and Bartrum* (1913)).

	1972	1907
Temperature (°C)	57	Hot
pH (after aeration)	8.8	—
Total dissolved solids	1345-1360	—
Total alkalinity (as $CaCO_3$)	876-882	—
Total hardness (as $CaCO_3$)	230-235	—
Li	9	—
Na	410	482
K	27	17.5
Rb	0.6	—
Cs	4*	—
Ca	82	96
Mg	4.8	5.9
F	0.9-1.0	—
Cl	157-163	165
B	19	—
SO_4	<1	—
SiO_2	150	106
HCO_3	1080**	1150
Al	0.4	—
Fe	—	9.2
Mn	0.04	—
Sr	0.4*	—
Zn	1.3*	—
Cr	<0.04	—
NH_4-N	2.9-6.9	—
NO_3-N	0.04	—

2. *Flora*

Mastigocladus laminosus (Ag.) Cohn was the dominant alga in the spring channels where it formed a mat at temperatures up to 50°C. Morphologically it resembled the variety *phormidioides* (Boye Petersen) Copeland which is unbranched and lacks heterocysts. Individual cells averaged 3-4 μm diameter and contained distinct "granules". Some filaments of *Oscillatoria geminata* Menegh. and a narrow diameter (2μm) *Phormidium* also occurred in the mat.

The dominant alga on the terrace below the bathing pools was not a filamentous form but a unicellular species of *Synechocystis*. These cells had a diameter of 2.0-2.4 μm and fitted the description of *S. minuscula* Weronichin. It formed a continuous cover in the more permanent flow channels where the water was rarely more than 10 mm deep, but was more patchily distributed on the damp ridges between the channels. Associated with it were occasional filaments of a very narrow diameter (0.6 μm) *Phormidium* species, and a larger (6-8 μm diameter) actively gliding species of *Oscillatoria*. In pools of still, warm water (27°C) below the terrace, dense growths of *Spirogyra* and some desmids (*Cosmarium*) occurred.

Around the perimeter of Spring C, dull blue-green clumps of floating *Oscillatoria* fitting the description of *O. terebriformis* Ag. ex Gomont (not the *O. terebriformis* "thermal red" of Castenholz 1969) formed a matrix for large numbers of diatoms (*Navicula*).

Many stones in the outlet stream were encrusted with algae including a *Phormidium* resembling *P. tenue* Gom., a diatom, *Fragillaria*, and long trailing streamers of the chlorophytes *Ulothrix* and *Oedogonium*.

3. *Standing crop of algae*

The chlorophyll *a* content of core samples was measured to obtain an estimate of algal standing crop. All cores were taken from undisturbed and apparently well established mats in shallow (<10 mm) permanently flowing channels where current velocities were similar. The temperature range sampled was 42-50°C as submerged algal mats were not found in flowing water outside these limits. Twenty four cores were analysed (Fig. 1). Highest concentrations of chlorophyll *a* were recorded in mats of *M. laminosus* at 47°C and total pigment levels (chlorophyll plus pheophytin) were highest at 47-49°C. An average of 39 percent by weight of the total pigment in *M. laminosus* cores was pheophytin (range 12-80 percent in individual cores) compared with 29 percent (range 24-34 percent) in cores dominated by *S. minuscula*. These results indicate that mats consist of both living and decaying cells and that the proportion of decaying material in mats of *M. laminosus* in particular can be substantial. In mats formed by this species the old material tends to be overlain by new growth and must decay *in situ* whereas mats of unicellular algae are only one or a few layers thick; and presumably most dead cells are quickly washed away by the current.

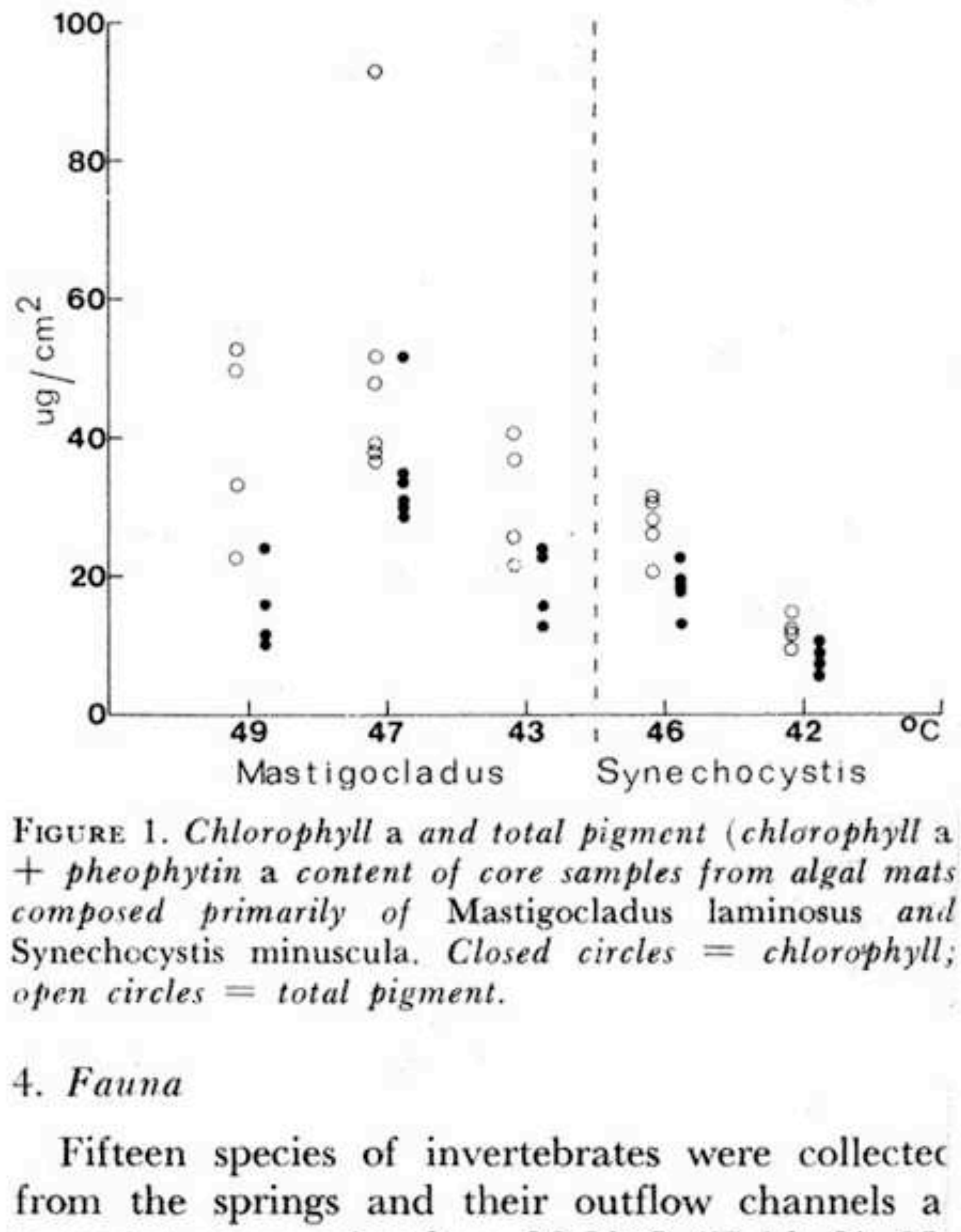

FIGURE 1. *Chlorophyll* a *and total pigment (chlorophyll* a *+ pheophytin* a *content of core samples from algal mats composed primarily of* Mastigocladus laminosus *and* Synechocystis minuscula. *Closed circles = chlorophyll; open circles = total pigment.*

4. *Fauna*

Fifteen species of invertebrates were collected from the springs and their outflow channels a temperatures ranging from 26-38°C (Table 2). No animals were found in the main spring, Spring I or the two warmer bathing pools which all had temperatures greater than 44°C; and, surprisingly none was observed on the algal mats at the side of the channels where temperatures were lower *Laccobius mineralis* and *Anisops assimilis* wer found in the coolest bathing pool (38°C) and *Saldula stoneri* occurred along its warm damp margin. Large numbers of larvae and pupae of *Ephydrella thermarum* were living among clumps of floating algae in Spring C (32°C) and the adult flies occurred on the water surface and surrounding grass. Larvae and pupae of the mosquito *Culex pervigilans* were also abundant in Spring C along with a few larval Stratiomyidae and an oligochaete, *Nais variabilis*. No animals were seen on the lower terrace but collections made in pools of cooler water (27°C) containing *Spirogyra* yielded numerous larval Stratiomyidae and small numbers of *L. mineralis* and *Liodessus plicatus*.

The stony stream arising from Spring C was examined over the temperature range 26-33°C.

TABLE 2. *The invertebrate fauna of the Copland River Springs and its distribution in relation to temperature (x = present; * = doubtful record (see text); — = not recorded).*

		Springs & pools			Stony stream						Max. temp. in Nth. Isl. thermal waters
Temperature (°C)		38	32	27	33	31	29	28	27	26	
Group	"Species"										
DIPTERA											
Ephydridae	*Ephydrella thermarum* Dumbleton (larvae, pupae)		x								46
Culcidae	*Culex pervigilans* Bergroth (larvae, pupae)		x						x		—
Dixidae	*Paradixa fuscinervis* (Tonnoir) (larva)					x					28*
Chironomidae	Tanytarsini sp. (larvae)				x	x	x	x	x	x	—
Stratiomyidae	Stratiomyinae sp. (larvae)		x	x							38.5
COLEOPTERA											
Hydrophilidae	*Laccobius mineralis* Winterbourn (larvae, adults)	x		x							38.5
Dytiscidae	*Liodessus plicatus* (Sharp) (adults)			x			x	x	x	x	34
Helodidae	Unidentified larvae					x			x		—
HEMIPTERA											
Saldidae	*Saldula stoneri* Drake & Hoberlandt	x									?
Notonectidae	*Anisops assimilis* White	x									34
Veliidae	*Microvelia* sp.					x					35
TRICHOPTERA											
Hydroptilidae	*Oxyethira* sp. (larvae)									x	—
Rhyacophilidae	*Hydrobiosis parumbripennis* McFarlane (larvae, pupae)									x	—
MOLLUSCA											
Hydrobiidae	*Potamopyrgus antipodarum* (Gray)							x	x	x	28
OLIGOCHAETA											
Naididae	*Nais variabilis* Piguet		x								—

Larvae of a species of Tanytarsini were abundant on the upper surfaces of stones throughout, whereas *L. plicatus* and larval Helodidae inhabited fine sediments in cooler water at the stream margins. *Potamopyrgus antipodarum*, *Hydrobiosis parumbripennis* and *Oxyethira* sp. are common members of normal stream faunas which occurred at or close to their upper temperature limits.

OTHER SOUTH ISLAND WARM SPRINGS

Observations were made at four other South Island localities where thermal activity occurs. The springs at Hanmer and Maruia have been tapped to supply water for commercial baths and consequently the natural spring environment has been largely destroyed. The springs at Hanmer have a temperature of 54°C and water leaves the baths at 33°C. The only algal growths seen were narrow diameter (1.2 μm) *Phormidium* which formed a mat on the surface of stones where the bath effluent enters a stream at 30-33°C. Pupae of an ephydrid, *Scatella* sp. were embedded in the mat. Maruia springs have a temperature of 58°C. In seepage around their margins *O. geminata* and *Phormidium ambiguum* Gom. were found while in channels leading from the baths (30-40°C) thick mats of *P. ambiguum* and narrow diameter (1.2 μm) *Phormidium* occurred. No fauna was seen below the baths but pupae of *Scatella* sp. were found in the seepage around the springs. At Franz Joseph small springs are found beside the Waiho River which is the outflow from the Franz Joseph Glacier. No fauna or flora occurred in the main spring at 44°C but *P. laminosum* and *M. laminosus* were collected at 31°C in its outflow channel, and *P. ambiguum* occurred in an adjacent channel at 27°C. At Fox Glacier a small warm pool (29.5°C) contained many larvae of *C. pervigilans* as well as the beetle *L. plicatus*.

DISCUSSION

The Copland Springs are located in a non-volcanic region of New Zealand but chemically they resemble the "Volcanic-Na, Cl-HCO_3 springs" category of Castenholz (1969). The concentration of dissolved solids found (about 1350 mg/l) is close to the median value for the earth's thermal springs while low nitrate-N and higher ammonium-N levels are characteristic of many hot springs (Castenholz 1969). A low sulphate level is also typical of other South Island warm springs (Ellis and Mahon 1964).

The upper temperature at which algae occurred in the Copland Springs (50°C) is low compared with that in many other New Zealand springs where it is frequently between 60 and 65°C (Brock and Brock 1971). The upper limit species, *M. laminosus,* which is an ubiquitous and cosmopolitan thermophyle, is the most common alga found at high temperatures in New Zealand thermal waters. Unbranched forms resembling var. *phormidioides* seem to be the most abundant if not the only forms in warm springs in this country. The maximum water temperature of the Copland Springs (57°C) is 7°C higher than the upper temperature at which algae were found. Why *M. laminosus* did not occur above 50°C is not entirely clear but it may have been because the orange mineral deposits present at the margins of the springs and on the floors of the outflow channels at higher temperatures prevented its establishment.

The presence of an extensive cover of *Synechocystis* is unusual in a New Zealand hot spring and this genus was not recorded by Brock and Brock (1971) in their survey of the North Island thermal region. Species of *Synechocystis* are found in thermal waters in various parts of the world however, *S. aquatilis* Sauvageau sometimes being common at temperatures up to 45-50°C (Castenholz 1969). In North America, *S. minuscula* has been reported from Yellowstone National Park at 36°C (Copeland 1936) and from Jackson Hot Springs, Montana, at 42 and 46°C (Kullberg 1971), almost exactly the same range it occupies at the Copland Springs.

Algal standing crops at the Copland Springs were comparable with those reported in other studies (Brock and Brock 1966, Winterbourn 1969) and the distribution of chlorophyll with temperature closely resembled that found by Brock and Brock (1966) in an alkaline (pH 9.1) Icelandic spring colonised by *M. laminosus*. In that spring the maximum standing crop (about 50 μg Chl a/cm^2) also occurred at 48°C and fell abruptly below 45°C. The present study has shown, however, that considerable variation in chlorophyll con tent can be found in cores taken in close proximity to one another. Contrary to Brock and Brock (1967), who concluded that pheophytins were not present in algal mats consisting primarily of *Synechococcus* studied in Yellowstone National Park, pheophytins were found in *Mastigocladus* and, to a lesser extent, *Synechocystis* dominated cores from the Copland Springs. Subsequent analyses of living and preserved samples taken from *M. laminosus* mats at Waimangu and Tokaanu in the North Island also showed that pheophytins represented up to 50 percent of the pigments measured at the 665 nm peak. This seems reasonable as during mat formation newly formed filaments overgrow and shade out those less capable of growth, and as a result layers of filaments in various stages of decomposition are formed (Stockner 1968).

The thermal fauna of the Copland Springs was an interesting one in several respects but perhaps most notable was the absence of insects on the benthic algal mats. In the North Island, larvae and pupae of the thermophilic *E. thermarum* are frequently abundant on algal mats up to 45°C (Winterbourn 1969; Brock and Brock 1971), but although present at the Copland Springs (the first time it has been recorded outside the North Island thermal area) it apparently was restricted to clumps of *O. terebriformis* at the margin of Spring C where temperatures were less than 32°C. This was surprising as extensive growths of blue-green algae were present in the area over a wide temperature range. In North American warm springs, ephydrid larvae and adults consume and assimiliate both algae and bacteria (Brock, Weigert and Brock 1969), and this is assumed to be the case in New Zealand as well. Perhaps the flora growing at higher temperatures in the Copland Springs is unsuitable as food.

A second ephydrid, an unidentified species of *Scatella*, was found at two South Island springs but not at the Copland Springs. At least one species of *Scatella* is known to inhabit North Island thermal waters (Dumbleton 1969) and although flies and pupae have been found at several localities they do not appear to be an important component of the thermal fauna.

Also, at the Copland Springs, a breeding population of the mosquito *C. pervigilans* was found; but *C. rotoruae* Belkin, the species occurring in North Island warm springs at 20-28.5°C (Belkin 1968, Dumbleton 1969), was absent. These two species are closely related, and originally it was suggested that *C. rotoruae* may be only a warm-adapted race of *C. pervigilans* (Belkin 1968). Dumbleton (1969) considered that the morphological affinities between them suggest that *C. rotoruae* segregated from *C. pervigilans,* presumably since the Upper Pleistocene, the period from which existing hydrothermal activity in the North Island appears to date. *Culex rotoruae* has not been recorded south of Rotorua in the central North Island but has been found in warm pools at Ngawha Springs, Kaikohe, 370 km to the north. *Culex pervigilans* is the commonest and most widespread culicid in New Zealand, breeding in a wide range of sites including natural ground pools and artificial containers. Apart from the Copland Springs it has been found in the warm (29.5°C) pool at Fox Glacier but in no other thermal waters.

The presence of *Paradixa fuscinervis* at 31°C is also of interest as a single individual of this species was reared by Belkin (1968) from material collected at 27-28°C in a thermal spring at Rotorua. Belkin thought this insect was probably a contaminant from a previous collection and not derived from the thermal spring, but the finding of a larva of *P. fuscinervis* in this study suggests that his may indeed have been collected there. Of the other insects, larval Tanypodini and Helodidae are recorded from New Zealand thermal waters for the first time while *L. mineralis* and *S. stoneri* were previously known only from the Rotorua-Taupo region (Winterbourn 1968, 1970). *Liodessus plicatus* and *A. assimilis* are common freshwater species which have been recorded previously in warm pools up to 34°C, whereas stratiomyid larvae of this or a similar species have been collected at up to 38.5°C (Winterbourn 1968). Clearly, the geographic isolation of the Copland Springs has not prevented them being colonised by several species which previously had been found only in the North Island thermal region. In fact, the only important inhabitants of North Island warm springs absent were *C. rotoruae* and two species of Hydrophilidae.

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