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THE TAXONOMY AND BIOLOGY

of

Chlamydogobius eremius (Zietz, 1896)

by

C.J.M. GLOVER B.Sc. (Sydney),
South Australian Museum

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Department of Zoology,
University of Adelaide.

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SUMMARY

1. This thesis is principally a study of the ecological, physiological and behavioural adaptations of C. eremius to its tenuous and fluctuating environment.

2. A section on morphology presents a re-description of the species, more complete than hitherto given; in which sexual-dimorphic characters are established. The morphological and meristic data demonstrate that a single species is represented by all the widely scattered populations.

3. A section on distribution establishes the widespread occurrence of the species within the Lake Eyre drainage system, and it is argued that floodwaters probably constitute the efficient dispersal mechanism by which this is effected.

4. A section on reproduction establishes that breeding occurs in two periods, between October to November and January to April. Neither mode of fertilization nor any courtship pattern has been established, but enlargement of the anal papilla in both sexes during the breeding period, suggests this structure may act as a gonopodium. It is shown that population build-up can be rapid.

5. A section on population structure, densities and growth rates establishes that populations vary greatly in size and that density within the individualhabitatmay diffe markedly from locality to locality, where either sex may predominate in any one population. Growth is rapid

within the first six months of life and maximum size attained at about 12 months. Males grow faster than females. Those fish born in October-November probably breed next October-November, those born in January-April possibly not till the following January-April.

6. A section on physical parameters compares inhabited and un-inhabited waters and discusses possible thermal and ionic factors influencing the occurrence of the species. Large thermal and ionic gradients are shown to exist within the inhabited range of habitats, in which inhabited waters are shown to be prone to extremely low oxygen levels. Thermal refuges and thermal acclimations are demonstrated. Remarkable tolerance to changes in salinity are demonstrated.

7. A section on non-physical environmental parameters indicates an omnivorous diet and the significance of vegetation in the life of the species. Fishes found in association with C. eremius and predatory forces are also discussed.

8. A section on behaviour describes movements and orientation in water currents. A series of experiments establishes sensory factors involved in food location and feeding. A series of responses to aspects of the environment are established; the fish is negatively phototactic and prefers fine-textured beds regardless of colour. Rapid changes in body colour, in response to different background colour, are described and shown to

be independent of vision. Activity patterns based on trapping data suggest a possible lunar activity rhythm. Aerial respiration is demonstrated.

9. The discussion concentrates on those adaptive features which appear to have enabled the species to survive and establish itself in an unstable environment.

DECLARATION

The work presented in this thesis is my own, unless otherwise acknowledged in the appropriate place; it has not previously been published or submitted to this or any other university for the award of any degree.

(C.J.M. GLOVER)

I INTRODUCTION

Chlamydogobius eremius (Zietz, 1896) is the only representative of the family Gobiidae known to inhabit waters of the central Australian region. Prior to this study it had been recorded from only two localities, its morphology was known only superficially and nothing was known of its biology other than that it inhabited bore waters.

This thesis started as an investigation of aspects of the ecology, physiology and behaviour of this animal because it appeared to be adapted to living in the interesting environment formed by artesian bore streams whose saline waters were known to be subject to fluctuations in composition, concentration and temperature and to periods of considerable drying up.

However, as a result of my initial surveys it appeared that the same species occurred much more frequentl and over a far more wide-spread area than was formerly believed. Studies of the morphology of the different populations confirmed the wide-spread occurrence of this one species and prompted an investigation of its apparentl efficient means of dispersion.

During the course of the surveys, aspects of the aquatic environment, of both inhabited and uninhabited waters were investigated, to establish, if possible, what factors determined the occurrence of the fish in some waters and not in others. Concurrently, field and laboratory studies were also made of the species' life cycle, ecology, population structure, growth, physiology and behaviour.

II MORPHOLOGY

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1. PREAMBLE

The Desert Goby, Chlamydogobius eremius (Zietz 1896), was originally described from material collected by the Horne Scientific Expedition from a railway bore at Coward Springs (locality 34, Appendix A) in the far north of South Australia (see fig 7). This type material was subsequently housed in the South Australian Museum (collection registration nos. F524, F525, F526). None of this early collection can now be located and therefore is presumed permanently lost.

Zietz (1896) placed the species in the genus Gobius Linnaeus, 1758, but McCulloch (1917) subsequently considered that it could not be retained within that genus and further that it could not be referred to any of the then known Gobiidae genera although he provisionally retained it within the genus Gobius. McCulloch and Ogilby (1919) in extensive revision of the Australian Gobiidae continued to provisionally retain the species within the genus while Whitley (1929) finally erected a new genus, Chlamydogobius, with Gobius eremius as the type species. To date this species is the only recognised member of the genus.

2. SYSTEMATIC DIAGNOSES

Family Gobiidae

(partly after Munro (1967)).

Usually small. Body elevated, oval to elongate, compressed or cylindrical. Usually ctenoid or cycloid scales, occasionally naked. Head naked before and between eyes, sometimes completely naked. Lateral line absent. Two dorsal fins, usually completely separate. Second dorsal and anal fins opposite and similar and both free from the caudal fin. Anal with one weak spine. Ventrals usually completely or partly united along their inner margins to form a suction disc. Gill openings moderate to wide, membranes connected to isthmus. Mouth usually large. Teeth in one or more rows in upper jaw, in two or more in lower.

Subfamily Gobiinae

Ventral fins completely or partially united to form a suction disc.

Genus. Chlamydogobius Whitley, 1929.

Chlamydogobius gen. nov. Whitley, Austr. Zool. 6, p. 122, 1929; type species Gobius eremius Zietz, Rept. Horn Exped., ii, 1896, p. 180, pl XVI, Fig. 5.

Whitley (1929) gave the generic characters for Chlamydogobius as the relative characters given in McCulloch and Ogilby's (1919) provisional key to the genera and species of the Subfamily Gobiinae, namely:-

> Soft dorsal and anal shorter, free from the caudal. Body scaly. Chin and mandibles without barbles. First dorsal with six spines. Head with only microscopic papillae in rows. Opercles naked or nearly naked. Exposed edge of shoulder girdle smooth. Upper pectoral rays not free nor differentiated from the others. Tongue not deeply notched. Head longer

without spines or large papillae. Scales smaller, more than thirty six in a longitudinal row. Mouth normal, maxilla not specially produced. Thirteen or less dorsal and anal rays. Snout normal. Nape naked.

Sole species, Chlamydogobius eremius (Zietz, 1896)
Gobius eremius Zietz, Rept. Horn. Exped. Centr. Austr. ii, 1896, p. 180, pl. XVI, Fig. 5.

Zietz's (1896) original abbreviated description of the species from material collected at Coward Springs railway bore (locality 34) was followed by a more complete redescription by McCulloch (1917) from contemporary material collected from a nearby locality, Strangways Springs railway bore (locality 29). This latter description was based on four specimens from a series of thirteen. This early collection from Strangways Springs is housed in the Australian Museum collection (Reg. no. I 13661).

Populations of C. eremius thrive in the surface flows at both the above localities to this day although it appears that water flow from the bores has considerably diminished in recent years partly as a result of a natural drop in artesian flow and partly because of largely unsuccessful Government efforts to block the pipes of these now redundant bores.

3. DESCRIPTION OF SPECIES

My examination of collections of C. eremius taken from a number of localities around the Lake Eyre region (Fig. 7) and west of Alice Springs (Fig. 8) reveals a uniformity of the various morphological characters (Table 1 between the different populations and insufficient consistent varients to suggest that any sub-species exist.

The following species redescription is based on the combined data recorded from a total of 336 specimens, 10-50mm standard length, collected from eighteen localities extending over the full known range of the species. The description agrees essentially with that of McCulloch (1917) except that the latter failed to recognise what I consider to be a single spine associated with the anal fin and a feature which Munro (1967) gives as a characteristic of the family Gobiidae. In addition I usually found a considerably larger number of caudal rays to be present, this apparently being due to the fact that I have taken into account the small rays present at the foremost dorsal and ventral edges of the caudal fin.

The bracketed meristic data are the more typical values for the respective measurements. Accurate scale counts were extremely difficult to estimate due to the thin and delicate form of the species scales. In many instances scales had been shed or considerably softened by immersion in formalin (5% strength) by the time preserved collections reached the laboratory, making counts impossible. Even when intact it usually proved difficult to distinguish individual scales. Various techniques were employed to view scales under a low power binocular microscope including oblique lighting, dehydration in ethyl alcohol (to cause scales to rise off the body surface) and ink prints, but none of these proved very satisfactory.

As with McCulloch's (1917) scale data the values recorded here are therefore no more than approximate. With regard to vertebral counts attempts were made to make these by means of X-ray photographs but the small size of the fish prevented sharp and distinct radiographs being obtained. An alizarin stain technique based on the method of Davis and Gore (1947) was employed on a small number of specimens from several scattered localities and this proved quite satisfactory, although extremely laborious and time consuming in preparing larger series. Consequently most of the vertebral counts were obtained by preparing sagittal sections of sampled series (10 specimens each) from the various collections.

Chlamydogobius eremius (Zietz, 1896).

Meristically no difference between the sexes. (Table compares ranges and means of meristic data of 25 ♂♂ and 25 ♀♀ from locality 17 as recorded in Appendix It will be seen there is no significant difference between the sexes).

Fin formula:	D_1 IV-VI (VI), D_2 7-14 (9), P 11-14 (13), A i, 5-11 (i. 7), V i 5, C 15-32 (27).
Scalation:	Cycloid and ctenoid, principally the former. Sc. approximately 37-49. Tr. approximately 15-19.
L.G.R.	6-9 (8).
Vert.	26-28 (27).

Body robust, depressed anteriorally, compressed posteriorly (see fig. 1 and 2). Proportions variable according to size and sex. Mouth large, extending to below the middle of eye. Teeth, three rows villiform each jaw, palate toothless. Ventral surface from tip of chin to anal papilla scaleless. Sexes separate, anal papilla of male comparatively long and slender with a shallow convex longitudinal trough on the dorsal surface (fig. 3) whereas that of female is short and stubby (fig. 4), the difference being most marked in fully grown adults. Table 2 compares the ranges and means of the ratio $\frac{\text{Anal Papilla Length}}{\text{Standard Length}}$ between the sexes from a collection made at locality 27. It will be noted that the mean ratio for males is greater than for females. Head of adult males conspicuously broader than that of adult females of similar length (Table 3), this again being most marked in fully grown individuals. Table 4 compares the ranges and means of the ratio $\frac{\text{Head Width}}{\text{Standard Length}}$ between the sexes from collections made at localities 24 and 27. It will be noted that at both localities the mean ratio for males is greater than for females.

Colour variable, light yellow to dark brown background on the dorsal and lateral surfaces and generally cryptically correlated with habitat background. Observations in the field and the laboratory (see p. 130) demonstrate that *C. eremius* has a pronounced ability to acquire cryptic colour changes in several minutes or less. 5-7 darker cross bars usually apparent across the dorsal surface of the body behind the nape of both sexes. Ventral surface between chin and anal papilla paler to silvery white. In some instances ventral surface of lower jaw of adult males pigmented bright yellow. Fins of individuals of both sexes less than approximately 25mm standard length usually transparent. Fins in adults over 25mm in length variable in colour. Fins of both sexes tend to be more intensely pigmented with increase in size. First dorsal fin pigmentation first to develop and often apparent in individuals less than 25mm standard length.

In live adult males (Fig. 5a) the posterior margin of the first dorsal fin generally exhibits a dark or brilliant blue pigment patch with a pale to brilliant yellow margin dorsally, extending to the anterior margin of the fin. The second dorsal, anal and sometimes the ventrals, may be darkly pigmented together with a white or yellow outer margin. The base of the second dorsal sometimes exhibits a yellow band. The caudal and pectorals more usually transparent or not as intensely pigmented, usually uniformly. Generally pigmentation is more intensively developed in larger specimens though in some instances relatively small individuals display maximally intense colours.

In live adult females (Fig. 5b) the posterior margin of the first dorsal fin usually displays a pale to dark blue pigmented patch (rarely as pronounced as in the male) and the other fins are either transparent or banded similarly to the adult males but much more lightly.

In preserved (alcohol or formalin) specimens the blue and yellow pigments are rapidly lost or reduced to tones of grey.

There does not appear to be any significant development or hightening of fin colouring in either sex during the breeding period. Fin colours once developed to the full in the adult appear to remain stable and not subject to seasonal change. Body colour (and fin colour to some extent) does change against different background colour but since the bed surface of most localities is largely uniform and constant most individuals of any one population tend to retain a fairly uniform colouring.

The maximum recorded length of any specimen is of a male collected from Blanche Cup Spring (locality 36) whose standard length was 60mm. Females usually obtain a maximum size slightly less than that of the largest males in any one population.

When I first commenced this study of C. eremius upon the population at the type locality, Coward Springs railway bore (locality 34), I was unable to distinguish positively the two sexes, principally because of the presence of egg-like structure in the body cavities of nearly all individuals examined. On closer examination these proved to be metacercarian stages of an unidentified trematode and there was nearly a 100% infection of the population at locality 34. Finally sperms were located in testies tissue and it was then apparent that the sexes were separate and the sex-linked characters given in Table 5 were found and which served as secondary sex distinguishing characters.

The only other incidence of parasitic infection of <u>C. eremius</u> has been located in the population at Johnson's No. 3 bore (locality 24). Specimens examined on each occasion this locality has been visited have been found to be infected, sometimes heavily, with an unidentified adult trematode in the body and gut cavities.

Table 1

Meristic Data recorded from *C. eremius* collections sampled from all known populations inhabiting permanent waters.

Vertebral counts were made from a sample of 10 specimens from each collection except where the total collection comprised less than this number in which case estimates were made on the entire collection. Where no range values are indicated for any of the meristic vectors the mean value is common to each individual specimen.

(1) Although fin spine counts less than vi are indicated these were very infrequent and occurred only with very small specimens. In these cases it appears probable that up to vi spines are in fact present but that some are indistinguishable due to the extremely small size of the specimens concerned.

Loc. No.	Locality Name	Date Sampled	No. of specs.	SL Range (mm)	Fin Ray Counts												Scalation (estimated approx.)							
					D_1		D_2		A		P		V		C		Sc.		Tr.		L.G.R		Vertebrae	
					Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
74	Glen Helen Gorge	Jan. 1969	15	24-44	v-vi	vi	9-10	9.5	i, 6-8	i, 7	12-14	13.0	o	i, 5	26-29	28.0	44-49	46.3	16-18	17.0				
75	Hermannsburg H.S.	12.II.70	10	11-24	o	vi	7-9	7.6	i, 6-7	i, 6.6	12-14	13.0	o	i, 5	15-20	18.0	43-48	46.9	15-17	16.4	7-8	8.0		
1	Dalhousie Springs	5.VIII.68	9	23-32	o	vi	8-9	8.7	i, 7-8	i, 7.5	12-13	12.2	o	i, 5	26-29	27.7	41-46	44.5	16-17	16.6	7-8	7.9	26-27	27.2
12	Algebuckina W.H.	31.VII.68	5	14-30	o	vi	o	9.0	i, 6-8	i, 7	13-14	13.0	o	i, 5	28-31	29.0	37-46	39.6	16-17	15.5	7-8	7.8	26-27	26.7
13	Wood Duck Bore	24.XI.69	10	14-31	v-vi	vi	8-9	8.8	i, 7-8	i, 7.5	12-13	12.9	o	i, 5	25-27	26.2	39-46	41.8	16-18	15.8	7-8	7.7	26-27	26.8
14	Peake Creek	30.VII.68	20	27-44	v-vi	vi	o	9.0	i, 7-8	i, 7.0	o	13.0	o	i, 5	27-31	29.0	38-47	44.0	16-18	15.5	7-8	7.9	27-28	27.1
15	Old Peake H.S. Bore	22.XI.69	12	18-28	o	vi	9-10	9.7	i, 7-8	i, 7.0	13-14	13.1	o	i, 5	22-27	24.8	37-46	41.5	16-17	15.4	7-8	7.2	26-28	27.0
16	Freeling springs	23.XI.69	26	31-42	o	vi	8-10	8.9	i, 6-8	i, 7.5	12-14	13.0	o	i, 5	23-30	26.2	37-47	41.7	15-17	15.4	7-8	7.6	26-27	26.9
17	Blyth Bore	24.XI.69	50	35-44	o	vi	8-10	9.2	i, 7-8	i, 7.3	12-14	12.7	o	i, 5	27-29	27.8	44-49	45.6	16-19	17.4	7-8	7.5	26-28	27.0
18	Birribirriana Spring	21.XI.69	12	36-47	o	vi	8-10	9.3	i, 7-8	i, 7.5	12-13	12.9	o	i, 5	23-28	25.3	41-49	45.1	16-18	16.8	7-8	7.9	26-27	27.0
19	Nilpinna Spring	21.XI.69	20	27-36	o	vi	8-10	8.9	i, 6-8	i, 7.2	12-13	12.8	o	i, 5	26-30	27.4	44-49	46.6	16-18	16.8	7-8	7.9	26-28	27.1
23	Johnson's No. 3 Bore	29.VI.69	43	13-50	iv-vi	vi	8-10	9.0	i, 5-11	i, 7.5	11-13	13.0	o	i, 5	25-31	29.0	39-49	44.1	15-18	16.8	7-9	8.1	27-28	27.0
27	Nunn's Bore	1.V.69	20	15-23	v-vi	vi	8-12	10.0	i, 6-8	i, 7.5	12-14	13.0	o	i, 5	25-30	28.0	38-48	43.6	16-18	17.1	6-8	7.3	27-28	27.2
29	Strangways Springs Railway Bore	25.XI.70	23	24-43	o	vi	8-10	9.2	i, 6-8	i, 7.7	12-13	12.9	o	i, 5	26-29	27.4	41-48	45.8	15-19	17.1	7-8	7.7	26-27	26.7
31	Beresford Reservoir	1.XI.70	4	35-41	o	vi	9-10	9.2	i, 7-8	i, 7.5	12-13	12.8	o	i, 5	24-26	25.0	39-44	41.7	16-17	16.7	7-8	7.7	o	27.0
33	Coward Springs proper	25.VI.69	18	34-48	v-vi	vi	8-9	8.6	i, 6-8	i, 7.1	13-14	13.0	o	i, 5	27-30	28.3	42-49	45.5	15-17	16.4	7-8	7.8	26-28	27.1
34	Coward Springs Railway Bore	26-27.VII.68	26	10-41	v-vi	vi	8-14	10.0	i, 7-10	i, 8.0	11-14	13.0	o	i, 5	26-32	29.5	39-49	43.9	16-18	16.8	7-8	7.8	26-27	26.8
44	Clayton Bore	22.XI.70	13	16-36	o	vi	8-10	8.8	i, 7-8	i, 7.5	12-13	12.8	o	i, 5	25-30	27.7	43-46	44.8	15-19	17.0	7-8	7.4	26-28	26.9

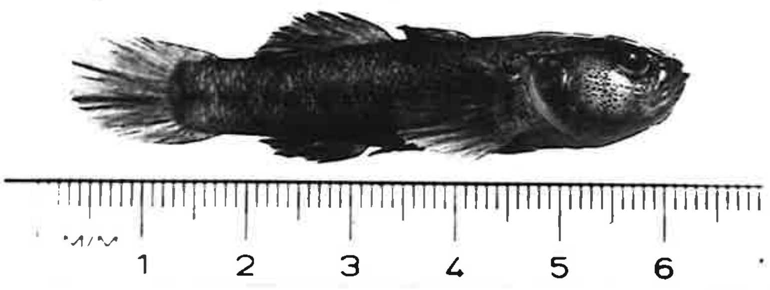
Figure 1

Male *C. eremius* from Nunn's Bore (locality 27) population; standard length 49 mm.

a. Lateral view.

b. Dorsal view.

c. Ventral view.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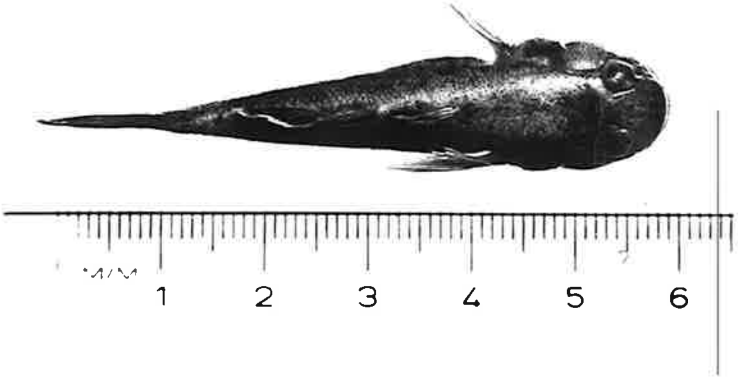
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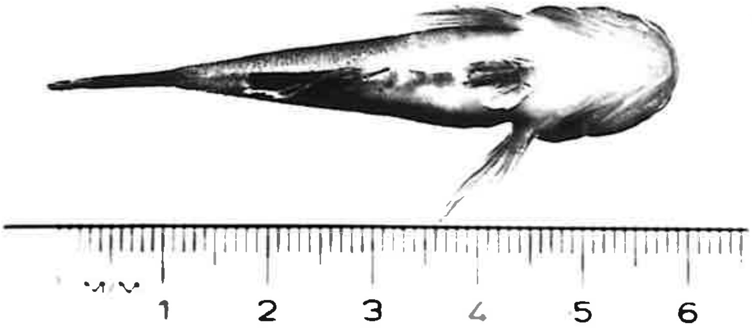
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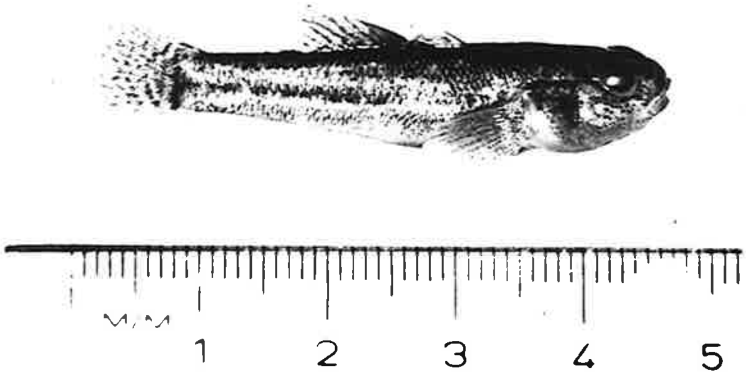
Figure 2

Female C. eremius from Nunn's Bore (locality 27) population; standard length 38 mm.

a. Lateral view.

b. Dorsal view.

c. Ventral view.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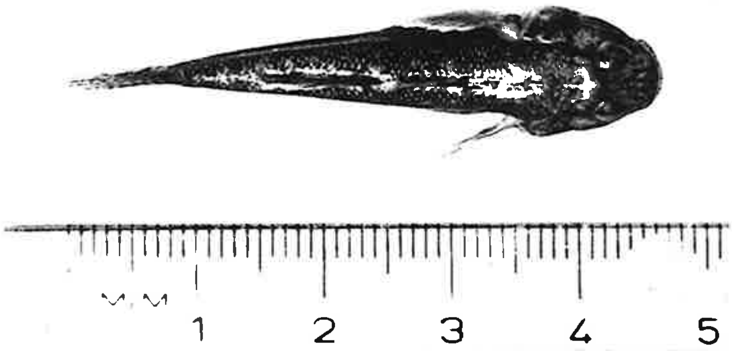
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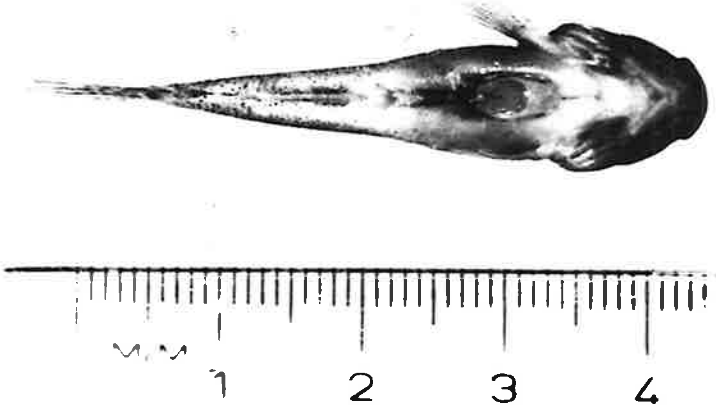
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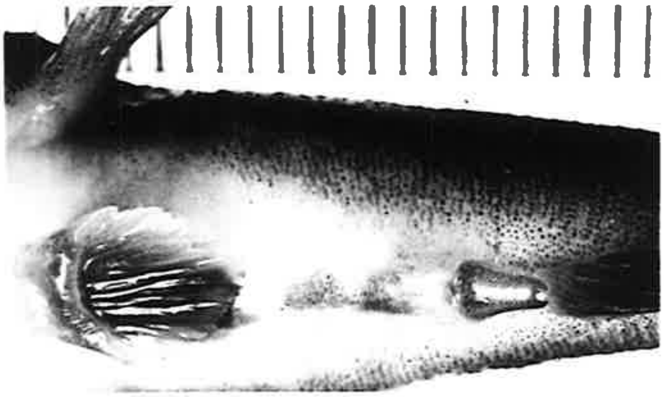
Figure **3**

Anal papilla of male C. eremius from Nunn's Bore (locality 27) population; standard length 49 mm.

a. Lateral view.

b. Ventral view.



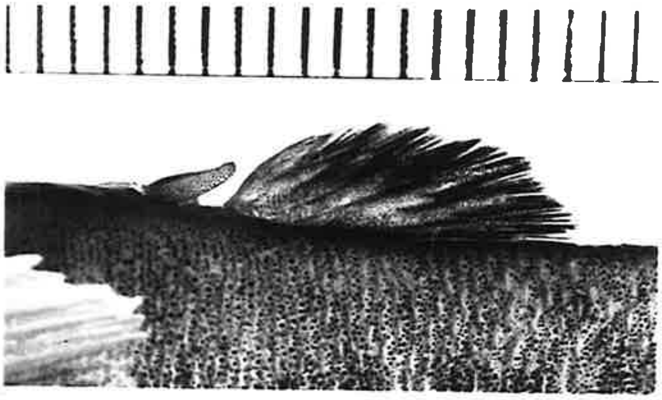


Figure 4

Anal papilla of female C. eremius from Nunn's Bore (locality 27); standard length 45mm.

a. Lateral view.

b. Ventral view.

	$\frac{\text{Anal Papilla}}{\text{Standard Length}}$	
	♂♂	♀♀
Range	0.05 - 0.07	0.02 - 0.04
Mean	0.06	0.03
Difference of means	0.03	

Table 2

Comparison of ranges and means of the ratio $\frac{\text{Anal Papilla}}{\text{Standard Length}}$ of 20 ♂♂ and ♀♀ collected at Nunn's Bore (locality 27) on 13.IV.70.

Table 3

Comparison of the ratio $\frac{\text{Head width}}{\text{Standard length}}$ between male and female C. eremius sampled from Nunn's Bore (locality 27), 13.IV.70.

Locality Nunns Bore (Loc. 27) Sampled 13.IV.70

Males			Females		
SL (mm.)	Head width (mm.)	Head Width / SL	SL (mm.)	Head width (mm.)	Head width / SL
26	4.9	0.18	30	5.2	0.17
28	5.3	0.19	30	5.5	0.18
31	6.3	0.20	31	6.0	0.19
38	8.5	0.22	33	6.3	0.19
38	8.8	0.23	33	6.8	0.21
39	8.2	0.21	34	7.1	0.21
39	10.0	0.26	35	7.3	0.21
40	9.1	0.23	35	7.5	0.21
41	8.6	0.21	36	7.5	0.21
41	9.1	0.22	37	7.6	0.20
42	8.8	0.21	37	7.7	0.21
42	9.3	0.22	38	7.8	0.20
42	9.7	0.23	38	8.0	0.21
45	10.0	0.22	39	7.8	0.20
			39	7.9	0.20
45	10.3	0.23	40	7.6	0.19
46	10.9	0.24	40	8.0	0.20
47	11.3	0.24	40	8.6	0.21
48	10.0	0.21	41	8.4	0.20
48	11.3	0.23	44	8.8	0.20
49	11.2	0.23			
50	11.8	0.24			
Range=0.18 - 0.26 Mean = 0.22			Range=0.17 - 0.21 Mean = 0.20		
Difference of means 0.02					

	$\frac{\text{Head Width}}{\text{Standard Length}}$			
Locality	Johnson's No.3 Bore (locality 24)		Nunn's Bore (locality 27)	
	♂♂	♀♀	♂♂	♀♀
Range	0.18 - 0.26	0.17 - 0.21	0.20 - 0.26	0.18 - 0.2
Means	0.22	0.20	0.23	0.19
Difference of means	0.02		0.04	

Table 4

Comparison of ranges and means of the ratio $\frac{\text{Head Width}}{\text{Standard Length}}$ of 25 ♂♂ and 25 ♀♀ collected at each of two localities, namely, Johnson's No. 3 Bore (locality 24) and Nunn's Bore (locality 27),

Figure 5 a

Live male _C_. _eremius_ (standard length 50mm) from Nunn's Bore (locality 27); enlarged approximately x 2.3.

Figure 5 b

Live female _C_. _eremius_ (standard length 48mm) from Nunn's Bore (locality 27); enlarged approximately x 2.3.

Table 5

Sexual-dimorphic characters in *C. eremius*.*

Characters	Males	Females
1	Anal papilla comparatively long and slender with shallow convex trough extending longitudinally along the dorsal surface.	Anal papilla comparatively short and stubby without longitudinal trough depression on dorsal surface.
2	Head width proportionately greater than in females of comparable size.	Head width proportionately more slender than in males of comparable size.
3	First and second dorsal and anal fins usually darkly pigmented with pronounced white or yellow marginal banding Yellow pigmentation of lower surface of jaw in some instances.	Second dorsal and anal fins transparent or only lightly pigmented and with only light marginal banding. First dorsal fin darkly pigmented but less intense that in males.

* Sex distinguishing characters are most pronounced in subjects approx.>25 mm SL. In smaller subjects these characters are either absent or poorly developed, and it is frequently difficult to ascertain the sex of the individual.

III DISTRIBUTION

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1. PREAMBLE

Prior to the present study the only recorded occurrences of C. eremius were at Coward Springs railway bore (locality 34) and Strangways Springs railway bore (locality 29) both of which are situated south west of Lake Eyre south. They were made by the Horne Expedition party in 1894. Three other early collections registered at the South Australian Museum lack precise locality data merely being indicated as originating from "Central Australia".

2. TOTAL AREA

As a result of a series of surveys I have made in the far north of South Australia during 1968-71 and surveys by the Arid Zone Research Institution (Northern Territory Administration) in the Northern Territory during recent years, it is now established that the species has an extensive distribution within the central Australian region. Figure 6 indicates the occurrences of all known established populations of C. eremius. Figures 7 and 8 show in detail the location of these localities in South Australia and the Northern Territory, together with other permanent water sites which have been inspected in South Australia but where the species has not been taken. Figure 9 indicates temporary aquatic sites which have been inspected in South Australia's far north and where the species has been taken. Appendix A details the names and geographical positions of all localities indicated.

On the basis of these data it is seen that although the species is largely concentrated in the waters of the numerous artesian bores and springs* situated in the western half of the Lake Eyre drainage basin, its range extends well north to the west of Alice Springs where it has been taken in permanent waters in the vicinity of the McDonnell Ranges. The latter are well beyond the immediate vicinity of Lake Eyre but connect with the drainage system entering the Lake Eyre basin.

Further collecting will probably reveal additional permanent populations in the intervening regions within the present known limits but these clearly will be restricted to the limited number of permanent water habitats found in this extremely arid region. The small collections made from ephemeral sites following rain probably represent transient occurrences arising from dispersal from permanent populations by floodwaters. It is possible that further surveying, particularly of the artesian waters of south west Queensland and north west New South Wales, will extend the known range of the species. West of Lake Eyre permanent waters are extremely scarce as they also are immediately north of the Lake where the Simpson Desert is located. The Simpson Desert Expedition of 1939 (Whitley, 1945) reported that the only surface waters encountered were very temporary and shallow waters of claypans and waterholes in the Coglin Creek, Charlotte Waters and the Diamantina River; C. eremius was not amongst the small collection of fishes taken by the Expedition party. In a personal communication from C.R. Fenner Esq., of Darwin I have been advised that although large collections of a variety of fishes were made by himself in 1970 from numerous water-holes and springs in the vicinity of the main road between Alice Springs and Darwin, neither C. eremius nor any other

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* See figures 10 and 11 .

Gobiidae was taken. The Arnhem Land Expedition (Taylor, 1964) similarly failed to locate this species, or related forms, from inland waters east of Darwin in 1948. Only one occurrence east of Lake Eyre is known, when I found the species at the Clayton Bore (locality 44). I did not find the species, or any other fish, elsewhere in the area despite trapping in many bores to the north east of Marree adjacent the Birdsville track.

Thus, to date, the total known range of this species is restricted between latitudes 23° 40' south and 29° 34' south and longitudes 132° 40' east and 138° 23' east.

Iredale and Whitley (1938) designated C. eremius one of the characteristic fishes of what they term the Sturtian region (central Australian waters west of the Darling River system) in their proposed classification of Australian inland aquatic zoogeographical regions. Selection of the species for this purpose seems well validated although it appears that the species may be further restricted to the Lake Eyre drainage system.

3. DETERMINANTS OF DISTRIBUTION

a. Dispersal

The marked morphological uniformity between populations throughout the known range of the species, as mentioned in Section 1, indicates that recent dispersion has occurred and/or that there is sufficient gene flow between populations to ensure that minimal morphological divergence has occurred. In view of the successful establishment of populations in various pools and streams associated with artesian bores since European settlement it is obvious that an efficient dispersal mechanism is operating and that so long as it continues to operate the species will retain its morphological uniformity and consequently its monotypic status.

The occurrence of small isolated populations in the ephemeral bodies of water following seasonal rains suggests that transport by floodwaters is probably an important, possibly the only, means by which dispersion of stock is effected from centres of permanent population (see p. 21). The extensive and substantial floodings (see Appendix C) and the extensive areas of low topographic relief characteristic of the central Australian region are certainly conducive to efficient and frequent dispersion of aquatic fauna by floodwaters.

The fact that all recorded occurrences, both permanent and transitory, are restricted to within the Lake Eyre drainage system supports the postulate that dispersion is probably effected exclusively by floodwaters and therefore can only occur within that drainage area. The general absence of the species from all but one of the many bore sites east of Lake Eyre and its apparent absence outside the Lake Eyre drainage basin tends to negate the proposition that dispersion is achieved even in part, by some form of aerial transport e.g. transportation of juveniles or adults via thermals (willy-willies) or of fertilised eggs via attachment to the feet of water-wading birds. There are probably other factors, especially of an aquatic chemo/physical nature that prevent the establishment of breeding populations of C. eremius in artesian waters outside the central Australian region (see Section VI) but these are probably secondary to the limitations imposed on distribution by the mode of dispersion.

Further evidence to support the postulate that aquatic birds are not a medium for dispersing C. eremius is provided by the observation that, until I successfully introduced a breeding population into the Blanche Cup mound spring (locality 36) in September 1970 (see Section V). this spring pool was devoid of any species of fish and probably always had been. Madigan (1936) made no reference to fish when he inspected the spring in 1927. The Blanche Cup spring is a prominent feature, located within 0.7Km of the population inhabiting Wobna spring (locality 35) and within 9.0Km of the populations at Coward Springs proper (locality 33) and Coward Springs railway bore (locality 34). Since the spring mound rises very steeply to approximately 41m above ground level and there is only a very small run-off of water it appears virtually impossible that fish could enter the spring pool (7m diameter) via floodwaters transporting stock from the nearby populations. Since all the nearby artesian water bodies and the Blanche Cup spring itself are visited frequently by various species of water birds (see Table 53) it would be expected that if birds did play a role in dispersion that the Blanche Cup spring would have become populated at some time in the past.

b. Suitable natural habitats.

From the above argument it appears highly probable that permanent populations can only become established where there is suitable permanent water. There are few waterholes in central Australia large enough to hold permanent bodies of water. Neither of the two permanent meteoric water bodies (localities 7 and 31) from which I have collected C. eremius appear to support very substantial populations; despite intensive trapping only a small number of specimens was taken at each locality. Artesian springs (and bores) on the other hand are relatively permanent and since many of them support abundant populations of C. eremius as opposed to the small populations to be found in the few populated waterholes it seems that evironmental conditions in artesian waters, at least those in the central Australian region, are particularly conducive to supporting breeding populations of this species. The artesian waters of central Australia therefore appear to represent the typical habitat for C. eremius. In spite of chemo/physical differences between the many central Australian artesian flows they all seem to be suitable to support breeding populations of this characteristically adaptive species (see Section VI). The only critical factor to ensure successful colonization of a permanent artesian water body appears to be the successful introduction of individuals of both sexes. Thus a locality's potential to harbour C. eremius is largely dependant on its capacity to intercept stock dispersed in floodwaters by virtue of its geographic position and surrounding topography in relation to other populated sites. The occurrences in ephemeral waters appear to be only transitory, representing a stage in the dispersion process.

c. Artesian Bores, Reservoirs and Dams

Artesian springs must have constituted the typical habitat of C. eremius before bores were sunk in the central Australian region. Since then, however, the species has so successfully populated many of the pools and streams associated with artesian bores that it is apparent that man's influence has been one of creating additional habitats thereby increasing the incidence of individual populations within the Lake Eyre basin.

Assuming that most, if not all, of the currently inhabited springs were inhabited before the appearance of bores, it appears that the latter have not so much extended the range of the species as that they have caused the intervening areas to become populated thereby facilitating inter-population gene flow so that any tendency towards sub-speciation through isolation has been slowed down.

The drilling dates of some populated bores (see Table 6) indicate that the species is capable of colonising and establishing itself within a relatively short time and it is almost certain that the populations listed in Table 6 were established well before their first officially recorded occurrences. Efforts to obtain information concerning the earliest appearances of fish at the latter sites from local residents have failed to provide conclusive data.

If effective dispersion is in fact achieved by floodwaters and a newly created habitat is within a reasonably short distance of an existing population with only low relief topography intervening and with drainage directing towards the new habitat it would only require a single substantial flood to potentially colonize the habitat. State and Commonwealth Railway records and my own observations (see Appendix C) of conditions adjacent the rail track between Marree and Alice Springs, indicate that extensive seasonal flooding frequently occurs in the vicinity of this railway line. Other records (see Appendix C) indicate that this situation applies to much of the central Australian region including the Lake Eyre drainage area. There are therefore, frequent occasions when dispersion may occur via floodwaters. Chance must also play a role and it may well be that a series of floodings must occur before successful colonization is finally achieved, if at all. Obviously the better the potential habitat's location in relation to drainage from other populations the better is it chances of being successfully colonized. Most of the known populated bores are in relatively close proximity to one or more populated artesian springs (see Table 7).

It is possible that in some instances natural seepages existed at the bore sites prior to the bore being sunk and that C. eremius may have been present at the outset but no data are available from the South Australian Mines Department or the State Pastoral Board of South Australia on this aspect.

Only one reservoir, the railway reservoir at Beresford (locality 31) has been found to be inhabited by C. eremius and since only four specimens were taken from a total of eight traps set for a 24 hour period it is probable that the population is not large. The considerable degree of water turbidity found at this reservoir, and which is characteristic of meteoric water bodies in this region, most certainly inhibits aquatic plant growth. As discussed in Section VII (p. 94) filamentous green algae is an important component in the ecology of C. eremius (as a habitat for small animal prey, as a food item itself and as protective cover.) It's absence or restricted abundance would therefore not be conduicive to supporting a large C. eremius population.

Furthermore the high retaining walls enclosing most man-made dams and reservoirs would appear to present an insurmountable barrier to colonization via floodwaters so that they play virtually no part in the occurence of C. eremius.

d. Fluctuations of Artesian Waterflows

The little data that are available on artesian flow rates (see Table 8) indicates that over a short term of several years, flow is relatively constant and conditions therefore stable. However, comparison of current flows with those apparent from early photographs of such bores as Nunn's (locality 27) and Coward Springs (locality 31) indicates that over a longer time period substantial changes in flow rate may occur. The flows at Nunn's and Coward Springs railway bores are today far less than when they were drilled twelve and eighty years ago respectivelly. (see fig. 12). A number of mound springs in the vicinity of Coward Springs and Strangways Springs are today either extinct or represented by no more than seepages or slight flows and quite inadequate as fish habitats. Since the mounds of some of these springs are quite large it follows that these springs were formally considerably more active and probably capable of supporting fish populations. Long terms fluctuations in the flow of artesian waters can therefore be sufficient to make a site more or less favourable for habitation. Recent Government efforts to block off the flows from certain disused bores, including the type locality of <u>C. eremius</u> (Coward Springs railway bore, locality 34), have resulted in considerable cut-backs in flow but sufficient natural seepages continue and appear to provide bodies of water adequate to maintain small populations.

Figure 6

Positions of established _C_. _eremius_ populations located in Australia. The enclosing line depicts the outer margins of the internal drainage basins of Lakes Eyre, Frome and associated lentic waters (based partly after Weatherley, 1967).

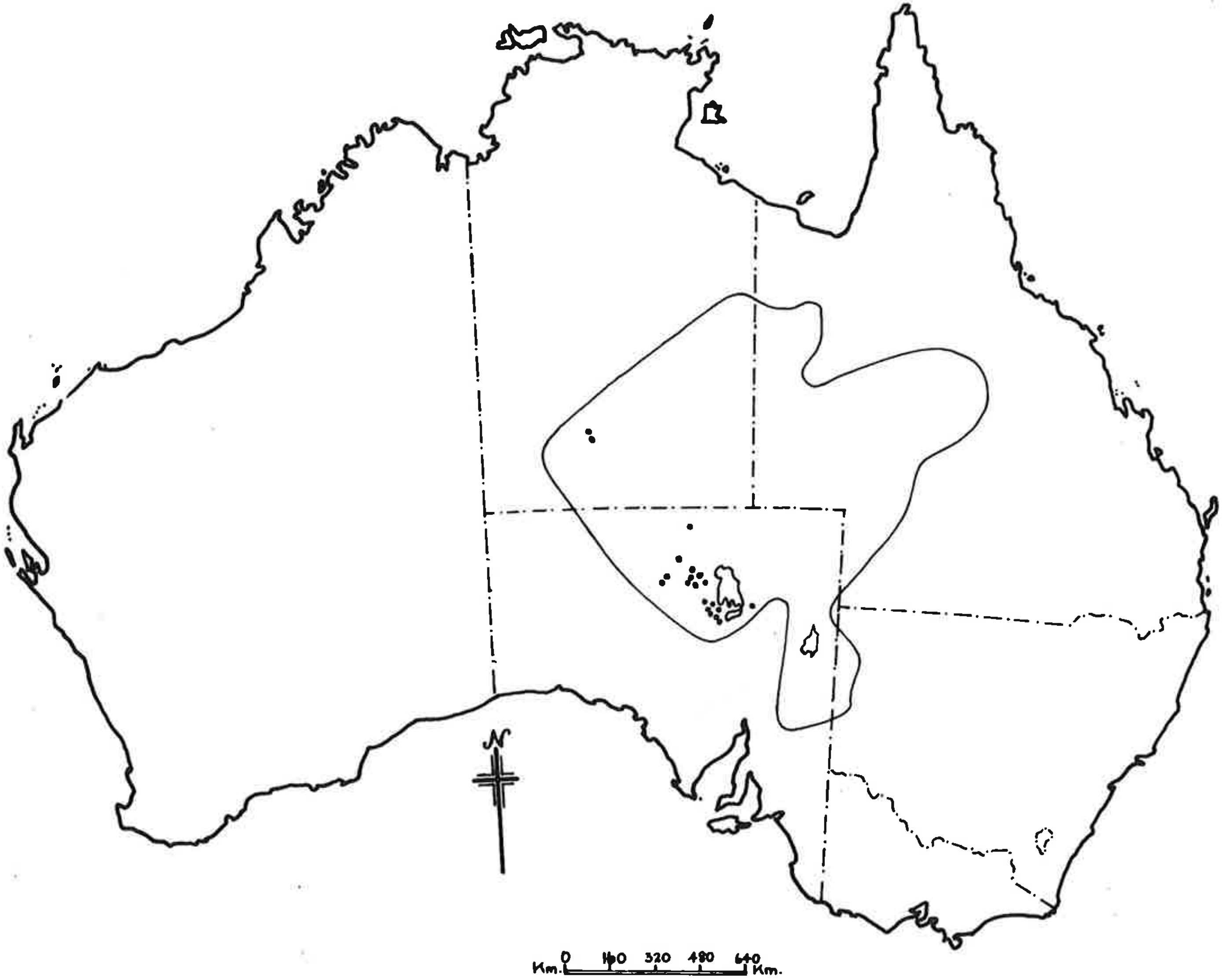
N
Km. 0 160 320 480 640 Km.

Figure 7

Permanent aquatic habitats inspected in the far north of South Australia.

Open symbols (△ , ○) indicate _C_. _eremius_ was not found present. Solid symbols (▲ , ●) indicate the species was found present.

The numbers adjacent the symbols indicate the localities as listed in Appendix A

Key.

△ = artesian water.
○ = meteoric water.
S = spring.
B = bore.
D = dam.
W = waterhole.

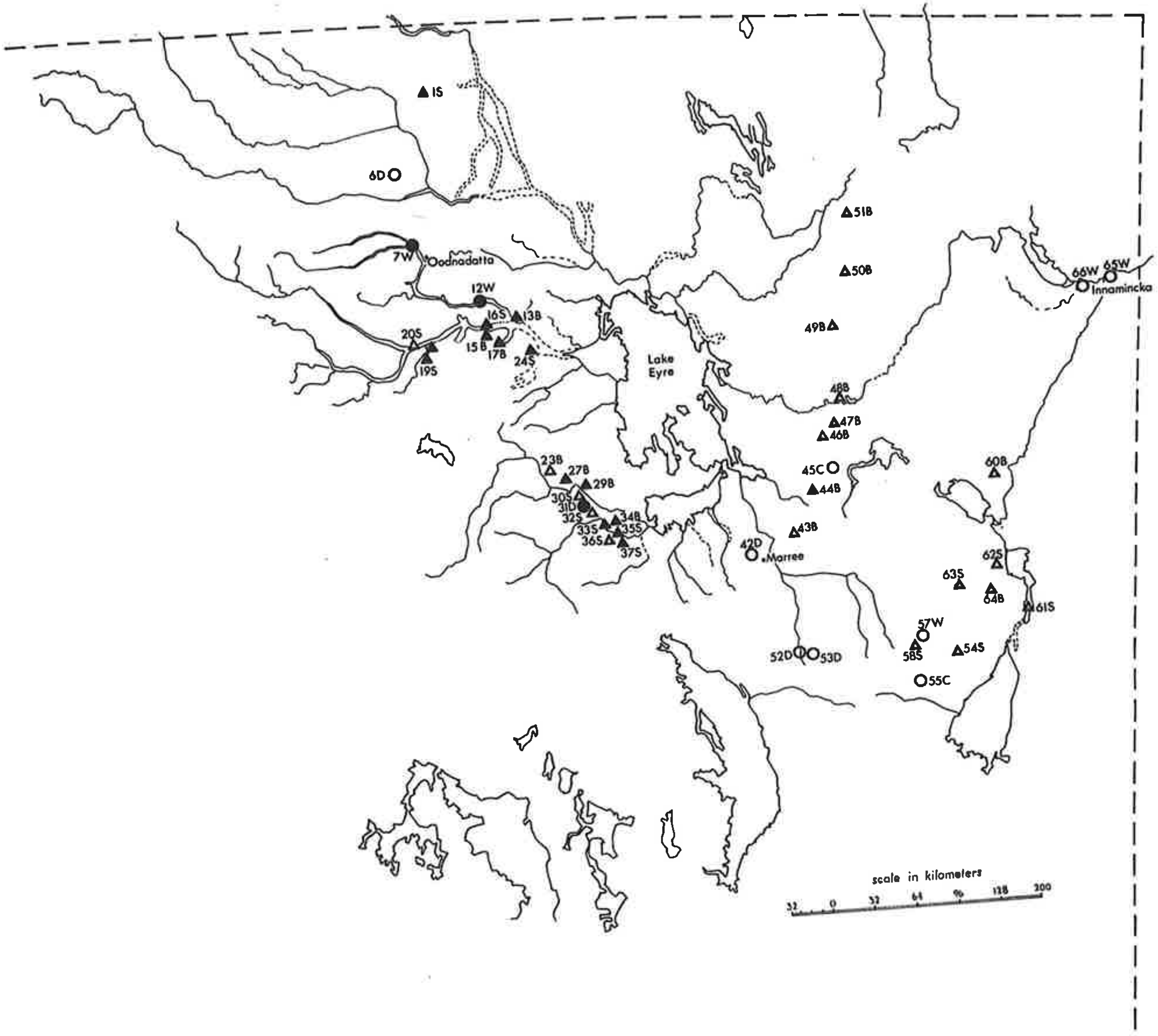
1S
6D
7W
Oodnadatta
12W
16S
13B
15B
17B
20S
19S
24S
Lake Eyre
51B
50B
49B
48B
47B
46B
45C
44B
43B
42D
Marree
66W
65W
Innamincka
23B
27B
29B
30S
31D
32S
34B
33S
35S
36S
37S
60B
62S
63S
64B
61S
57W
58S
54S
52D
53D
55C
scale in kilometers
32
0
32
64
96
128
200

Figure 8

Positions of _C_. _eremius_ populations located in the Northern Territory, Australia. The numbers indicate the localities as listed in Appendix A . Both localities constitute permanent or semi-permanent meteoric waters.

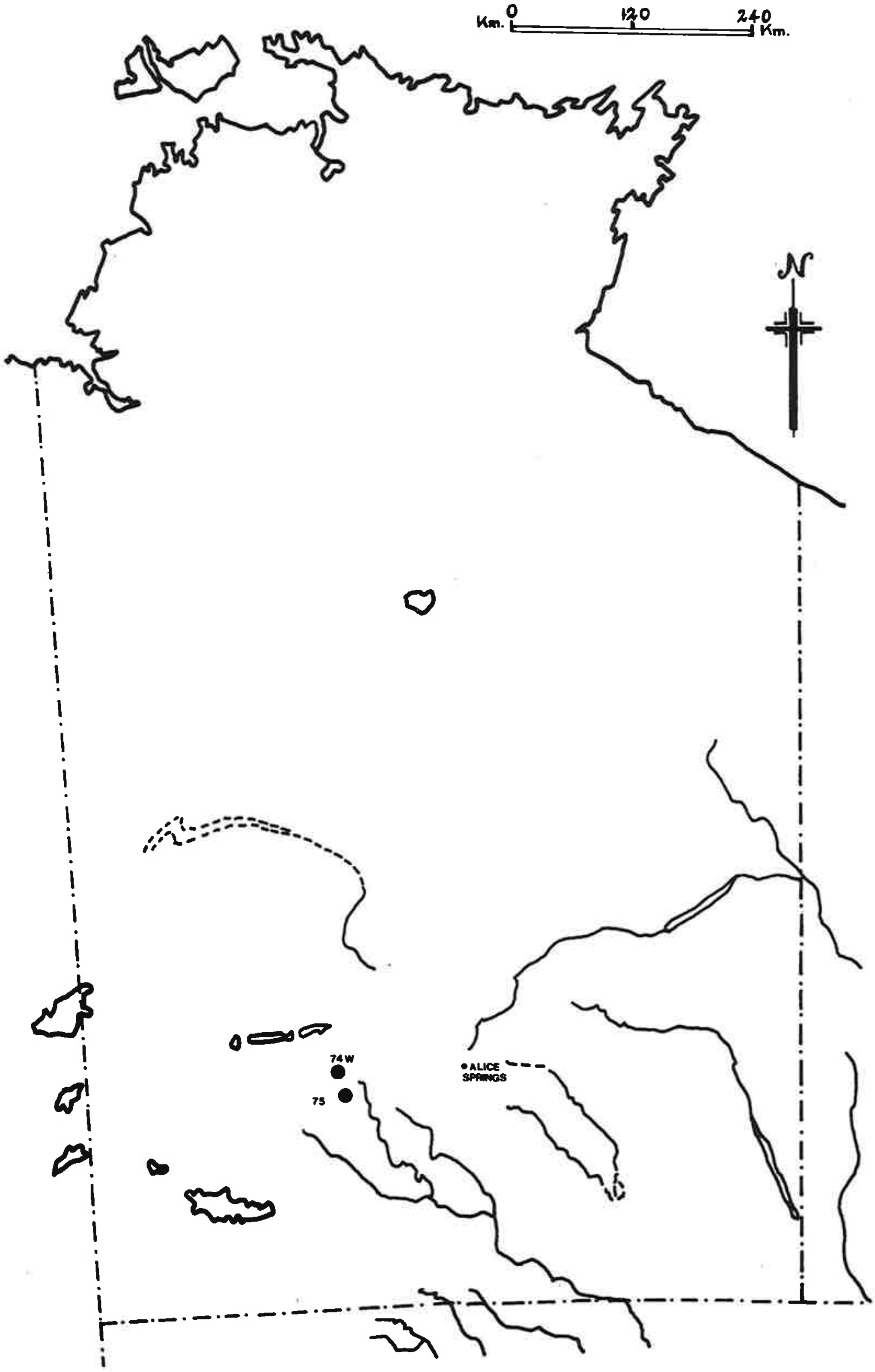
Km. 0
120
240 Km.
N
74 W
75
ALICE SPRINGS

Figure 9

Temporary aquatic habitats inspected in the far north of South Australia.

Open symbols (△ , ○) indicate C. *eremius* was not found present. Solid symbols (▲ , ●) indicate the species was found present.

The numbers adjacent the symbols indicate the localities as listed in Appendix A

Key.

△ = artesian water.
○ = meteoric water.
S = spring.
B = bore.
D = dam.
W = waterhole.

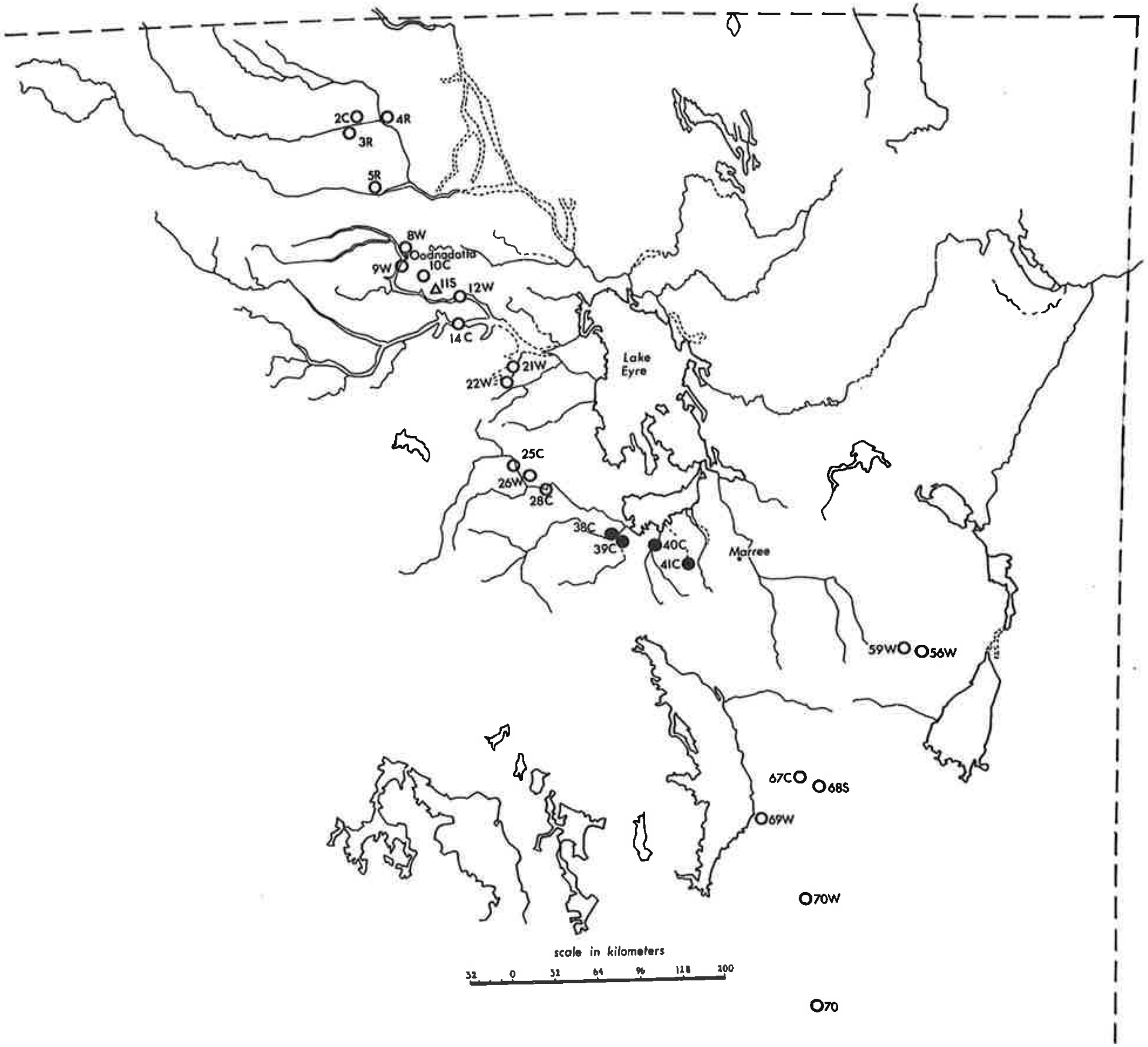
2C
4R
3R
5R
8W
Oodnadatta
9W
10C
11S
12W
14 C
21W
22W
Lake Eyre
25C
26W
28C
38C
39C
40C
41C
Marree
59W
56W
67C
68S
69W
70W
70
scale in kilometers
32
0
32
64
96
128
200

Figure 10

View of section of the stream associated with the Coward Springs Railway Bore (locality 34), February, 1968. Inhabited by *C. eremius*.

Figure 11

View of section of the stream associated with the Wobna Spring (locality 35), April 1968. Inhabited by *C. eremius*.

Figure 12

Coward Springs Railway Bore (locality 34), photographed in 1890 (above) and 1969 (below).

Loc. No.	Bore	Date Sunk	Date *C. eremius* first recorded present	Time gap (years)
34	Coward Springs Railway Bore	1886	4.V.1894	8
29	Strangways Springs Railway Bore	1886	4.V.1894	8
13	Wood Duck Bore	1913	21.XI.69	56
17	Blythe Bore	1918	23.XI.69	51
24	Johnson's No. 3 Bore	1918	Circa 1930	~12
27	Nunn's Bore	1956	29.VII.68	12

Loc. No.	Bore	Date Sunk	Date Last time inspected *C. eremius* present	Time gap (years)
64	Woolatchi Bore	Circa 1895	24.X.69	74
60	Montecolina Bore	1920	29.X.69	49
23	Honeymoon Bore	1956	30.V.71	15

Table 6

Drilling dates of some artesian bores in the central Australian region.

Table 7

Minimum distances between all known *C. eremius* inhabited bore waters (also some un-inhabited bores) and the nearest respective inhabited artesian spring.

Table 7

			Nearest Spring inhabited by *C. eremius*	Approx. min. distance apart (Km).
Bores inhabited by *C. eremius*	Wood Duck Bore		Freeling Springs	30
	Blythe Bore		Freeling Springs	16
	Old Peake H.S. Bore		Freeling Springs	1
	Nilpinna H.S. Bore		Nilpinna Spring	0.5
	Johnson's No. 3 Bore		Freeling Springs	67
	Nunn's Bore	9 Km apart	Coward Springs proper	45
	Strangways Springs Railway Bore		Coward Springs proper	35
	Coward Springs Railway Bore		Coward Springs proper	2.5
	Clayton Bore		Wobna Spring	153
Some Bores not inhabited by *C. eremius*	Honeymoon Bore		Coward Springs proper	71
	Lake Harry Bore		Wobna Spring	130
	Dalkaninna Bore		Wobna Spring	180
	Cannawaukininna Bore		Wobna Spring	204
	Etadunna Bore		Wobna Spring	212
	Kopperamanna No. 1 Bore		Wobna Spring	228

Locality No.	Bore Name	Date flow recorded	Flow rate (gallons/hr)
46	Cannawaukaninna	1964 1966	22,000 22,500
44	Clayton	1946 1966	33,300 28,800
48	Kopperamanna	1964 1966	21,000 21,000
-	Frome Creek	1964 1966	380 300
43	Lake Harry	1964 1966	2,500 2,400
50	Mirra Mitta	1964 1966	22,400 19,200
-	Pandi Burra	1964 1966	17,000 18,600

Table 8

Flow Rates of Some Artesian Bores

in the central Australian region.

Data provided by the Hydrology Section,
South Australian Department of Mines.

IV REPRODUCTION

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1. PREAMBLE

As described previously (see p. 9) C. eremius is heterosexual and sexually di-morphic. Although a series of groups, ranging from 2 - 40 individual adults of both sexes, have been kept under regular surveillance during the period 1969-71 in laboratory tanks under conditions approximating as closely as possible to the natural environment, none have been seen to breed, no released eggs have been located, and at no time have I observed any behaviour suggestive of courtship, spawning, nest building or any other form of behaviour relating to breeding. Furthermore, despite careful examinations including sieving the bottom silt from the stream beds through fine nylon mesh nets during the frequent visits made to Nunn's Bore (locality 27), Coward Springs railway bore (locality 34) and Wobna Mound Spring (locality 35) between December 1967 and May 1971, I failed to locate any released eggs either attached to the base of aquatic vegetation, in nests, suspended or floating in water or settled in bottom silt.

The enlarged anal papilla in both sexes during the breeding season (see p. 26) suggests that this structure may act as a gonopodium. If this should be so, then fertilization could be internal or spawning could take place with the sexes in close proximity. Since there is no evidence that the species is live-bearing it is therefore more likely that fertilization is external.

2. BREEDING PERIOD

(a) Period

In order to establish during which period of the year the species breed, I took monthly samples of 20 males and 20 females from the population at Nunn's Bore (locality 27) during a 14 month period from 13.IV.70 to 31.V.71.

Each such specimen was subsequently examined and the following data recorded using dial calipers observed through a low power binocular microscops - standard length (SL), anal papilla length and maximum length and breadth of each gonad. From these data two indices were calculated, the ratio $\frac{\text{anal papilla length}}{\text{SL}}$ as a measure of anal papilla size and the ratio

$$\frac{\left[\begin{array}{c}\text{Sum lengths}\\ \text{left + right}\\ \text{gonad}\end{array}\right] \left[\begin{array}{c}\text{Sum widths}\\ \text{left + right}\\ \text{gonads}\end{array}\right]}{\text{SL}}$$

as a measure of relative gonad size which I refer to as the "gonad size index". These data are presented in Appendix T and summarized in Table 9 . To get some indication of the reliability of my measurements all measurements on the sample of males taken on 13.IV.70 (see Appendix T) were repeated. These gave an identical mean for the ratio $\frac{\text{anal papilla}}{\text{SL}}$ and a mean value for the gonad size index within 4.8% of the original determination.

Graph 1 plots the monthly mean values of these indices which are given in full in Table 9 . It will be noted that the gonads begin to increase rapidly in size, in both sexes, during August with a maximum size of testes occurring in September and of ovaries in October. The pronounced drop in mean ovary size at the end of November reflects the shedding of eggs during the period from October as is established by stripping experiments. A second size peak in both testes and ovaries at the end of January followed by a further drop during the following 3 months indicates a second, more prolonged, phase of egg shedding during the period between the end of January and the end of April. As mentioned earlier, correlated with the enlargement of the gonads is an enlargement of the anal papilla in both sexes.

Figures 13 to 14 illustrates the typical size of the gonads of both sexes, relative to body cavity size, at different times throughout the year.

Thus the breeding season of C. eremius occurs in two periods; the first between October and November, the second between January and April. However, since no sample was obtained in December 1970 it is uncertain whether the first period continues into December or whether the second period commences in that month.

(b) Eggs

Ripe adult females are readily "stripped" during the periods October to November and January to February and a few eggs can be obtained with more difficulty as late as the end of April. Again no data are available for December. On stripping pale orange-amber eggs are extruded from the tip of the anal papilla. Such freshly extruded eggs possess an adhesive mucus covering which enables them to readily attach to solid surfaces and they sink in artesian water.

The direct count of the number of eggs in the ovaries of dissected female specimens of different sizes which were taken from the population at Nunn's Bore (locality 27) demonstrates (see Table 10) that the number of eggs present per female is proportionate to the size of the individual female, as indicated by its SL. The total number present averages between 150-250 eggs (approximately), which when fully developed are spherical in shape with a diameter varying between 1.1mm and 1.4mm.

(c) <u>Sperm</u>

At no stage have I found any male with running milt nor have I been able to "milk" any specimen.

Sperm have, however, been found in the gonads of males, by microscopic examination, of mounted slides of teased and squashed testes tissue stained with ocein-acetic acid solution.

In a collection of 35 males, 20-50mm SL, taken from Johnson's No. 3 Bore (locality 24) on 3.IX.68 all specimens were found to possess sperm bearing testes. Of a sample of 20 males, 25-45mm SL, taken from Nunn's Bore (locality 27) on 31.X.70 sperm was only located in the testes of those 14 specimens $\geqslant$ 40mmSL; in none of the 6 specimens $\leqslant$ 39mm SL were sperm present. Of a collection of 8 males, 23-40mm SL, taken from Blanche Cup

Spring (locality 36) on 31.I.71 only one specimen, the largest, 40mm SL, was found to have sperm. Sperm were not located in the testes of any of 6 males, 27-39mm SL, sampled from Blanche Cup Spring (locality 36) on 1.III.71; specimens of this size range have been established (see p. 38) as representing the previous October-November brood and therefore would not be expected to be sexually mature at that time.

Although the data are limited, it appears on the basis of the gonads examined from male specimens taken at Blanche Cup Spring (locality 36), when only the largest (40mm SL), possessed sperm, that the remainder presumably represented the generation born during October-November. Therefore it appears that males do not become sexually mature until at least the breeding season following their own hatching that is approximately 10 months later. The single specimen, 40mm SL, that did possess sperm presumably represented one of the original parent generation introduced on 2.IX.70.

Size in itself, however, is no criterion of sexual maturity since sperm was located in the gonad tissue of all 35 males, 20-50mm SL, taken at Johnson's No. 3 Bore (locality 24) on 3.IX.69, that is during the earlier breeding period. Even the smallest specimen in this case possessed well developed testes containing sperm and none gave a gonad size index <1.0. Assuming that the breeding periods established for the population at Nunn's Bore (locality 27), that is October-November and

January-April, also apply to the population at Johnson's No. 3 Bore (locality 24) it is likely that the smaller sexually mature males collected on 3.IX.69 represent the brood hatched in the breeding period between January-April 1969 whilst the larger specimens represent the brood born earlier, i.e. between October-November 1968.

(d) Fecundity

Although the number of eggs produced per female does not appear to be high, there is indirect evidence that, in terms of the numbers of fish that survive to adult size, population build-up can be rapid.

The majority of the populations studied appear to be of quite substantial size and the population of 100 adults (50 males, 50 females) introduced into the previously un-inhabited Blanche Cup Spring pool (locality 36) on 2.IX.70 (see p. 36) subsequently gave rise to an appreciable population so that a total of 627 fish (439 males, 188 females) were recovered on 31.V.71 from 8 traps set during the previous night. This trapping rate is indicative of the size to which the population had grown in a period of 9 months. Furthermore many of the new generation had clearly not yet grown to a size sufficient to be caught in the traps used (see p. 44).

On 24.XI.70 25 adult females, presumably of the original introduced population, were trapped in the Blanche Cup Spring (locality 36) and marked by clipping off their ventral fins (see p. 37). On 31.V.71 3 of 179 females recovered in a total catch of 508 (329 males, 179 females) were so tagged and employing the formula $P = N \times \frac{M}{R}$ (where P = total population, M = number of marked individuals, R = number of marked individuals recovered in a total of N. individuals captured) (after Andrewartha, 1961), the population of the pool was estimated to be of the order of 4000 +. Since the Blanche Cup Spring pool is largely enclosed (see p. 18) and can therefore be regarded as virtually a self contained habitat and because males and females appear to be equally capable of being trapped (see p. 40), this estimate of the size of the population at that time appears to be reasonably acceptable and indicates an extremely rapid build-up in numbers.

	♂♂			♀♀		
Date collected	Mean AP/SL	Range gonad size index	Mean gonad size index	Mean AP/SL	Range gonad size index	Mean gonad size index
13.IV.70	0.06	0.32 - 1.06	0.62	0.03	0.41 - 1.16	0.88
22.VI.70	0.05	0.26 - 0.92	0.57	0.03	0.47 - 1.48	0.94
31.VII.70	0.05	0.22 - 1.32	0.60	0.03	0.44 - 1.39	0.84
24.VIII.70	0.06	0.18 - 2.07	1.17	0.03	0.71 - 2.18	1.13
27.IX.70	0.07	0.35 - 2.89	2.34	0.05	0.47 - 5.08	2.38
31.X.70	0.06	0.24 - 1.96	0.85	0.04	0.75 - 6.04	2.54
25.XI.70	0.06	0.11 - 1.82	0.83	0.04	0.40 - 3.72	1.50
31.I.71	0.06	0.11 - 1.98	1.04	0.04	0.38 - 4.78	2.00
28.II.71	0.06	0.25 - 2.31	1.04	0.03	0.40 - 2.55	1.49
31.III.71	0.06	0.36 - 1.89	0.93	0.03	0.53 - 2.64	1.14
25.IV.71	0.05	0.03 - 0.72	0.38	0.02	0.33 - 1.61	0.88
31.V.71	0.05	0.27 - 1.29	0.64	0.04	0.43 - 1.26	0.89

Table 9

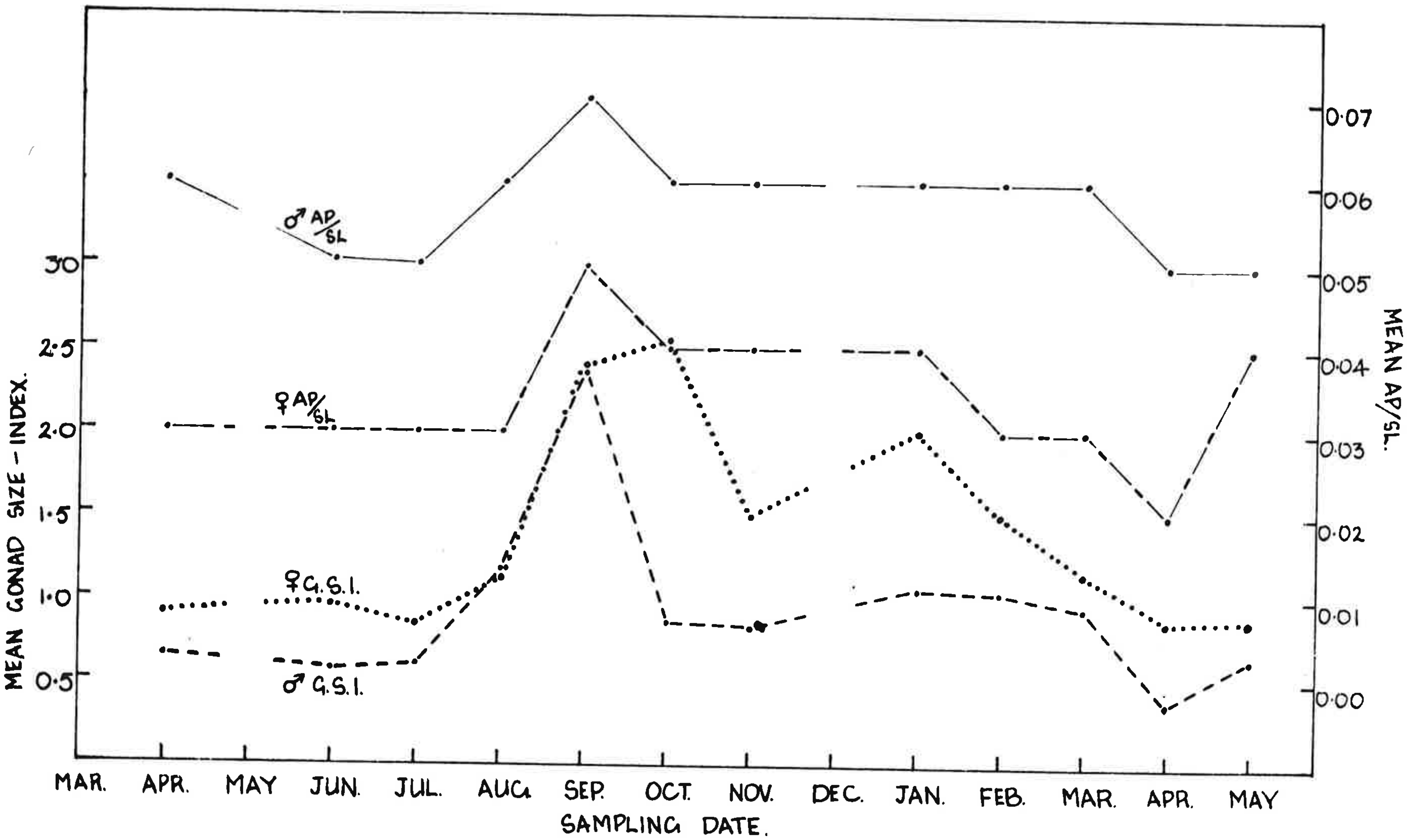
Seasonal Gonad / Anal Papilla Development in *C. eremius* at Nunn's Bore (locality 27) 1970-71.

Data Summarized from Appendix T

Graph 1

Mean values of "gonad size index" (G.S.I.) and the ratio $\frac{\text{anal papilla length}}{\text{standard length}}$ for male and female *C. eremius* sampled from Nunn's Bore (locality 27) on different occasions between April 1970 and May 1971.

Data from Appendix T.



♂ AP/SL
♀ AP/SL
♀ G.S.I.
♂ G.S.I.
MEAN GONAD SIZE - INDEX.
3·0
2·5
2·0
1·5
1·0
0·5
MEAN AP/SL.
0·07
0·06
0·05
0·04
0·03
0·02
0·01
0·00
MAR.
APR.
MAY
JUN.
JUL.
AUG.
SEP.
OCT.
NOV.
DEC.
JAN.
FEB.
MAR.
APR.
MAY
SAMPLING DATE.

Figure 13

Ventral views of dissected *C. eremius* males showing gonads. Each selected from collections made at different times from the Nunn's Bore (locality 27) population. Respective collection dates, standard lengths (SL) and gonad size indices (GSI) of specimens noted beneath each photograph. Enlarged approximately x4.

13.IV.70
SL = 49 mm
GSI = 0.67

22.VI.70
SL = 46 mm
GSI = 0.42

30.VII.70
SL = 52 mm
GSI = 0.67

24.VIII.70
SL = 51 mm
GSI = 1.11

27.IX.70
SL = 55 mm
GSI = 1.70

31.X.70
SL = 44 mm
GSI = 0.70

25.XI.70
SL = 42 mm
GSI = 0.36

31.1.71
SL = 49 mm
GSI = 0.59

28.II.71
SL = 47 mm
GSI = 0.49

31.III.71
SL = 53 mm
GSI = 1.45

25.IV.71
SL = 48 mm
GSI = 0.37

31.V.71
SL = 46 mm
GSI = 0.51

Figure 14

Ventral views of dissected *C. eremius* females showing gonads. Each selected from collections made at different times from the Nunn's Bore (locality 27) population. Respective collection dates, standard lengths (S L) and gonad size indices (G S I) of specimens noted beneath each photograph. Enlarged approximately x4.

13.IV.70
SL = 41 mm
GSI = 0.85

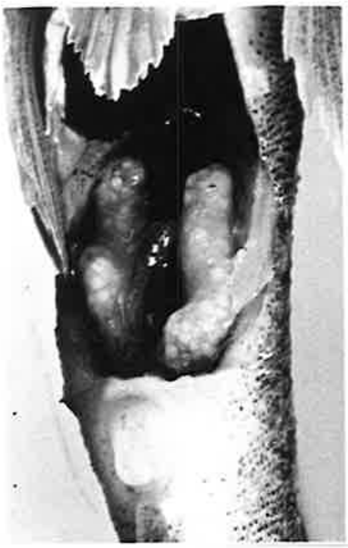
22.VI.70
SL = 45 mm
GSI = 0.81

30.VII.70
SL = 45 mm
GSI = 0.70

24.VIII.70
SL = 45 mm
GSI = 1.01

27.IX.70
SL = 46 mm
GSI = 1.68

31.X.70
SL = 45 mm
GSI = 3.67



25.XI.70
SL = 45 mm
GSI = 0.86

31.I.71
SL = 39 mm
GSI = 1.99

28.II.71
SL = 42 mm
GSI = 1.34

31.III.71
SL = 48 mm
GSI = 2.57

25.IV.71
SL = 42 mm
GSI = 0.75

31.V.71
SL = 49 mm
GSI = 1.38

Table 10

Number of eggs present, their sizes and other data relating to the ovaries of several different sized *C. eremius* collected from Nunn's Bore (locality 27) on 31.IX.70.

SL	AP	Ovary length		Ovary width		Gonad size Index	No. of eggs		Total	Egg diam. (mm.) (20 samples each)	
		left	right	left	right		left ovary	right ovary		Range	Mean
25	0.9	5.3	5.3	1.4	1.4	1.18	71	84	155	0.4 - 0.6	0.5
32	2.2	11.4	11.4	2.9	3.4	4.48	62	78	140	1.1 - 1.4	1.2
35	2.0	11.2	11.2	3.3	3.2	4.16	66	98	164	1.1 - 1.4	1.2
40	2.6	12.0	12.9	3.5	4.1	4.73	99	132	231	1.1 - 1.4	1.3

TABLE 10

V POPULATIONS STRUCTURE, SIZES AND GROWTH RATES

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1. PREAMBLE

Scales, otoliths and vertebral structures offer no features which can be used to determine age in *C. eremius*. Although scale laminae are visible they are nearly always regularly spaced, so giving no indication of periodic changes in growth rate. Similarly, otoliths, vertebrae and operculae are uniform in appearance, without evidence of growth rings. Being unable to make age determinations by such features I decided to attempt to examine the size-age structure of *C. eremius* populations by length frequency analyses.

2. SIZE-AGE STRUCTURE

A series of collections were made by trapping on different occasions at Johnson's No. 3 Bore (locality 24) and Nunn's Bore (locality 27) which were then analysed for frequency of standard lengths (see Appendices I-K and L). The data so obtained from the larger collections were plotted as histograms and in some instances as probability curves (after Cassie, 1954) using various groupings of standard lengths in order to ascertain which, if any, separated and indicated any different size groups present to best advantage.

With respect to Johnson's No. 3 Bore (locality 24) populations the most indicative analysis was obtained from a collection made on 3.IX.68. Histograms 1a and 2a depict the length-frequencies of males and females respectively taken on this occasion. In both histograms the lengths have been grouped in the 2mm intervals 20-21mm, 22-23mm etc. which proved to be the most indicative grouping. In addition, probability curves (Graph 2) were plotted for both sexes from the same data, employing intervals of 2mm in the following groupings, 19-20mm, 21-22mm etc. These respective length groupings, for both the histograms and probability curves, showed different size groups to best advantage and were the groupings employed for subsequent plotting of standard length-frequencies. However, compared to the histogram, the probability curve proved unsatisfactory as a means of discerning size groups in these collections.

From the histograms 1a and 2a plotted from the data obtained from the Johnson's No. 3 Bore (locality 24) collection of 3.IX.68 it can be seen that two principal size groups appear to be present in both sexes, ranging from 26-39mm, and 42-47mm in the case of males and 22-34mm and 36-38mm in the case of females; two size groups are less evident in the male population than in the female population. Both sets of probability curves indicate, though not markedly, size breaks in the male and females populations at about the lengths 40mm and 34mm respectively, which coincide approximately with the breaks apparent in the histograms.

The data of two subsequent collections, 14.VI.70, 27.VIII.70, from Johnson's No. 3 Bore (locality 24) plotted in histograms 1b & 2b and 1c & 2c respectively, also indicate two size groups in the male populations although not in the females. Note that the probability curves (Graph 3), like the histograms, of the data from the 27.VIII.70 collection indicate for the males a size break at about 37mm and 46mm, but for the females no break.

In respect of the analyses of the collection from Nunn's Bore (locality 27), the data obtained from the collection of 13.IV.70 as depicted in histograms 3a and 4a and the probability curves (Graph 4) indicate two reasonably distinct size groups for the female population, 29-36mm and 38-41mm standard length, but not for the male population. The collection of 22.VI.70 suggests in both the histograms (3b and 4b) and the probability curves (Graph 5) that two size groups are present in each sex. The data from two other collections (24.VII.70, 1.XI.70) from Nunn's Bore (locality 27) as plotted in histograms 3c & 4c and 3e & 4e are difficult to interpret and may indicate that only a single age group is present in both sexes. However a wide size range is represented and it is unlikely that only one age group would be present; the data suggest that a second age group is present in both male collections.

Although it was difficult to clearly differentiate size-age groups in most of the collections, two size-age groups are present on some occasions.

In an attempt to solve the problem I introduced a population of C. eremius into the pool of the previously uninhabited Blanche Cup Spring (locality 36) which had been trapped repeatedly on previous occasions and no fish had been caught. The Blanche Cup Spring pool (locality 36) is an enclosed circular body of water 16mm in diameter with a maximum depth of approximately 1mm at its centre. The aquatic vegetation in this pool is the same as at Coward Springs proper (locality 33) viz. Cyperus laevigatus and filamentous green algae (Spirogyra sp.). On 2.IX.70, 50 adult males and 50 adult females collected from Johnson's No. 3 Bore (locality 24) were transferred to and released unmarked into the Blanche Cup spring pool (locality 36). Prior to being released the length-frequencies of these fish were recorded. These data are presented in histograms 5a and 6a .

Fifty nine days later, 8 baited wire mesh traps (see Appendix D) were introduced into the pool for a 15 hour over-night setting period. The standard lengths of all fish collected were measured and they were returned to the pool. This procedure was repeated on several occasions over the next 6 months. Appendix N presents the length-frequency data from these measurements and histograms 5b,6b to 5h, 6h indicate the size structure of these successive collections.

The fish were released unmarked because no effective marking technique had been employed up to that time, in spite of attempts made in the laboratory and the field using different methods devised by other workers, including the attachment of nylon threads (Reinboth, 1954), impregnation with fluorescent pigment granules by means of compressed air (Phinney, 1966), (Phinney, Duane, Miller & Dahlberg, 1967), and the injection of liquid latex (Riley, 1966). Attempts to mark by means of branding with a heated iron usually resulted in infection within a few days, soon followed by death. Finally the fish were marked by clipping off the ventral fins. Tests in the laboratory had shown that provided the fins were not cut too closely to their base that the fish suffered no apparent harmful effect from this operation. Therefore on the morning of 24.XI.70 all female fish (25) collected during the previous night at the Blanche Cup Spring (locality 36) were marked by this method. Clipped individuals were recovered but as fin re-growth was rapid the fins were re-clipped each time a marked individual was recaptured. Usually on re-growth the fin was deformed so that it was normally not difficult to ascertain if a fish was in fact one of the original marked specimens, despite subsequent re-growth.

The recovery of each marked female fish is represented on the histograms by means of a small cross (x) above the size range of the particular fish. Similarly, a "d" above a particular size range indicates that a fish of that size range was dead upon being recovered from the trap.

From the histograms 5b,6b to 5h,6h plotted from the data obtained from the successive collections taken at Blanche Cup Spring (locality 36) it is seen that:-

(a) The original populations of both sexes rapidly grew to a maximum length of 50-60mm standard length.

(b) Since large numbers of fish shorter than those originally released in the pool began to appear in traps from January 1971 onwards a new generation had apparently been bred sometime between early September (when the parent population was introduced) and that month.

(c) This new generation was probably born over a period of a month or more since on 1.III.71 its members had a relatively wide size range; for example on 1.III.71 trapped males of the new generation ranged between 24mm and at least 39mm standard length and females between 28mm and 40mm standard length. As indicated elsewhere (see p. 26), it seems that breeding occurs in two periods, between October-November and January-April respectively, so accounting for the wide range.

(d) The new generation, particularly the males, grew rapidly since they appear to have become partly absorbed into the parent size range about 5 months after birth.

(e) It appears probable that once the parent generation grows to maximum size mortality rates accelerate, since all dead fish found in traps were in this upper size range (see Table 11).

(f) Since some of the new generation of males approach maximum size within about the first 6 months of life, it would seem that by the size-frequency technique it is possible to distinguish more than one size-age group of males only for about 6 months following a breeding period. Young females on the other hand appear to grow more slowly and the parent and next generation can therefore be distinguished by length analyses for a longer period.

(g) Since adult mortalities were relatively frequent following the appearance of the new generation and the number of parent population fish that were trapped progressively dropped following their initial introduction (see Table 12), it appears that the parent generation progressively drops in numbers after breeding and therefore at least some members of it do not survive until the following breeding season.

On the available data I am unable to estimate the species longevity. However, since small fishes of temperate and tropical regions are reported to frequently have a life span of less than 2 years (Lagler et al, 1962) and reported longevities of different Gobiidae in captivity vary between approximately 6 months and 2 years (Flower, 1925; Flower, 1935; Fry, 1957), it is probable that <u>C. eremius</u> does not live more than about 2 years.

Since growth in <u>C. eremius</u> has been shown to be rapid, at least in the early stages of life, it appears that sexual maturity may be achieved by the first breeding season after being born (that is, 9 to 12 months later). Certainly adult size would be aquired by then but as shown elsewhere (see p. 29) size itself is no criteria of sexual maturity.

Until longevity and the number of times breeding occurs in the individual has been established it is not possible to ascertain how many generations are present in an adult population.

3. SEX RATIOS

Table 13 lists the sex ratios found in certain trapped collections of <u>C. eremius</u> from various localities.

Collecting by a fine nylon mesh dab net at Blanche Cup spring (locality 36) provided a collection in which the ratio of the sexes (see Table 14) was of the same order as that of a trapped collection retrieved the same day, so that it may be concluded that both sexes are equally likely to enter or escape from a trap. It therefore seems probable that the larger trapped collections at least, do indicate the approximate proportion of the sexes in the respective populations.

However, as shown in Table 13 there are instances in which substantial changes in sex ratio occur. For example, there is a marked reversal of the sex ratio between collections made at Nunn's Bore (locality 27) on 24.VIII.70, (when males = 66.6%, females = 33.4%), and on 1.XI.70 (when males = 34.1%, females 65.9%). Again, at Wobna Spring (locality 35) there is a sex-ratio reversal, though less pronounced, which occurred during the period 11.VI.70 to 23.VIII.70 when females were dominant (53.2%) on the first date but males were dominant (58.4%) on the second.

These fluctuations may indicate possible seasonal fluctuations in activity on the part of the sexes but further study is needed to clarify the issue. Due to the late stage at which it became possible to sex C. eremius I have insufficient data of the sex ratios of trapped collections at any one locality, at different times of the year, to enable possible seasonal fluctuations to be established.

It is therefore apparent that with the data available no more than an approximate estimate can be made of the sex ratios of the respective populations. Thus it appears that either sex may predominate in any one population and that this may be by as much as 40% or more of the total population (for example, as at Blanche Cup Spring (locality 36)) though usually the difference is apparently far less and in fact there may be virtually no difference.

4. POPULATION DENSITIES

Visual observations made in the field between 1968-71 indicate that the sizes of *C. eremius* populations vary greatly in terms of both total numbers and density. For example the populations inhabiting the shallow, lightly vegetated, streams at Coward Springs proper (locality 33) and Wobna Springs (locality 35) were clearly relatively small compared to the abundantly populated pools and side-shallows at Johnson's No. 3 Bore (locality 24) which were deeper and more heavily vegetated.

Trapping data recorded along the streams at Coward Springs railway bore (locality 34) and Wobna Spring (locality 35) indicates (see Appendices E and P) that relative abundance can vary markedly from place to place within the individual habitat. As shown elsewhere (see p. 95) abundance in *C. eremius* correlates with the amount of aquatic vegetation present.

Only one attempt has been made to estimate absolute densities within a habitat. At Coward Springs railway bore (locality 34) on 21.II.68 a galvanised iron quadrat (50cm deep) was placed successively at several stations along the stream. The enclosed fish were collected by means of a nylon mesh dab net which was used to sieve the enclosed water and bed silt (down to a depth of approximately 5cm sub-bed). Because of the weight of the quadrat and difficulty in traversing the soft silt bed it took approximately 20 seconds, from the time the water was entered, to set the quadrat in position. Thus any active fish could readily escape upon being disturbed prior to the quadrat area being sealed off. Nevertheless, numbers of from 2-35 fish were successfully trapped within the quadrat at each station.

Table 15 presents the numbers of fish per square metre trapped at the four stations at which readings were made. These absolute densities follow a pattern similar to that of relative densities obtained by trapping data recorded on 28.V.68 (see Appendix E) and also given in Table 15 .

Relative densities have been regularly recorded along the streams at Coward Springs railway bore (locality 34) and Wobna Spring (locality 35) and the data is given in Appendices E and F . These recordings were made by setting a single baited wire mesh trap (see Appendix D) at each station for an approximately 15 hour overnight period. Counts made of the fish so trapped indicated the relative abundance of fish in the vicinity of each station at the time of trapping.

5. GROWTH RATES

The data (see Table 12) obtained from length-frequency analyses from collections made at Blanche Cup Springs (locality 36) has enabled me to obtain some estimate of growth rate in C. eremius at various stages.

Considering, firstly, growth in the early stages:- It is estimated, from the gonad size index data (see section IV) that breeding occurs some time between October-November, followed, apparently, by a later breeding period between January-April. Therefore the small fish first trapped on 1.II.71, which would be derived from the parent population put into the spring on 2.IX.70, would be approximately 3-4 months of age and born in the first period, as any later born individuals are unlikely to have reached a size to be trapped on 1.II.71. Thus over the first 3-4 months of life, growth in terms of standard length, is 43.3mm for males and 40.3mm for females. Subsequent growth however appears to be considerably less. From 1.II.71 to 1.III.71 the increase in mean standard length amongst the male population is calculated to be only 1.4mm, from 1.II.71 to 31.III.71 again only 1.4mm with a further decrease between 31.III.71 and 25.IV.71 to only 0.7mm mean increase. The subsequent drop by 0.6mm in mean length determined for the collection on 31.V.71 is probably due to an increase in the frequency of smaller size-range fish being trapped, presumably those from the brood born in the later January-April period. With regard to the female population the growth from 1.II.71 to 1.III.71 appears to be negative but this is probably a result of the relatively few numbers being trapped; between 1.III.71 and 31.III.71 there is an apparent increase in mean standard length of 31.mm but between 31.III.71 and 25.IV.71 only 1.0mm increase. The apparent drop in mean length between 25.IV.71 and 3.V.71 is again probably due to an increase in the number of smaller size range fish being trapped from the brood born in the January-April period.

With regard to the adult parent population:- Assuming the parent population introduced on 2.IX.70 comprises mainly the Johnson's No. 3 Bore (locality 24) broods of the previous October-November and January-April then with regard to males the mean increase in standard length over the two months to 31.I.70 was 11.1mm, between 31.X.70 and 24.XI.70 2.9mm, between 24.XI.70 and 1.II.71 3.1mm and between 1.II.71 and 1.III.71, 0.6mm increase.

For the females over the same periods, growth in terms of mean standard length was estimated at 13.4mm, 4.6mm, 0.5mm and 0.1mm. The apparent drop in mean length in the following collections (31.III.71, 25.IV.71) is probably due to the small numbers trapped.

On the basis of the above data it is concluded that:-

(a) In fish born in the October-November period growth is rapid in the first 3-4 months thereafter (coinciding with the summer months and hence higher water temperatures) with both sexes obtaining a mean standard length of approximately 40-44mm at the end of this period.

(b) Growth is much reduced in the next 3 months up to April in those individuals born in October-November and possibly also in those born in January-April. Between April-May it appears there is actually a reduction in size. Although as pointed out, this may be due partly to increasing numbers of small fish being trapped, it will be noted that this period of reduced growth rate coincides with winter months and hence cooler water temperatures.

(c) Growth later in life, towards the next summer, appears to accelerate, coinciding with increasing ambient and water temperarures.

(d) A maximum size of approximately 60mm standard length is attained about the age of 17 months. Since all the specimens that were taken from the traps dead ranged in size between 50-58mm standard length the species possibly does not survive more than 24 months (see p. 39). On the other hand it is possible the species has a greater longevity but does not grow beyond 60mm standard length.

(e) Growth appears to be more rapid at all stages in males than in females. The mean size for males in any one population is invariably greater than females, though females that do survive are capable of attaining a length as great as the maximum male length.

Histogram 1a.

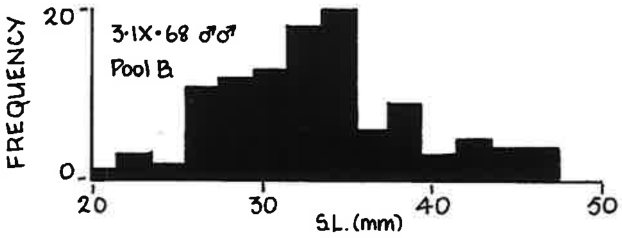
C. eremius males trapped at Johnson's No. 3 Bore (locality 24) on 3.IX.68.

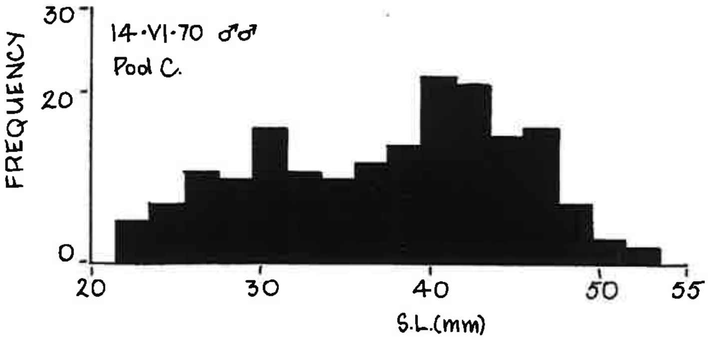
Histogram 1b.

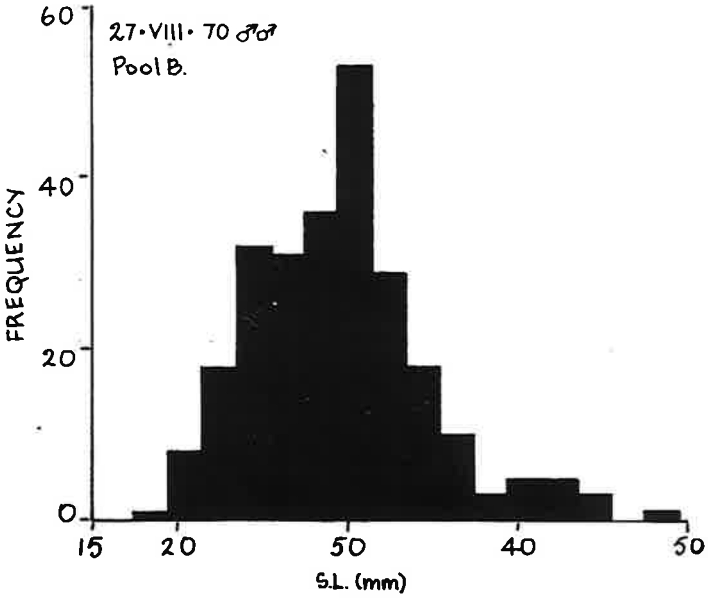
C. eremius males trapped at Johnson's No. 3 Bore (locality 24) on 14.VI.70.

Histogram 1c.

C. eremius males trapped at Johnson's No. 3 Bore (locality 24) on 27.VIII.70.


FREQUENCY
20
0
3·IX·68 ♂♂
Pool B
20
30
40
50
S.L. (mm)


FREQUENCY
30
20
0
14·VI·70 ♂♂
Pool C.
20
30
40
50
55
S.L.(mm)


FREQUENCY
60
40
20
0
27·VIII· 70 ♂♂
Pool B.
15
20
50
40
50
S.L. (mm)

Histogram 2a.

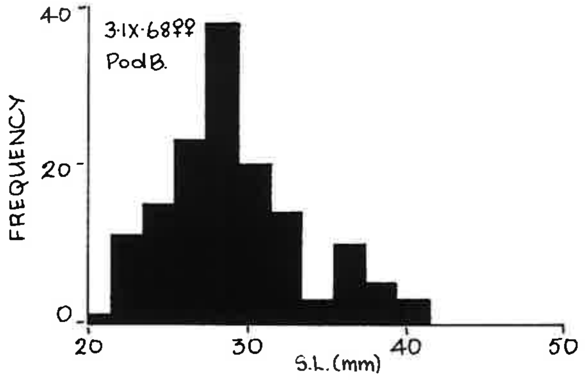
C. eremius females trapped at Johnson's No. 3 Bore (locality 24) on 3.IX.68.

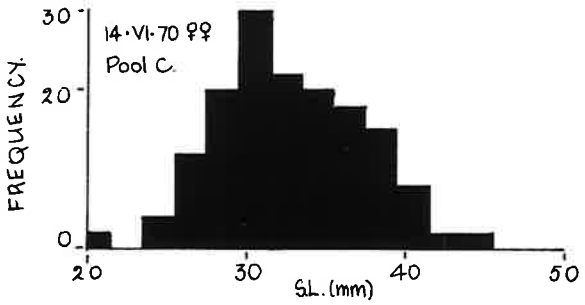
Histogram 2b.

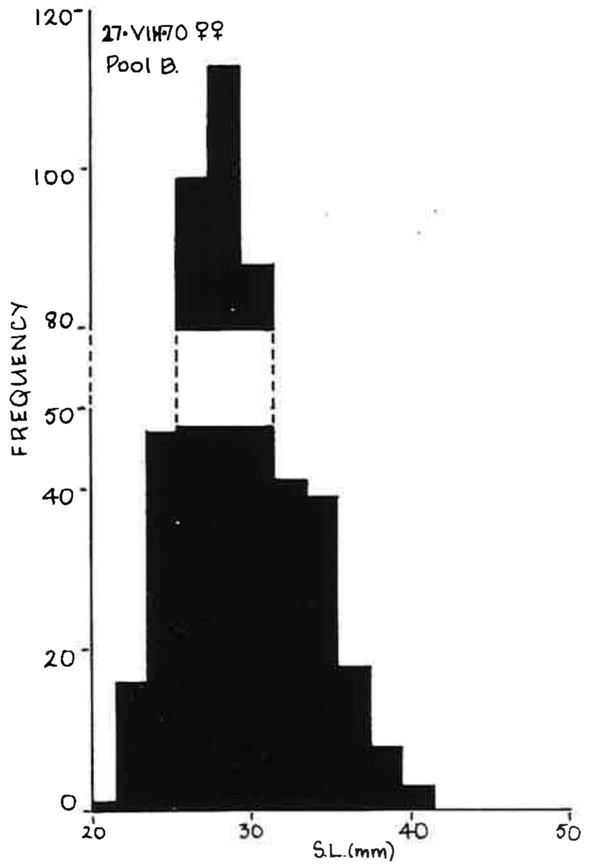
C. eremius females trapped at Johnson's No. 3 Bore (locality 24) on 14.VI.70.

Histogram 2c.

C. eremius females trapped at Johnson's No. 3 Bore (locality 24) on 27.VIII.70.

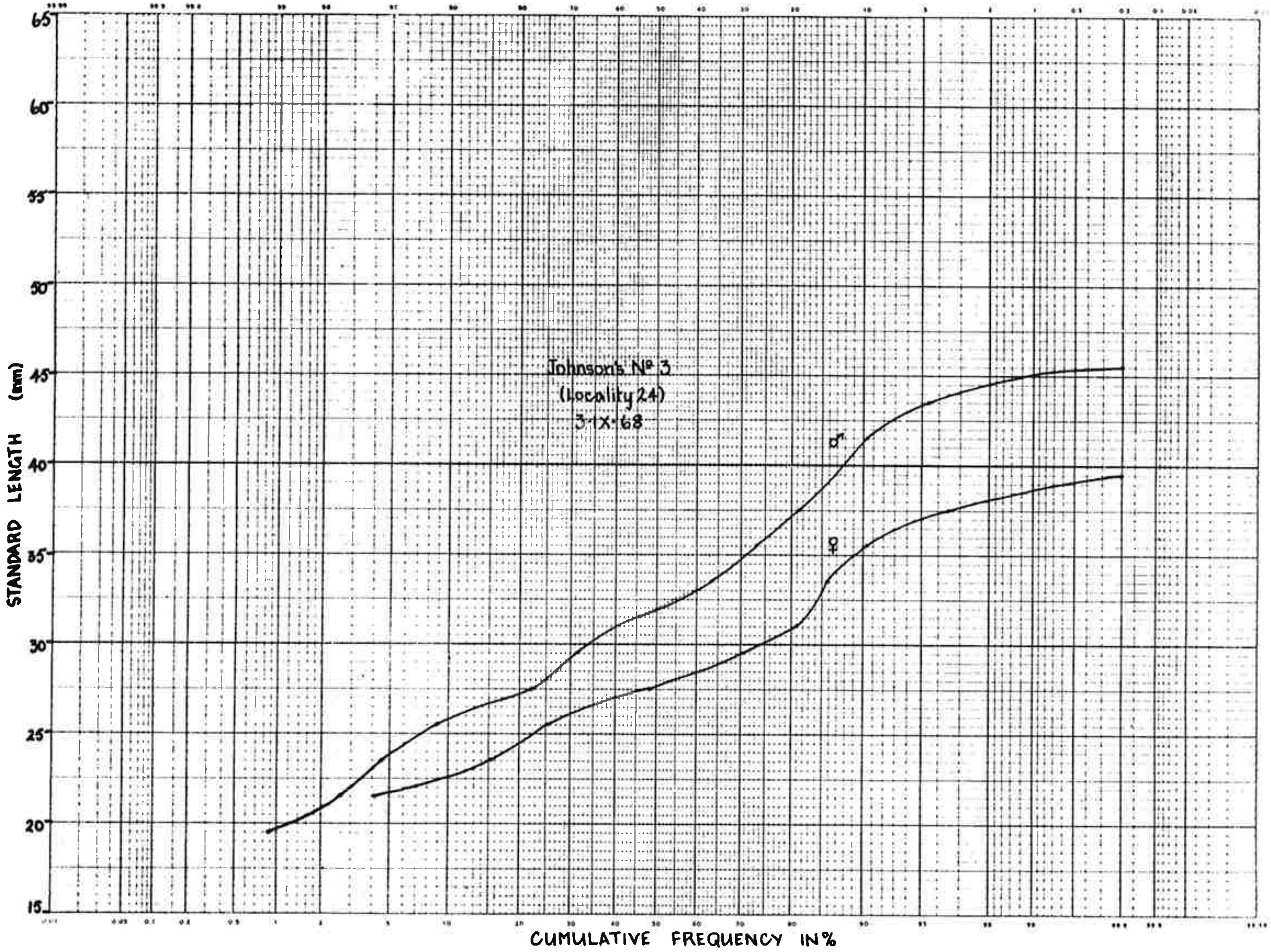

3·IX·68 ♀♀
Pool B.
FREQUENCY
40
20
0
20
30
40
50
S.L. (mm)


14·VI·70 ♀♀
Pool C.
FREQUENCY
30
20
0
20
30
40
50
S.L. (mm)


27·VII·70 ♀♀
Pool B.
FREQUENCY
120
100
80
50
40
20
0
20
30
40
50
S.L. (mm)

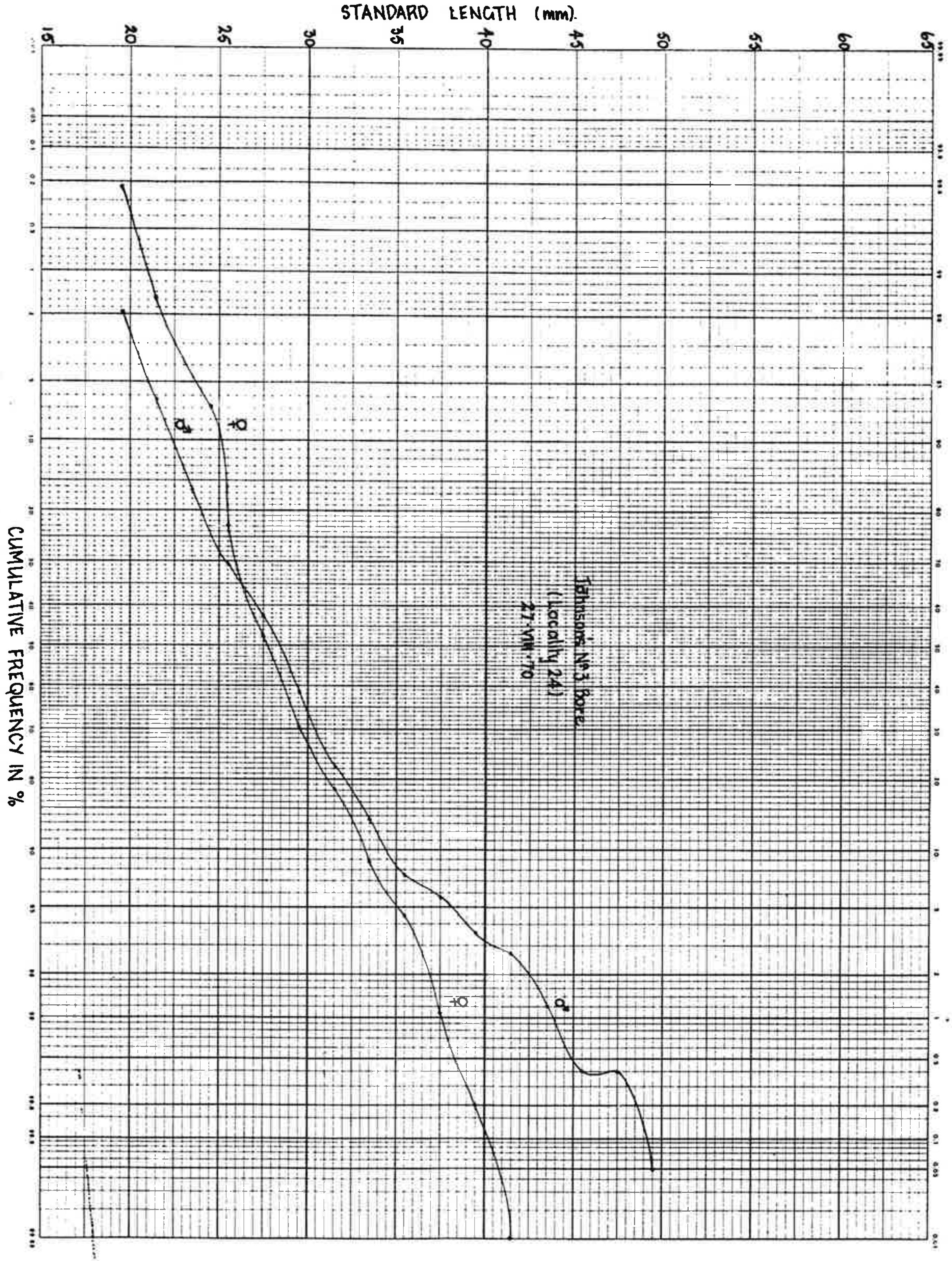
Graph 2

Cumulative percentage length distribution of a collection of male and female *C. eremius* trapped at Johnson's No. 3 Bore (locality 24) on 3.IX.68.


Johnson's Nº 3
(Locality 24)
3·X·68
♂
♀
STANDARD LENGTH (mm)
65
60
55
50
45
40
35
30
25
20
15
CUMULATIVE FREQUENCY IN%

Graph 3

Cumulative percentage length distribution of a collection of male and female *C. eremius* trapped at Johnson's No. 3 Bore (locality 24) on 27.VIII.70.


STANDARD LENGTH (mm).
15
20
25
30
35
40
45
50
55
60
65
CUMULATIVE FREQUENCY IN %
♀
♂
♀
♂
Johnson's No 3 Bore
(Locality 24)
27-VIII-70

Histogram 3a.

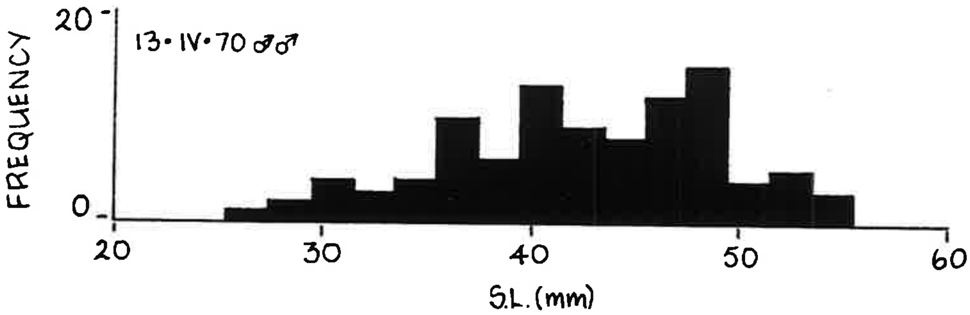
C. eremius males trapped at Nunn's Bore (locality 27) on 13.IV.70.

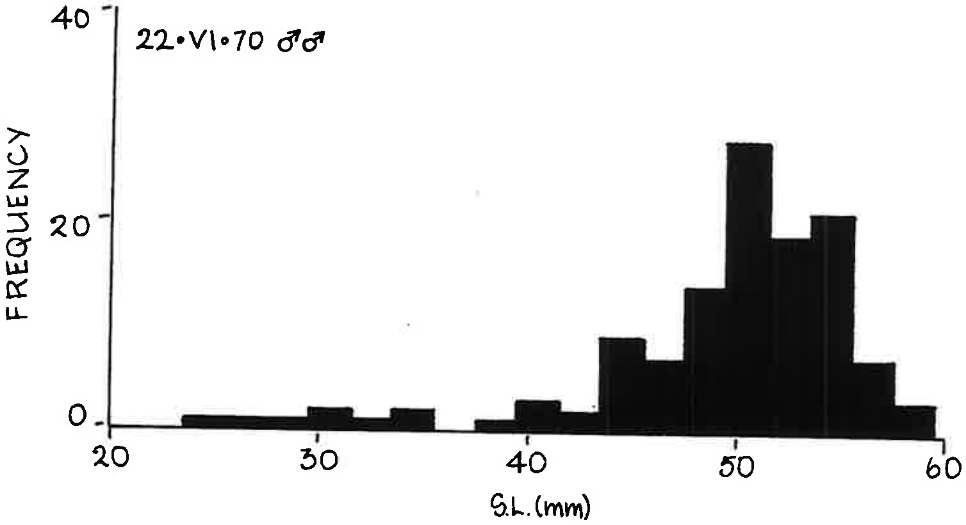
Histogram 3b.

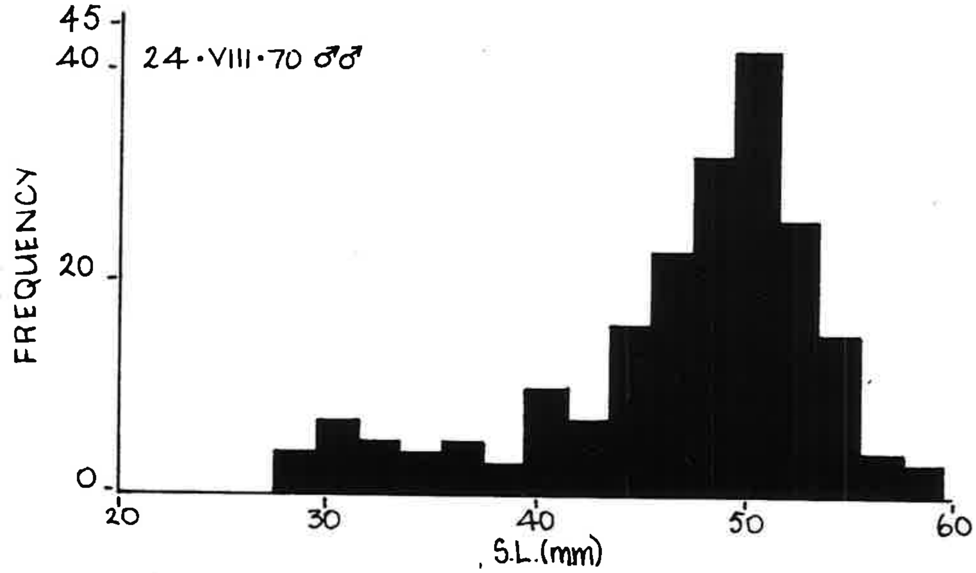
C. eremius males trapped at Nunn's Bore (locality 27) on 22.VI.70.

Histogram 3c.

C. eremius males trapped at Nunn's Bore (locality 27) on 24.VIII.70.


20
0
13·IV·70 ♂♂
FREQUENCY
20
30
40
50
60
S.L.(mm)


40
20
0
22·VI·70 ♂♂
FREQUENCY
20
30
40
50
60
S.L.(mm)

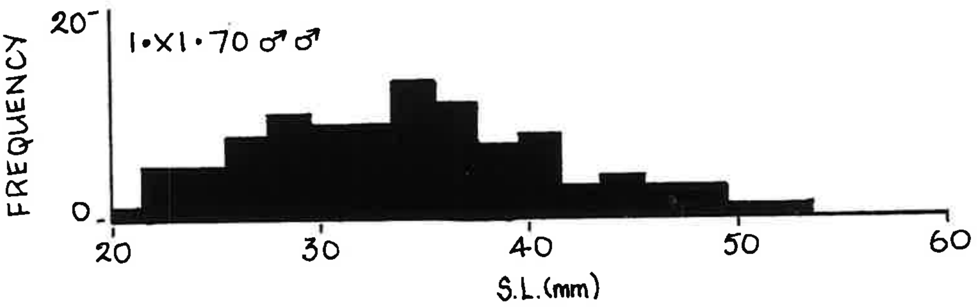

45
40
20
0
24·VIII·70 ♂♂
FREQUENCY
20
30
40
50
60
S.L.(mm)

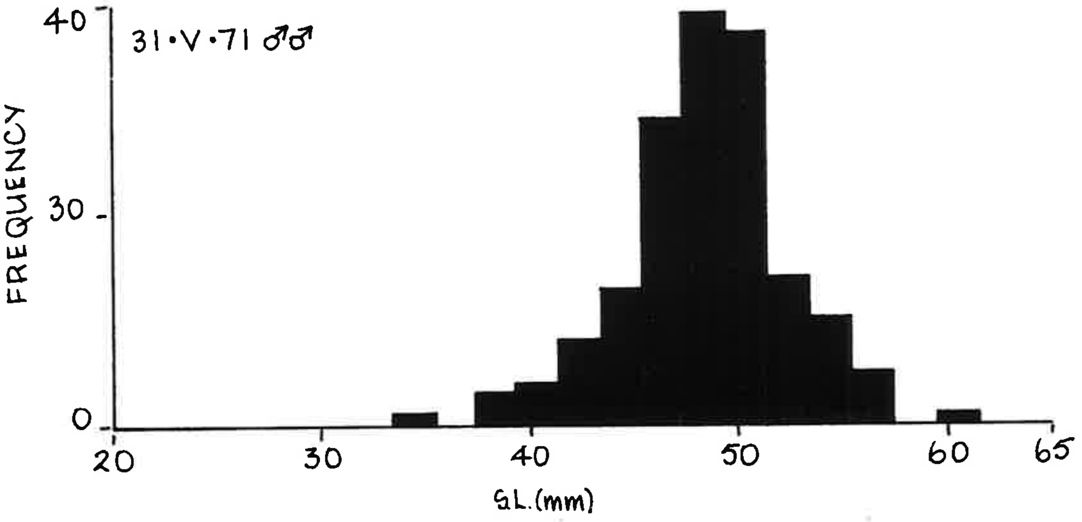
Histogram 3d.

C. *eremius* males trapped at Nunn's Bore (locality 27) on 1.XI.70.

Histogram 3e.

C. *eremius* males trapped at Nunn's Bore (locality 27) on 31.V.71.


FREQUENCY
20
0
1·XI·70 ♂♂
20
30
40
50
60
S.L.(mm)


FREQUENCY
40
30
0
31·V·71 ♂♂
20
30
40
50
60
65
S.L.(mm)

Histogram 4a

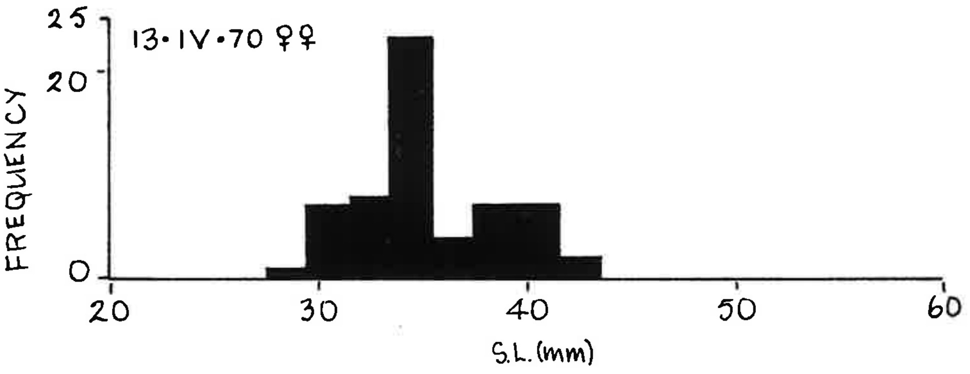
C. *eremius* females trapped at Nunn's Bore (locality 27) on 13.IV.70.

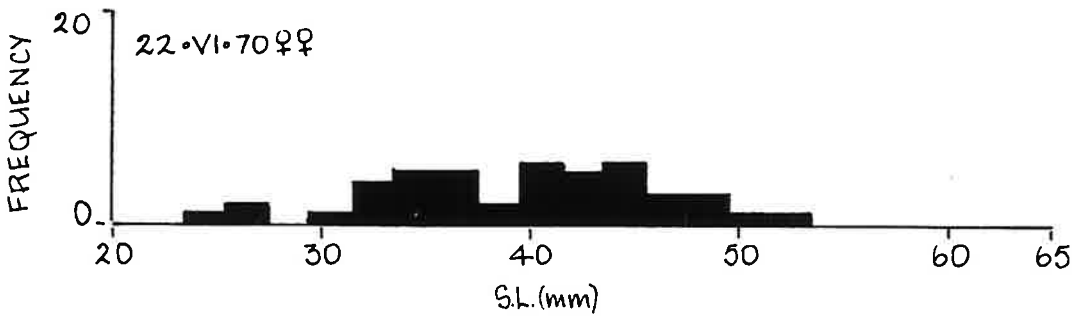
Histogram 4b.

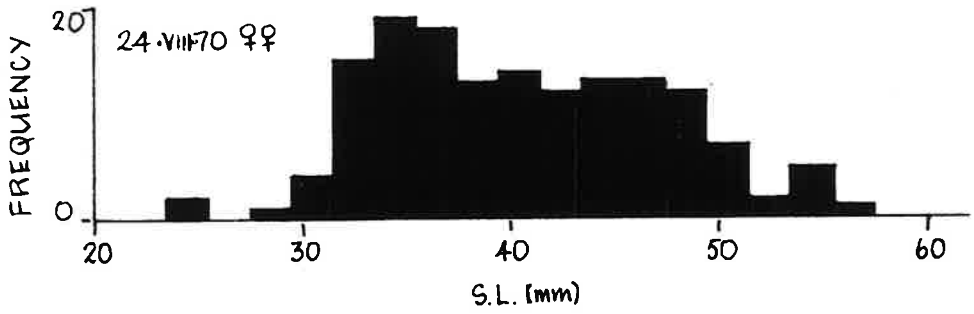
C. *eremius* females trapped at Nunn's Bore (locality 27) on 22.VI.70.

Histogram 4c.

C. *eremius* females trapped at Nunn's Bore (locality 27) on 24.VIII.70.


13·IV·70 ♀♀
FREQUENCY
25
20
0
20
30
40
50
60
S.L. (mm)


22·VI·70 ♀♀
FREQUENCY
20
0
20
30
40
50
60
65
S.L. (mm)

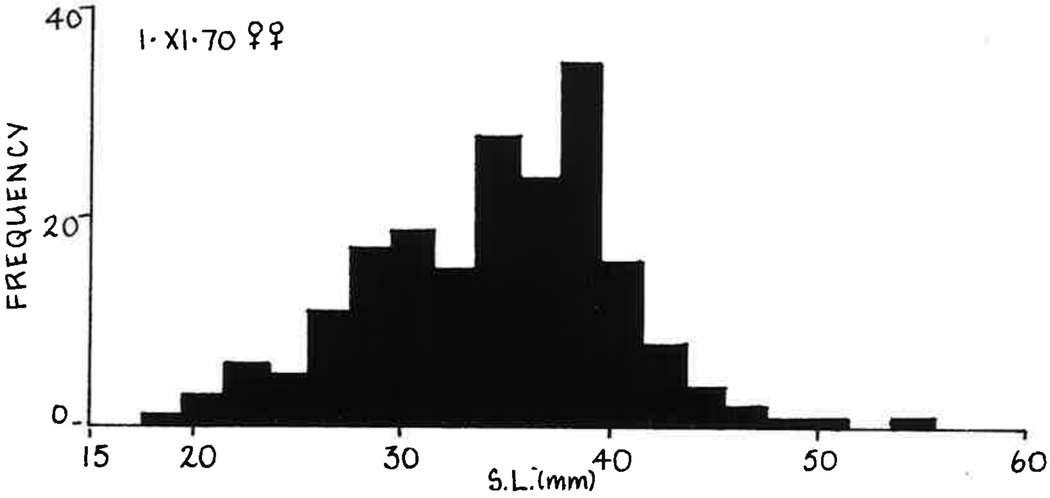

24·VIII·70 ♀♀
FREQUENCY
20
0
20
30
40
50
60
S.L. (mm)

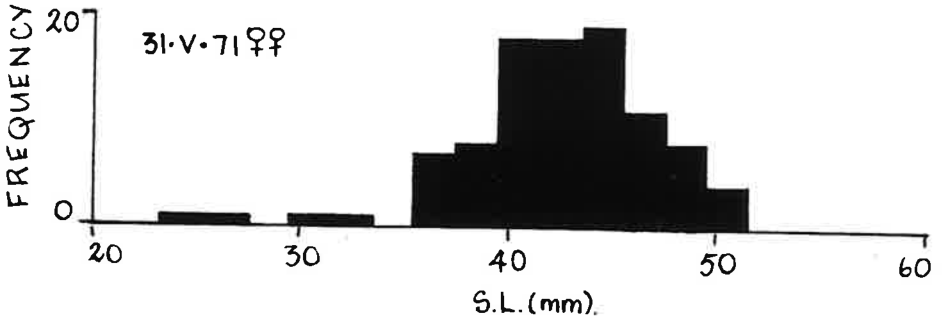
Histogram 4d.

C. eremius females trapped at Nunn's Bore (locality 27) on 1.XI.70.

Histogram 4e.

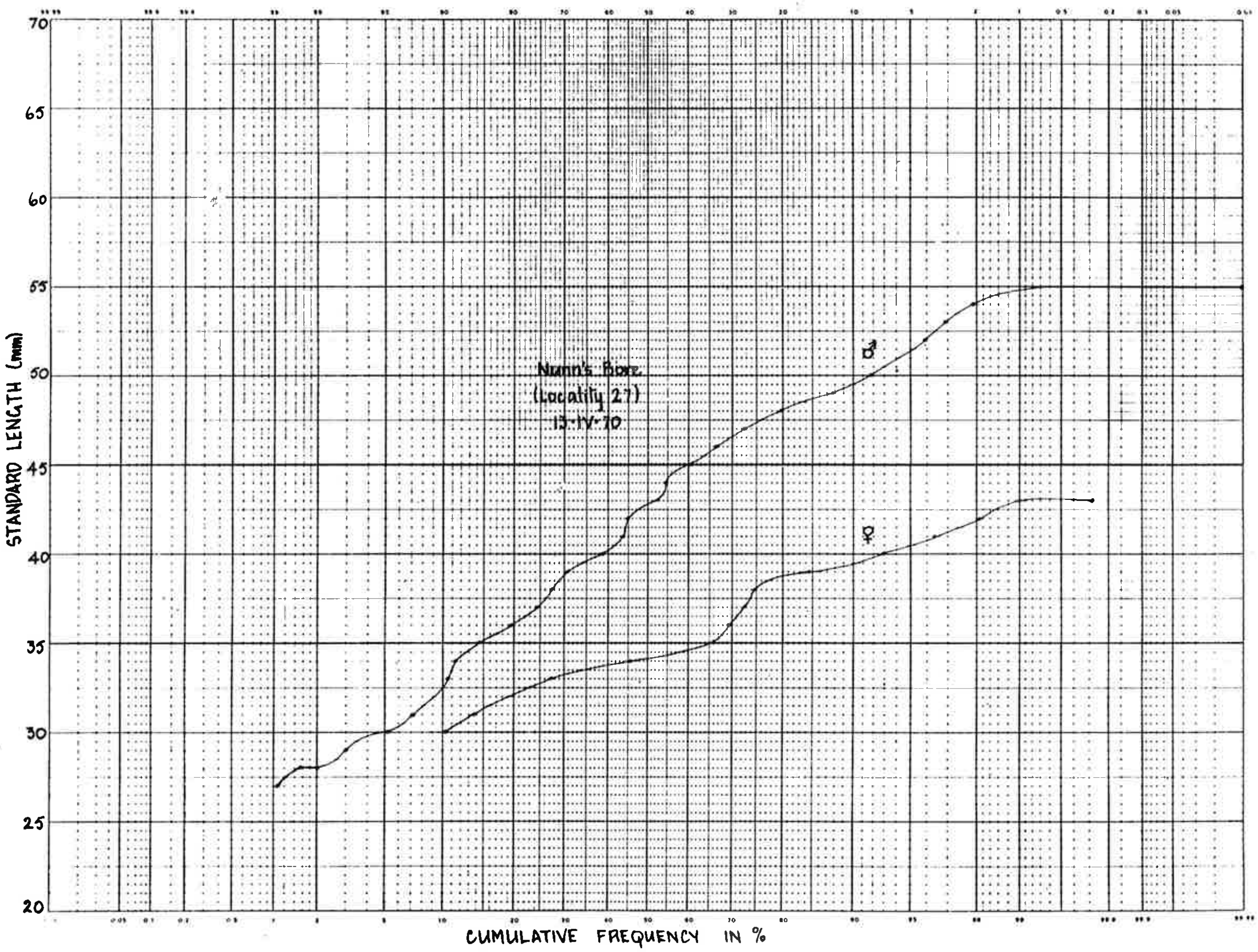
C. eremius females trapped at Nunn's Bore (locality 27) on 31.V.71.


1·XI·70 ♀♀
FREQUENCY
40
20
0
15
20
30
40
50
60
S.L.(mm)


31·V·71 ♀♀
FREQUENCY
20
0
20
30
40
50
60
S.L.(mm).

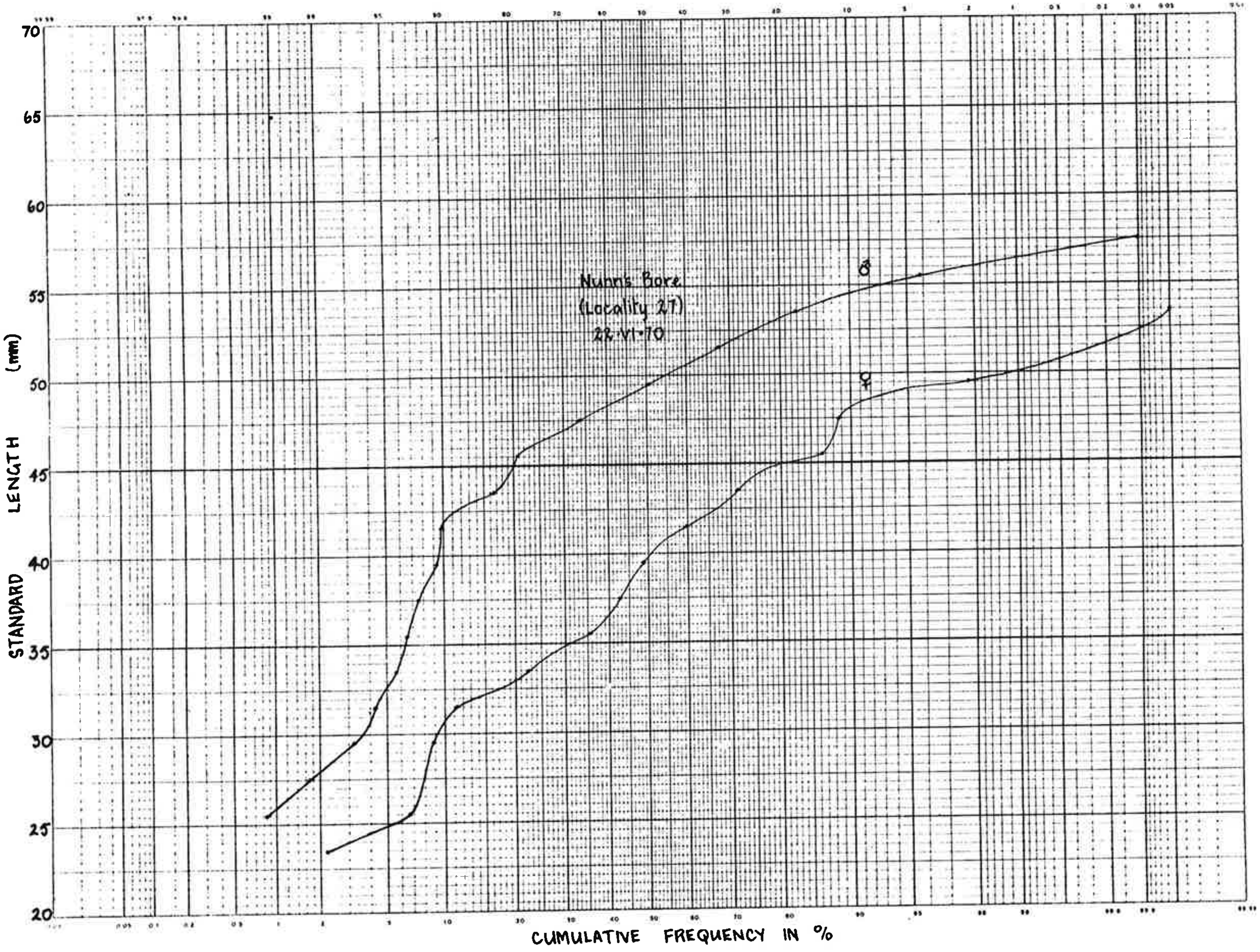
Graph 4

Cumulative percentage length distribution of a collection of male and female *C. eremius* trapped at Nunn's Bore (locality 27) on 13.IV.70.


Nunn's Bore
(Locality 27)
13·IV·70
♂
♀
STANDARD LENGTH (mm)
70
65
60
55
50
45
40
35
30
25
20
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99
CUMULATIVE FREQUENCY IN %

Graph 5

Cumulative percentage length distribution of a collection of male and female C. eremius trapped at Nunn's Bore (locality 27) on 22.VI.70.


Nunn's Bore
(Locality 27)
28·VI·70
♂
♀
STANDARD LENGTH (mm)
70
65
60
55
50
45
40
35
30
25
20
CUMULATIVE FREQUENCY IN %
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99

Histogram 5a.

C. eremius males trapped at Blanche Cup Spring (locality 36) on 2.IX.70.

Histogram 5b.

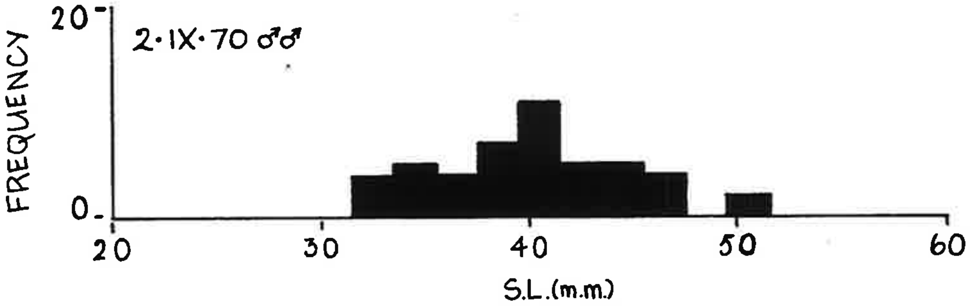
C. eremius males trapped at Blanche Cup Spring (locality 36) on 31.X.70.

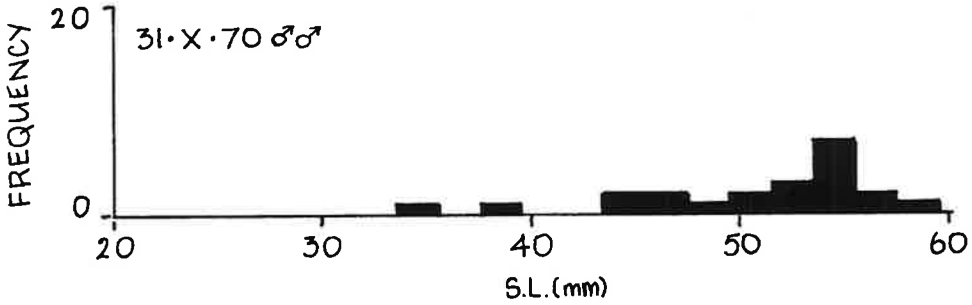
Histogram 5c.

C. eremius males trapped at Blanche Cup Spring (locality 36) on 24.XI.70.

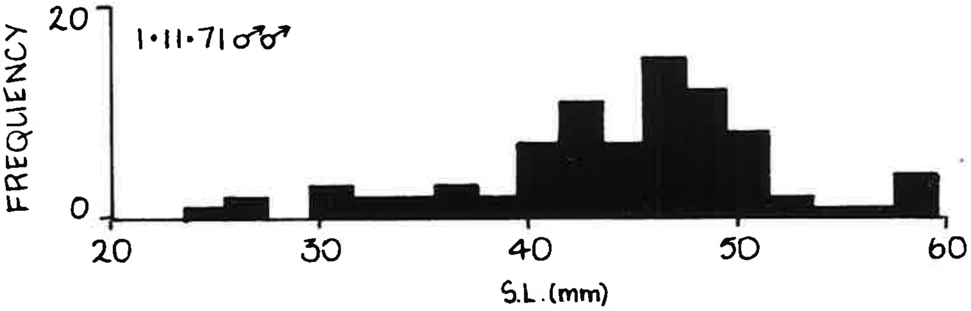
Histogram 5d.

C. eremius males trapped at Blanche Cup Spring (locality 36) on 1.II.71.


2·IX·70 ♂♂
FREQUENCY
20
0
20
30
40
50
60
S.L.(m.m.)


31·X·70 ♂♂
FREQUENCY
20
0
20
30
40
50
60
S.L.(mm)


24·XI·70 ♂♂
FREQUENCY
20
0
20
30
40
50
60
65
S.L.(mm)

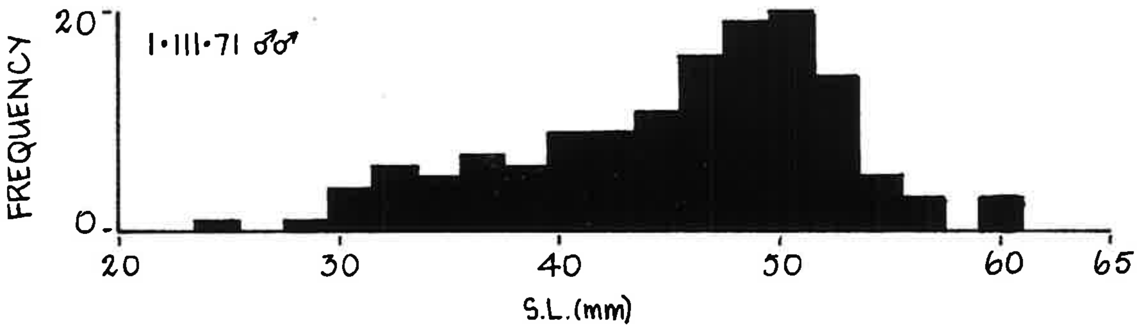

1·II·71 ♂♂
FREQUENCY
20
0
20
30
40
50
60
S.L.(mm)

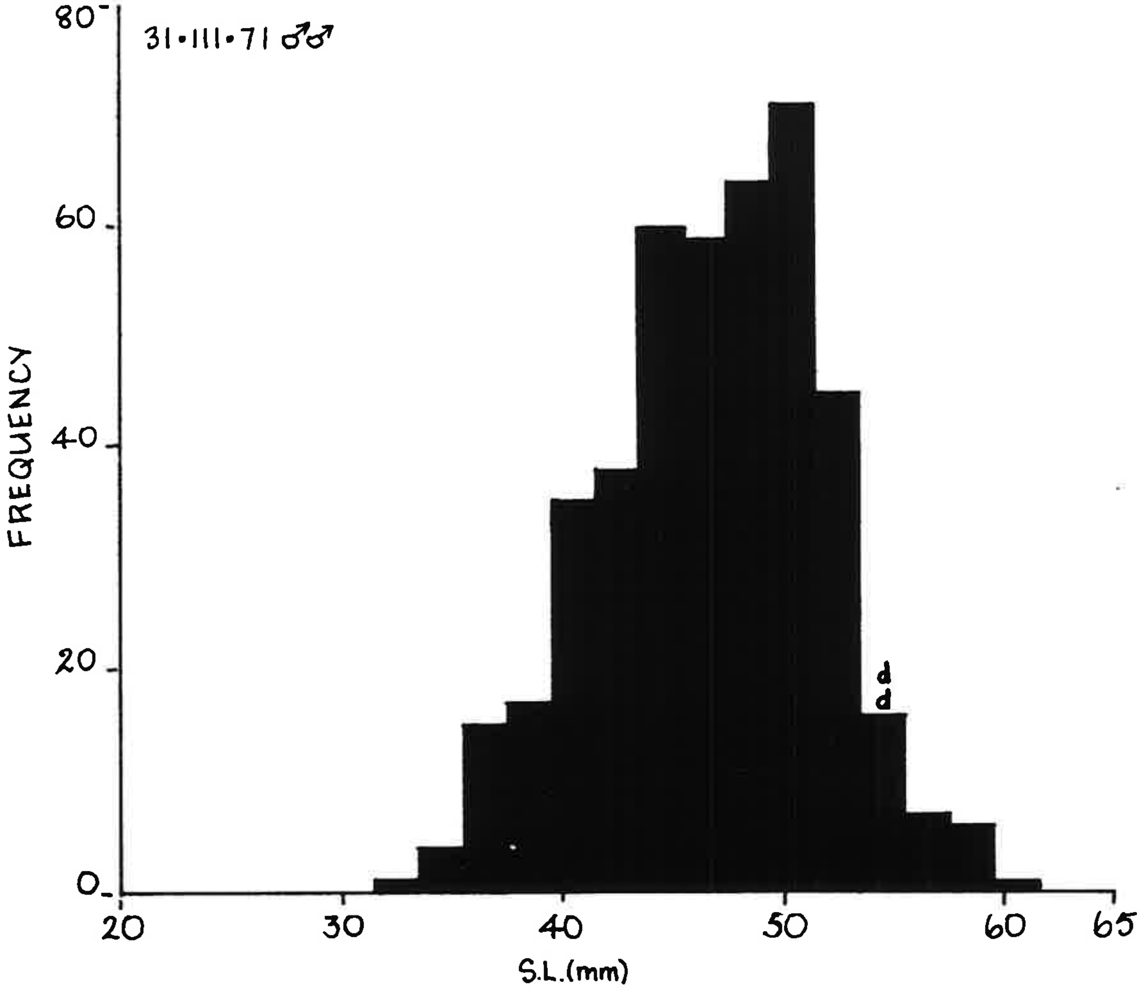
Histogram 5e.

C. eremius males trapped at Blanche Cup Spring (locality 36) on 1.III.70.

Histogram 5f.

C. eremius males trapped at Blanche Cup Spring (locality 36) on 31.III.71.


1·III·71 ♂♂
FREQUENCY
20
0
20
30
40
50
60
65
S.L.(mm)

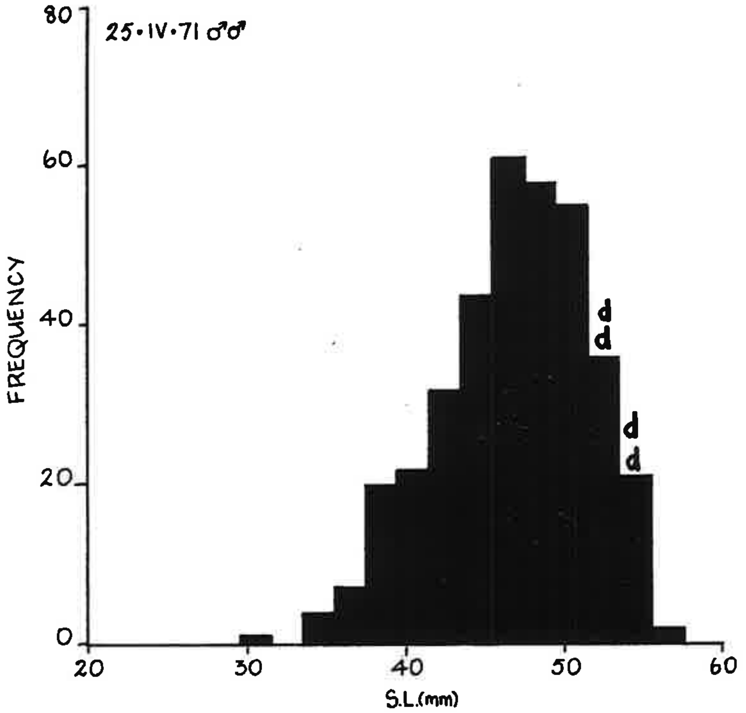

31·III·71 ♂♂
FREQUENCY
80
60
40
20
0
d
d
20
30
40
50
60
65
S.L.(mm)

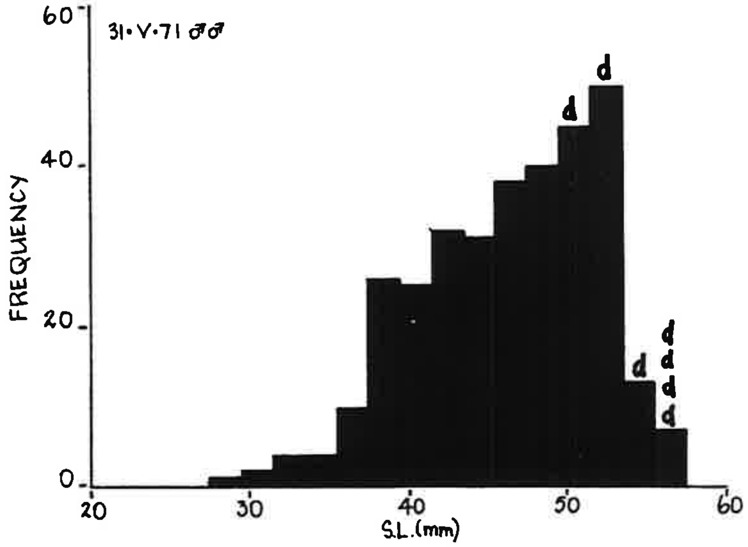
Histogram 5g.

C. *eremius* males trapped at Blanche Cup Spring (locality 36) on 25.IV.71.

Histogram 5h.

C. *eremius* males trapped at Blanche Cup Spring (locality 36) on 31.V.71.


25•IV•71 ♂♂
FREQUENCY
80
60
40
20
0
d
d
d
d
20
30
40
50
60
S.L.(mm)


31•V•71 ♂♂
FREQUENCY
60
40
20
0
d
d
d
d
d
d
d
20
30
40
50
60
S.L.(mm)

Histogram 6a.

C. eremius females trapped at Blanche Cup Spring (locality 36) on 2.IX.70.

Histogram 6b.

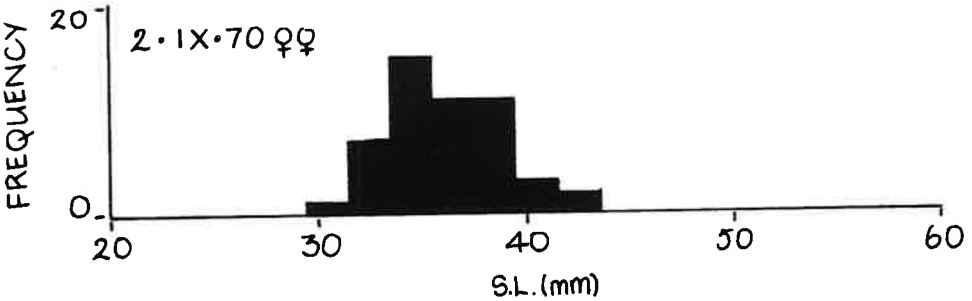
C. eremius females trapped at Blanche Cup Spring (locality 36) on 31.X.70.

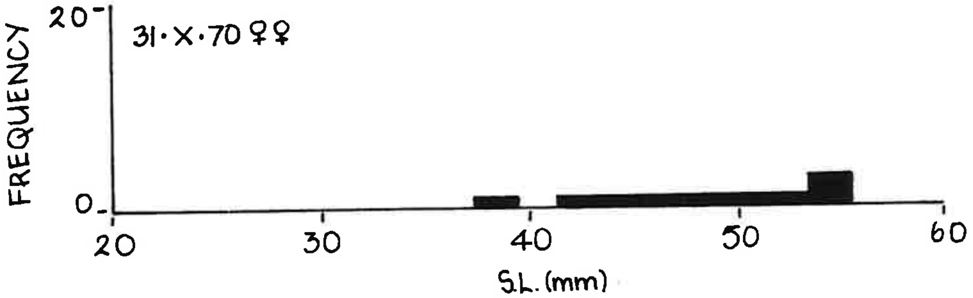
Histogram 6c.

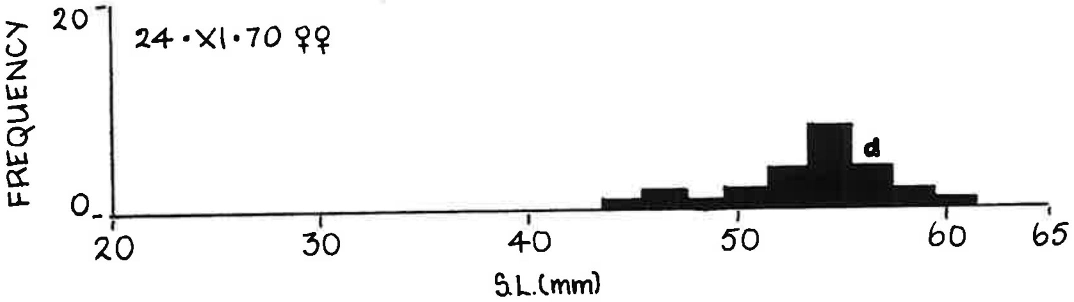
C. eremius females trapped at Blanche Cup Spring (locality 36) on 24.XI.70.

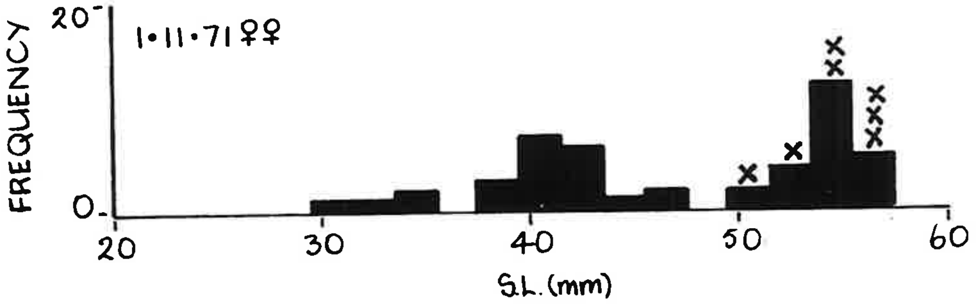
Histogram 6d.

C. eremius females trapped at Blanche Cup Spring (locality 36) on 1.II.71.


2·IX·70 ♀♀
FREQUENCY
20
0
20
30
40
50
60
S.L.(mm)


31·X·70 ♀♀
FREQUENCY
20
0
20
30
40
50
60
S.L.(mm)


24·XI·70 ♀♀
d
FREQUENCY
20
0
20
30
40
50
60
65
S.L.(mm)


1·II·71 ♀♀
FREQUENCY
20
0
20
30
40
50
60
S.L.(mm)

Histogram 6e.

C. eremius females trapped at Blanche Cup Spring (locality 36) on 1.III.71.

Histogram 6f.

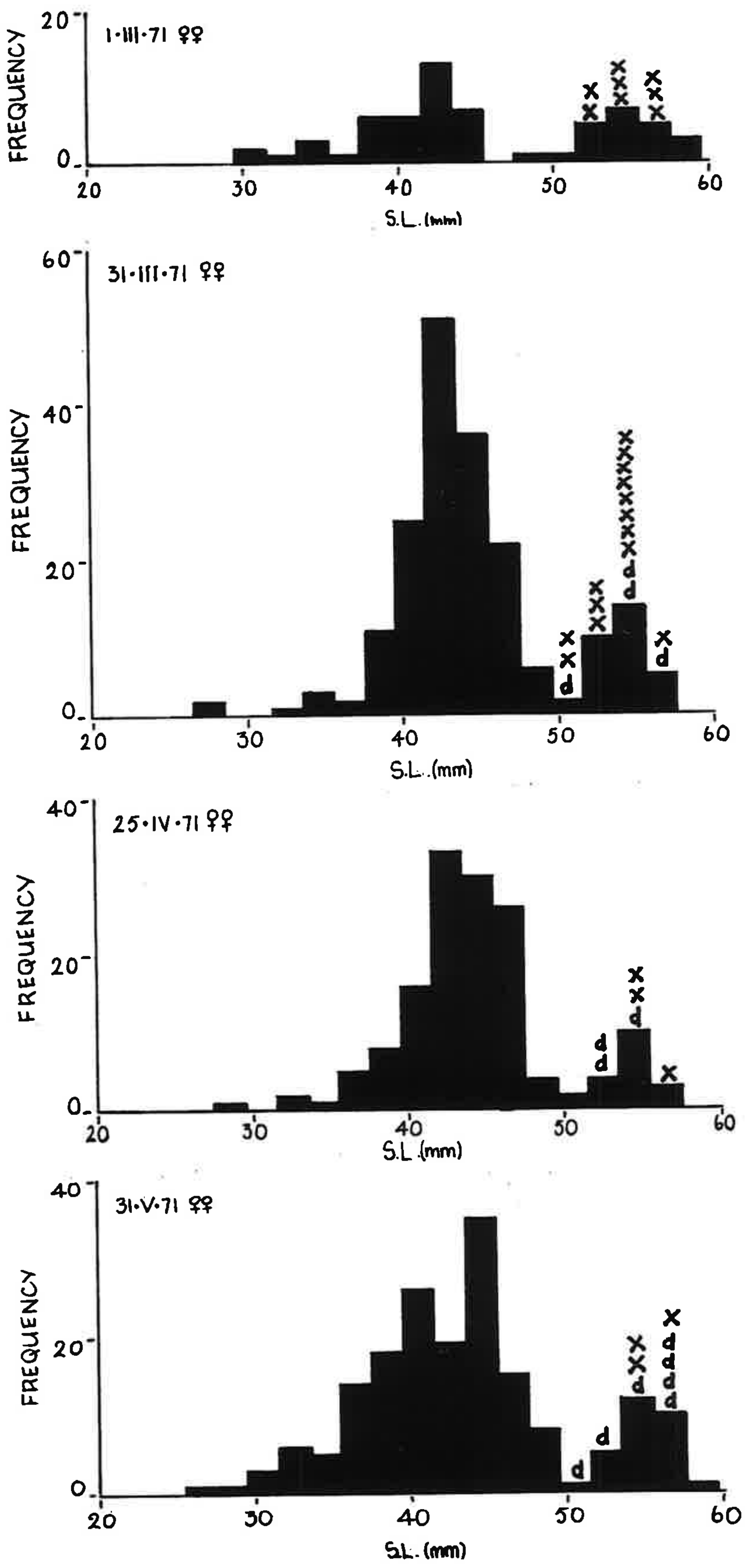
C. eremius females trapped at Blanche Cup Spring (locality 36) on 31.III.71.

Histogram 6g.

C. eremius females trapped at Blanche Cup Spring (locality 36) on 25.IV.71.

Histogram 6h.

C. eremius females trapped at Blanche Cup Spring (locality 36) on 31.V.71.


1·III·71 ♀♀
FREQUENCY
0
20
20
30
40
50
60
S.L. (mm)
X X
X X X
X X X
31·III·71 ♀♀
FREQUENCY
0
20
40
60
20
30
40
50
60
S.L. (mm)
d X X
X X X
d d X X X X X X X X
d X
25·IV·71 ♀♀
FREQUENCY
0
20
40
20
30
40
50
60
S.L. (mm)
d d
d X X
X
31·V·71 ♀♀
FREQUENCY
0
20
40
20
30
40
50
60
S.L. (mm)
d
d
d X X
d d d d X

Date sampled	S.L's (mm) of fish dead upon recapture.	
	Males	Females
25.XI.70		56
31.III.71	54, 55	51, 54, 55, 56
25.IV.71	52, 53, 54, 54	52, 53, 55, **55**
31.V.71	50, 53	52, 54, 56, 57, 57, 57, 58

Table 11

Standard lengths of fish, recovered dead, from traps set in Blanche Cup Spring (locality 36).

Table 12

Numbers of C. eremius, their range of standard length and mean standard length, upon introduction and upon each successive trapping, from the Blanche Cup Spring (locality 36).

Table 12

Males						
	Introduced pop.			next generation		
Date Sampled	Total no trapped	SL Range (mm.)	SL Mean (mm.)	Total no trapped	SL Range (mm.)	SL Me (mm.
2.IX.70 (introduced)	50	32-51	40.6			
31.X.70	24	38-62	51.7			
24.XI.70	21	48-60	54.6			
1.II.71	6	55-59	57.7	77	25-53	43.3
1.III.71	6	56-60	58.3	133	25-54	44.7
31.III.71				439	33-60	46.1
25.IV.71				363	31-56	46.8
31.V.71				328	28-57	46.2

Females						
	Introduced pop.			next generation		
Date Sampled	Total no trapped	SL Range (mm.)	SL Mean (mm.)	Total no. trapped	SL Range (mm.)	SL Me (mm.
2IX.70	50	31-43	35.9			
31.X.70	9	35-57	49.3			
24.XI.70	25	47-60	53.9			
1.II.71	23	50-57	54.4	23	31-47	40.3
1.III.71	22	49-58	54.5	41	28-45	39.8
31.III.71	30	51-57	54.1	158	33-50	42.9
25.IV.71	17	52-57	54.4	128	28-50	43.0
31.V.71	28	52-58	55.0	152	27-51	41.3

Loc. No.	Locality	Day (D) or night (N) setting	Date Sampled	Total no.	%	
					♂♂	♀♀
16	Freeling Springs	N	23.xi.69	121	54.5	45.5
17	Blyth Bore	N	23.xi.69	93	58.1	41.9
24	Johnson's No. 3 Bore, pool A	N	3.ix.68	255	43.9	56.1
		N	26.viii.70	113	41.5	58.5
		N	27.viii.70	131	34.3	65.7
		N	28.viii.70	124	37.9	62.1
		N	29.viii.70	96	45.8	54.2
		D	30.viii.70	196	36.2	63.8
		D	31.viii.70	108	28.7	71.3
		D	1.ix.70	155	30.3	69.7
		D	2.ix.70	236	38.1	61.9
24	Johnson's No. 3 Bore, pool B	D	14.vi.70	147	39.4	60.6
		D & N	27.viii.70	725	34.6	65.4
24	Johnson's No. 3 Bore, pool C	D & N	14.iv.70	335	54.2	45.8
27	Nunn's Bore	D & N	13.iv.70	158	62.6	37.4
		D & N	22.vi.70	166	72.8	27.2
		D & N	24.viii.70	456	66.6	33.4
		D & N	1.xi.70	302	34.1	65.9
		D & N	31.v.71	262	62.9	37.1
35	Wobna Spring	N	11.iv.70	136	41.2	58.8
		N	11.vi.70	113	46.8	53.2
		N	23.vi.70	117	43.3	56.7
		N	30.vii.70	146	51.3	48.7
		N	23.viii.70	101	58.4	41.6
		N	28.ix.70	62	50.0	50.0
		N	31.x.70	33	42.4	57.6
		N	25.xi.70	80	57.5	42.5
36	Blanche Cup Spring	D & N	1.ii.71	130	64.6	35.4
		D & N	1.iii.71	225	61.7	38.3
		D & N	31.iii.71	628	69.9	30.1
		D & N	25.iv.71	508	71.5	28.5
		D & N	31.v.71	508	64.7	35.2

Table 13

Sex Ratios Recorded from some Trapped Collections of *C. eremius*.

How sampled	Date and time sampled	Total no's	%		Difference in results obtained by the two methods
			♂♂	♀♀	
Trapped over-night	31.V.71 1100 hrs	508	64.76	35.24	5.61%
Dab net	31.V.71 1330 hrs	164	59.15	40.85	

Table 14

Sex ratios of a trapped C. eremius collection compared with that of a collection obtained by dab net at Blanche Cup Mound Spring (locality 36).

Station	Absolute densities recorded 21.II.68. (numbers /m^2)	*Trapping rates recorded 28.V.68.
1	2	0
5	25	14
6	37	25
8	2	3

Table 15

Absolute densities and trapping rates recorded at Coward Springs Railway Bore stream (locality 34) on 21.II.68 and 28.V.68 respectively.

* A single wire mesh trap set at each station for a 15 hour period overnight on 27.V.68.

VI THE ENVIRONMENT - PHYSICAL PARAMETERS

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1. WATER TEMPERATURE.

(a) Preamble

C. eremius has been collected in water over a wide range of temperatures. The maximum temperature at which the species has been taken was 40.0°C (locality 24, Johnson's No. 3 bore, 24.XI.69) and the minimum 9.0°C (locality 12, Algebuckina water hole 31.VII.68). A live collection taken from Nunn's bore (locality 27) survived a water temperature less than this 9.0°C during an overnight stop on the return journey from the field when the water temperature in the holding drums was recorded as 7.5°C at 0810 hours on 13.VIII.68 when ambient temperature was 8.4°C. Although the fish displayed no activity whilst the water temperature was being recorded they displayed marked activity upon being disturbed by actual physical contact immediately after.

(b) Comparison between inhabited and non-inhabited waters.

Table 16 lists ambient and water temperatures recorded at inhabited and non-inhabited localities when I visited them during the surveys in the north of South Australia. I visited most of these places only once and therefore for these only one set of temperature readings are available. Systematic readings taken over at least a twelve month period have been made along the stream flow at each of two inhabited localities (Coward Springs bore - locality 34, and Wobna spring - locality 35), which indicate the general range of temperature fluctuations in the individual water body due to seasonal climatic factors (see later).

At most of the localities listed in Table water temperature was recorded at only one station and in the case of artesian flows this was usually near the point of outflow and therefore approaching the maximum value for the particular stream. However at some artesian sites temperature was recorded at different points along the stream and in these instances the maximum and minimum temperatures recorded are shown. These provide a general indication of the range of water temperatures present in the individual artesian fed stream.

Since most of the readings have been taken at different times of the year and at different times of the day, they are not strictly comparable. Nevertheless the October 1969 and November 1970 readings from non-inhabited waters and November 1969 readings from inhabited waters, both comprising mainly artesian flows, are sufficiently close in time to enable a reasonably meaningful comparison to be made between them. Excluding the particularly high temperature artesian flows of localities 44 to 51 inclusive it will be noted that the maximum temperatures recorded cover approximately the same range and approximate to the same mean values in both inhabited and non-inhabited waters (see Table 17). Furthermore where a range of temperature is shown for individual localities the lower value is of the same order in both inhabited and non-inhabited waters, including those of the high temperature outflows at localities 44 to 51 inclusive (see Table 1b).

Thus it is concluded that with regard to temperature, similar values and ranges are encountered in the majority of inhabited and non-inhabited waters. With similar thermal conditions thus prevailing the absence of C. eremius from any central Australian artesian fed waters cannot be due to any direct thermal barrier. A statistical analysis of water temperatures demonstrated no overall significant difference between the temperatures of inhabited and non-inhabited waters (Appendix V, report A).

(c) Thermal Gradients within the Individual Artesian Stream.

i. Longitudinal Gradients.

Regular bottom-water temperature readings have been made at stations along the populated artesian springs at Coward Springs railway bore (locality 34) and Wobna Spring (locality 35) over the periods February 1968-January 1969 and April 1968-November 1970 respectively. These data, together with other simultaneous measurements, including trapping rates, are presented in Appendices E and F . Table 21 presents similar data recorded on one occasion at Johnson's No. 3 bore (locality 34).

With regard to water temperature the above data show:-

1. That in artesian fed streams thermal gradients exist longitudinally along the stream path. During warmer months the water temperature tends to rise within increasing distance from the point of outflow whereas during cooler months water temperature tends to drop.

2. The maximum temperature range present at any one time tends to occur during the cooler months. Table 18 indicates the maximum ranges of temperature of water in which C. eremius has been observed while the measurements were taken at three different localities.

3. Although the species does therefore on occasions simultaneously occupy a wide range of water temperatures it has never been recovered alive from traps set for any prolonged period in water in excess of 40.0°C. Observations and tests conducted at Johnson's No. 3 Bore during summer and at other times, have shown that individuals make brief excursions into water at or in excess of 40.0°C and survive. Nevertheless when held for a period, within traps, in water close to or in excess of 40.0°C they rapidly collapse and subsequently die (see p. 60). Thus it appears that 40.0°C or just below this value, is the upper thermal limit to which the species can tolerate prolonged exposure although it can enter water several degrees warmer for brief periods and still survive.

4. Within the range of water temperatures normally present along the stream at Coward Springs Bore (locality 34) and Wobna Spring (locality 35) there appears to be no correlation between temperature and the number of C. eremius trapped.

For example, the trapping rates at Coward Springs Bore stream show no correlation with water temperature at the respective trap sites on 31.VIII.68 (see Graph 6) which varied between 13.5°C and 29.9°C, a range of 16.4°C; nor at Wobna Spring on 25.VI.69 (see Graph 7) when water temperature at the trap sites in the main streams varied between 22.3°C and 30.0°C, a range of 7.7C°, thus, over these temperature ranges and values it appears that C. eremius exercises little or no thermal selectivity and that water temperature within such ranges is of no direct significance in determing local abundance or paucity in numbers.

On the other hand the trapping and water temperature data recorded along the Johnson's No. 3 Bore stream on 3.IX.68 (see Table 21 and Graph 8) does suggest that the species exercises thermal selectivity when a particularly wide range of water temperatures is present. In this set of data water temperatures at the trap sites range between 14.7°C and 36.5°C, a range of 21.8°C. As a consequence it appears that there is a significantly greater abundance of the species at temperatures ranging between 20.0°C and 30.0°C than at temperatures $<$ 20.0°C or $>$ 30.0°C. Other trapping/temperature data recorded at Johnson's No. 3 Bore (see Table 25 and Graph 9) indicate greater abundance at temperatures of the order of 25.0°C to 35.0°C with a pronounced drop in numbers at temperatures $<25.0^{\circ}$C and $>35.0^{\circ}$C.

ii. Lateral Gradients.

Water temperature transects made across the stream at Wobna Spring (locality 35) and between open water and the interior of stands of vegetation at Johnson's No. 3 Bore (locality 24) have demonstrated the existance of pronounced thermal gradients.

Table 20 presents data recorded at Wobna Spring (locality 35) in April 1969 from which it is apparent that water temperature within patches of filamentous green algae (Spirogyra sp.) was up to 4.2° less than in open mid-stream water.

Tables 21 to 25 and Graphs 12 to 15 present data recording bottom-water temperatures between mid-stream or open-water pools and varying distances within stands of mixed vegetation (Typha domingensis L., Cyperus laevigatus L. and Scirpus sp.) in pools or shallows adjacent the main stream at Johnson's No. 3 Bore (locality 24). These data indicates some very pronounced thermal gradients in which water temperature drops with increasing distance into stands of vegetation and vegetated shallows. Table 26 presents data comparing bottom-water temperature in an open pool and adjacent vegetated side shallows at Johnson's Bore in May and November 1969. It will be noted that the larger gradient occurred during the cooler May period when water temperature averaged 17.2°C less in the vegetated side shallows than in an open pool associated with the main channel. Such thermal gradients probably exist in all other similarly vegetated artesian water bodies.

Visual observations made of the *C. eremius* population at Johnson's No. 3 Bore (locality 24) in September 1968, May and November 1969 and June, August and November 1970, indicated that the species was more abundant within the vegetated stands or side shallows, at any one time, than they were in open water in pools or the main stream. During November 1969 and 1970 this was particularly noticeable when far fewer individuals were sighted, at any one time, in the open water of the pool than at other times.

In November 1970 an attempt was made to time the period continuously spent by individuals in the open water of a large pool (mean-bottom water temperature 40.8°C) at Johnson's No. 3 Bore (locality 24) before returning to the adjacent shallows. Due to difficulty in distinguishing a particular individual for any extended period from the time after it entered open water to the time it withdrew to the vegetated shallows little objective data were obtained. Nevertheless five individuals were successfully maintained in sight for the time each spent in open water, namely 105, 202, 257, 290 and 330 seconds.

It is not known how frequently they re-entered open water but laboratory observations of individuals maintained in various sized tanks (see p. 103) provided with vegetation cover (Cyperus laevigatus L.) showed that under these conditions individuals maintain themselves almost continuously under cover, making at most no more than three or four brief incursions of several minutes duration each into open water during daylight hours. Field observations of individual movements into the flowing main stream at Johnson's bore, where water temperatures in the higher reaches are 40°C+, showed that such incursions were very infrequent and of extremely short duration of no more than 10 seconds.

As demonstrated later (see p. 124) C. eremius is negatively phototactic, characteristically spending considerably more time under cover than under open illumination. As suggested this probably constitutes a predator-defence and food searching process. However in the field, due to the characteristically lower temperatures (especially in summer months) in vegetated shallows, than in open water, it appears highly probable that such cooler vegetated shallows also constitute a thermal refuge.

(c) Vertical Thermal Gradients

Included in the routine data recorded at Coward Springs railway bore (locality 34) and Wobna Spring (locality 35) (see Appendices E and F) are bottom-water temperatures and the temperatures of the silt 2.5cm beneath the bed surface at each station. At Coward Springs railway bore temperature was also recorded at 9.0cm depth. Appendices G and H show these bottom water temperatures and the differences between them and the recorded sub-bed temperatures.

Considering the Coward Springs data it is noted that, excluding station 1 (where sub-bed temperature was always higher than bottom-water temperature), sub-bed temperature at either depth was with few exceptions less than the bottom water temperature except in June 1968 when the thermal gradient was inverted. Furthermore this difference was usually greater at 9.0cm depth than at 2.5cm depth. Table 27 and Graph 16 depict the mean water and sub-bed temperatures at the Coward Springs bore stream on each occasion data was recorded. It is seen that the maximum difference between bottom-water and sub-bed temperatures tends to occur during the warmer months when bottom-water temperatures are higher and when the sub-bed temperature at 2.5 and 9.0cm depth averaged 4.4 and 5.8C° less than the average bottom-water temperature. The maximum differences recorded was on 21.II.68 when at station 8 the sub-bed temperature at 2.5cm depth was 7.8C° less than bottom-water temperature (37.8°C) and at station 3 at 9.0cm depth was 9.8C° less than bottom-water temperature (37.8°C). As will be shown later (see p. 67) the mean critical thermal maxima of specimens of C. eremius sampled at the bore stream on the same date was determined to be 40.8°C. Since specimens were collected at both stations 3 and 8 on this date, it is clear that those fish inhabiting these stations were subject to a bottom-water temperature very close to the maximum tolerance level for that time of the year. The pronounced thermal gradient between the bottom-water and beneath the fine silt bed offers a potential thermal refuge as was confirmed on this date (and on two other occasions, viz. 14.XII.67 and 15.XI.68) when a number of C. eremius specimens were sifted from bed silt, between stations 3 and 8, sampled down to a depth of approximately 5cm.

The data recorded at Wobna Spring (locality 36) (see Table 28 and Graph 17) agree in part with those from Coward Springs railway bore (locality 34). At the Wobna Spring head (station 1) the sub-bed temperature, with two minor exceptions, exceeded or equalled bottom-water temperature. Beyond station 1 there were similar differences between bottom-water and sub-bed temperatures but generally these were not as large as those recorded at Coward Springs railway bore (locality 34). In addition, although the sub-bed temperature was more often less than bottom-water temperature there were many more zero gradients and temperature inversions than at Coward Springs railway bore (locality 34) and these were not restricted to the cooler months of the year. Graph 17 plots the mean values given in Table 28 . The pattern of this graph although far less distinct is similar to that of Graph 16 of the

Coward Springs railway bore (locality 34) data. These smaller differences and more frequent inversions appear to be due to the faster flowing stream and the different texture of the bed silt of the main channel at Wobna Spring (locality 35), (a coarse sand rather than a fine mud). When one considers the data (see Table 29) recorded at Stations 12 and 13 (a large side pool which occasionally contained standing water and has a fine silt bed unlike the main channel) it is seen that the differences between sub-bed and bottom-water temperatures are generally far larger and temperature inversions far fewer than recorded in the main channel. In addition when the data in Table 29 was graphed (Graph 18a) the very pronounced pattern is clearly similar to that of Graph obtained from the Coward Springs Bore (locality 34) data. Furthermore on 30.III.69 at station 10, Wobna Spring (locality 35), several *C. eremius* were found immediately below the stream bed surface where the differences between bottom-water temperature (28.5°C) and at 2.5cm sub-bed depth was -1.5C°.

Whether the fish actively burrow into the silt bed is unconfirmed since laboratory observations have not indicated any burrowing behaviour by *C. eremius* in tanks provided with fine silt beds. Resting individuals do however tend to settle passively into bed surfaces composed of fine silt and thereby become partially buried. It is conceivable that a sufficiently large thermal gradient between the surface and beneath the silt bed might stimulate the species to burrow, but this has not been tested.

(d) A Thermal Refuge.

The following field experiments and observations at Johnson's No. 3 Bore (locality 24) indicate that the thermal gradient discussed in the previous section (p. 57) provides an important thermal refuge for C. eremius. This is particularly so during summer months when the temperature of open pools and other bodies of water may rise to lethal levels towards the middle of the day.

i. On 3.IX.68 at station 1 (see Table 21) several individuals were observed to make brief excursions, from amongst the stands of mixed vegetation, into the swiftly flowing open water of the main channel (bottom-water temperature 41.7°C). After some rapid swimming movements lasting no more than approximately 5 seconds the individuals darted back into the vegetated shallows. A trap containing 50 fish selected from a large number trapped nearby during the previous night (bottom-water temperature at trap site at time of collecting = 36.5°C) was set in water at the edge of the main stream, just out from the vegetation fringe where bottom-water temperature was 41.7°C. At the end of 7 minutes all but three of the fish were either dead or in a state of collapse. The trap was immediately reset in the cooler water at the original collecting point. Within a minute 10 of the comotose fish appeared to recover but the remainder had not recovered after a period of 5 minutes.

ii. Immediately following the previous experiment a similar test was conducted at station 2. Fifty fish collected in nearby shallows in traps set during the previous night (bottom-water temperature at trap site at time of collecting = 34.1°C) were transferred in a trap into water at the side of the main channel where bottom-water temperature was 40.8°C at time of setting. All but 5 had collapsed after 10 minutes. Upon being reset at the original collecting point the majority appeared to recover within several minutes.

iii. On the morning of 2.IX.70 fish collected during the previous night in several traps at each of three sites in shallows were transferred, in traps, into water in the middle of the main channel adjacent the respective sites. Table **30** details the effects on the fish as a result of being transferred into the warmer water. It will be noted that the lower the temperature into which the fish were transferred at each of the sites the longer the period taken for the initial deaths to occur and the greater the survival capacity of the remaining individuals.

iv. On 26.XI.69 at 0800 hours, 9 wire traps were set in a large open pool. Upon being collected after 4 hours all the fish taken in 3 of the traps were found to be dead, whilst those in the remaining traps were all alive.

Table 22 details the number trapped in each of these traps and the bottom-water temperature recorded at each trap site when each trap was collected. From the data it appears that temperatures in excess of 40.0°C prove fatal to C. eremius, at least when exposed to these temperatures from a period varying up to 4 hours (the setting time). There is no way of telling how long the fish were in the traps before dying. It is quite feasible that if the period of exposure had been longer that the fish collected alive at the lower water temperatures would have eventually died. Nevertheless it is clear that the fish do enter and will survive varying periods in water at, or in excess of, temperatures which would eventually prove fatal.

v. On 29.XI.69 three traps were set at 0830 hours in a pool in open water immediately adjacent a stand of mixed vegetation. Eight hours later at 1630 hours the traps were withdrawn and 27 of the 39 trapped fish were found to be dead. At the time the traps were collected the bottom-water temperature at the trap sites was recorded as 39.0°C and at 15 and 30cms within the adjacent stand of vegetation, as 32.5°C and 31.0°C respectively, i.e. 6.5 and 8.0C° less than in the open water. It is probable that water temperatures went beyond these levels earlier in the day, nevertheless this clearly demonstrates the thermal refuge available to fish at quarters close to open unshaded water that attains lethal temperatures.

(e) Thermal Acclimation.

The thermal tolerance studies, reported below, that I have made upon C. eremius in the field and the laboratory demonstrate that within the individual waterway the species is acclimated to the temperature of the water at the section inhabited, that the species undergoes seasonal thermal acclimation correlated with changes in water temperature and that it acclimates rapidly to increases in water temperature.

Technique.

The technique I devised for measuring upper thermal tolerance is not a formerly standardised procedure therefore the results are not strictly comparable with those obtained from similar investigations on other species.

The technique entails subjecting fish to progressively increasing water temperature and noting at what level they collapse. Initially it was intended that this test would measure the upper thermal death point but this was not feasible, since in many instances apparently dead subjects revived, at least temporarily, upon being transferred back to cooler water following the conclusion of a test. Owing to this difficulty in ascertaining at just what point death occurred, I decided to measure critical thermal maxima (c.t.m.) the criteria for which I took as the temperature at which the test subject undergoes total collapse and cessation of all externally visible body movements (partly after Cowles (1942)) concept. Four fish selected at random were employed for each test and the critical thermal maximum was determined as the mean of the four individual readings taken. In the field the test was usually conducted within an hour of the fish being collected.

The equipment used in these tests comprised a 500ml. capacity polythene beaker set in a large water bath (23 litre metal drum) and held in position by means of a wire frame (see fig. 15). Prior to the start of a test the water in the bath was raised to near 100°C by means of a single-burner butane camp stove. When this had been achieved the burner was extinguished, and the polythene beaker was placed in the water bath. The beaker contained the four test subjects and was filled to approximately three-quarter capacity with water, at or near ambient temperature, which had been taken from the locality from which the test subjects themselves came. As the temperature of water in the beaker rose bottled medical grade air was passed through the beaker water via an aquarium air stone. The purpose of the rising stream of small air bubbles was to ensure an efficient mixing of the water so that heating was relatively uniform and that dissolved oxygen was maintained at the maximum possible saturation point. This was to minimize possible asphyxiation effects upon the test subjects due to the progressive drop in O_2 solubility levels as water temperature rose. By this means it was hoped that the principal stress and ultimate collapse of the fish would be due primarily to direct heat action. A polythene baffle was attached to the inside wall of the beaker (see fig. 16) to prevent rising air bubbles spreading across the water surface and obscuring the test subjects. Polythene flywire around the aperture at the base of the baffle prevented fish moving into close proximity around the air stone and out of view of the observer. In addition, polythene flywire was fitted over the top of the beaker to prevent fish leaping out and at the same time allow an uninterrupted view of their condition. The temperature of the water in the beaker was kept under constant surveillance by means of a 0-50°C glass bulb thermometer. By this technique a fairly rapid and uniform transfer of heat took place between the water bath and the test beaker enabling lethal levels to be reached in approximately 10 minutes. The general tendency was for subjects to collapse in order of increasing size i.e. smaller fish more often collapsed at lower temperatures than larger specimens.

The number of test subjects employed for each test was few in order to avoid excessively depleting the populations upon which relative density and tagging and recovery studies were simultaneously being conducted. Nevertheless a statistical analysis (see p. 67) of the data obtained has indicated that samples of four subjects were adequate to provide valid data.

(i) Acclimatization along a Thermal Gradient.

Data have been obtained from thermal tolerance tests conducted upon samples taken from the C. eremius populations at different stations at Wobna Springs (locality 35) and Johnson's No. 3 bore (locality 24) which indicate that the species acclimates to local water temperature differences which occur simultaneously within individual waterways.

At Wobna Spring (locality 35) on 26.VII.68 four subjects were selected from collections trapped at stations 7 and 12 respectively. Within an hour of being collected these samples were subjected to thermal tolerance testing. Table 31 presents the results of these tests together with the water temperature at each of the collecting sites. It is seen that the two samples taken from water differing by 9.9C° showed a significant difference of 4.0C° in their respective mean critical thermal maxima.

At Johnson's No. 3 bore (locality 24) on 3.IX.68 test samples were taken at five stations along the bore stream which extended over a wide thermal gradient of 22.5C°. Within an hour of being collected the samples were tested in turn to establish their respective critical thermal maxima. The results of these observations, presented in Table 32 and Graph 11 , suggest a correlation exists between water temperature at the collecting sites and the critical thermal maxima.

(ii) Seasonal Acclimation.

Monthly field determinations of upper thermal tolerance have been made with fish sampled from the Coward Springs railway bore (locality 34) population over the period February 1968 to March 1969 inclusive. These data, together with bottom-water temperatures recorded at the sampling sites, are presented in Table 33 and Graph 18b .

It is seen that as the water temperature rises in summer relative to winter levels, the c.t.m. of *C. eremius* also rises by 5.9C°. Thus the species acclimates to seasonal changes in water temperature. A similar phenomenon has been found to occur in other fishes including *Carassius auratus* (Linnaeus) (Hoar 1955) and *Ameiurus nebulosus* (Le Sueur) (Brett, 1944) in which an upward shift in the upper (and lower) lethal temperatures in summer months relative to winter levels has been noted.

With regard to the data in table 33 statistical analysis has shown a simple linear correlation of 0.73 between water temperature and critical thermal maxima and a significant difference (at 5% level) between the critical thermal maxima means for February and June 1968 (Appendix V , report B).

(iii) Acclimation Rates.

In order to gauge the order of rapidity with which *C. eremius* acclimates in response to changes in water temperature I conducted a series of thermal tolerance tests in which the progressive change in critical thermal maxima levels was measured of stock exposed to increases in water temperature.

1. Technique

Laboratory stock were maintained in a near constant temperature in a relatively cool basement room for fourteen days prior to each trial in order to acclimate the fish to a known cool temperature. A daily morning and afternoon check was made of the water temperature in the holding tanks to determine the range of fluctuation over the acclimating period. This did not exceed 3.0C° and therefore it may be considered that a fairly stable acclimating temperature was maintained over the pre-trial periods. Immediately prior to a trial commencing 4 fish were selected at random from the holding tanks and tested for their mean critical thermal maxima in the manner previously described (see p. 63). Twenty five fish were then selected at random from the holding tanks and directly introduced into water in a test tank maintained at approximately

11.1C° and 14.3C° higher than the respective pre-trial acclimating temperature. At pre-determined time intervals after being introduced into the higher temperature water test subjects were removed from the tank and their critical thermal maxima determined.

2. Results.

Trial A. In this trial 4 fish were used for each set of determinations which were made at 24 hour intervals. Table 34 and Graph 20 present the results of this trial. It will be noted that since the graph more or less levels off at +24 hours it appears that thermal acclimation occurs within the first 24 hours exposure to the rise in temperature from ∼ 20°C to 31.1°C. For a water temperature rise of ∼ 11.1°C mean c.t.m. rose 1.3°C.

Trial B.

This trial commenced with 4 fish being used for each set of determinations. However due to the aerator failing some time prior to the third set of readings being taken several deaths occurred prematurely. It was therefore necessary to reduce the number of readings taken at subsequent determinations to two. Thus the accuracy of these mean values is somewhat reduced. The determinations in this trial were made at

5 hour intervals. From the results presented in Table **35** and Graph **19** it appears that acclimation occurs and is completed between 5 and 10 hours after exposure to the higher water temperature. For a water temperature rise of ~ 14.3°C mean critical thermal maxima rose 0.9C°.

Fry (1958) has pointed out that acclimatization by fish to increasing temperature is a relatively rapid process and the results of these artifically induced acclimatizations upon C. eremius confirm that this species is no exception. Doudoroff (1942) and Brett (1944) found that in many fishes maximum acclimatization to thermal increase was achieved within less than twenty four hours at temperatures above 20°C. This appears to be the case with C. eremius since the results of the second acclimatization trial indicate that the species fully acclimated within ten hours to an approximately 14.3C° rise, from ~ 19°C to 33.3°C.

Since the typical artesian fed habitat of C. eremius, such a Johnson's No. 3 bore (locality 24), displays substantial thermal gradients over relatively short distances e.g. 21.1C° and 16.1C° over 60cm and 20cm distances respectively (see p. 54), it is obviously to the species' advantage to be able to readily adapt to sudden changes in water temperature, as it can.

2. CHEMICAL CHARACTERISTICS OF THE INLAND AQUATIC ENVIRONMENT AND SALINITY TOLERANCE IN C. EREMIUS.

(a) Preamble

In order to compare the chemical characteristics of waters inhabited by *C. eremius* with those of non-inhabited waters in the central Australian region and elsewhere I collected water samples from a number of the localities inspected during the course of field surveys. These samples were subsequently analysed by the Australian Mineral Development Laboratories (Adelaide). Appendix Q lists AMDEL reference numbers of these analyses which are detailed in Table 36 , to show the comparison between inhabited and non-inhabited waters.

(b) Characteristics of Water Inhabited by C. eremius.

(i) Ionic Content

It is evident from the data given in Table 36 and summarized in Table 37 that the located populations of *C. eremius* typically occur in permanent bodies of surface waters, usually of artesian origin associated with either natural springs or bores. The ions found in all of these artesian waters are similar but the proportions of the ions vary and the total salinities extend over a relatively wide range (i.e. 347 - 8435 p.p.m.). All except three of the populated artesian water sites have a salinity greater than or equal to 3,000 p.p.m., a value which Williams (1964) arbitrarily classified as "saline".

Considering the minor occurrences recorded from ephemeral waters (small water holes, rivers, creeks); in such habitats C. eremius is subject, at least temporarily, on some occasions to far lower salinities than would normally be encountered (following heavy rainfall) and on other occasions to considerably higher salinities (during periods of high evaporation), especially in small or isolated standing bodies of water. These minor occurrences appear to result from the dispersion of individuals away from the principal population sites by floodwaters. Although such waters cannot be regarded as permanent habitats for C. eremius populations they nevertheless must be taken into account because they possibly constitute a method for the dispersal of the species (see p. 17).

In addition to such small ephemeral waters it is clear that the larger more permanent water bodies (waterholes, reservoirs, dams, artesian pools and streams) are also subject to significant temporary fluctuations of salinity due to the same climatic factors. Thus even the permanently established C. eremius populations are exposed to occasional marked changes of salinity. Salinity in fact is probably constantly changing, certainly in standing bodies of water.

Within individual artesian fed surface waters salinity gradients and differences in ionic contents may occur along the stream path and between the main stream and associated bodies of water at any one time.

Water samples taken simultaneously at several points along the artesian streams at Coward Springs railway bore (locality 34) and Wobna Spring (locality 35) indicate that ionic content and total salinity gradients exist along the paths of artesian surface flows. The data from these samplings (see Tables 38-39) shows that total salinity can rise quite markedly in a slowly flowing stream (28% over a distance of 453 metres at locality 34) or only slightly in a swiftly moving stream (2% over a distance of 126 metres at locality 35), and that the proportion of individual ions may change so that some (e.g. Cl, SO_4, HCO_3, Na, Mg) may increase whilst others (e.g. NO_3, Ca,) decrease. In addition the ionic composition and total salinity of outflowing artesian water may change significantly over a varying period of time (see Table 40) and it has been found that, depending on climatic factors, marked temporary variations in salinity can occur in an artesian body of water, particularly in standing water to the side and at the terminal section of the flow (see Table 38). C. eremius is therefore subject to, and clearly successfully adapted to, wide fluctuations in water salinity and composition in time and space, even in apparently permanent bodies of water.

(ii) Water pH.

The hydrogen ion concentration of inhabited waters was recorded (by means of 'Oxyphen' papers) over the range pH 6.8 - 11.0. The pH levels of meteoric waters (originating from rainfall) and of artesian waters at the point of outflow were close to pH 7.0, ranging between pH 6.8 and 7.6 (see Table 36). In contrast, data recorded along the artesian streams at localities 34 and 35 (see Appendices E and F) and elsewhere shows that hydrogen ion concentration typically increases with increasing distance from the outflow point. The maximum recorded pH range at any one time within an individual body of water was a range of 4.0 pH units at locality 34 (26.VII.68) from pH 7.0 to pH 11.0 over a distance of 460 metres along the stream flow. I have found such a hydrogen ion gradient to be a normal feature of artesian fed streams and the rising values appear closely correlated with the density of aquatic vegetation, particularly filamentous green algae, in association with standing or minimally flowing water. In addition, transects of water temperature, depth and pH made on 30.IV.69 at several stations across the stream at Wobna Spring (see Table 20) indicate that hydrogen ion concentration is higher amongst stands of filamentous green algae than in adjacent open flowing water, by as much as 0.9 pH units. However I have found no evidence of vertical hydrogen ion gradients. At Coward Springs railway bore (locality 34) on 30.VI.68 I recorded no differences in pH between surface and bottom-water samples taken at each Station. Water samples were obtained by means of a 25ml pipette. Table 41 indicates the water depth and surface and bottom-water pH readings made at each station.

A comparison of trapping rates with water pH at different stations along the streams at localities 34 and 35 (see Appendices E and F) does not indicate any apparent correlation between species abundance and water pH within the ranges encountered.

Doudoroff and Katz (1950) reviewing literature on water toxicity in relation to fish concluded that most adult fish are able to live indefinitely in waters with pH above 5.0 and up to 9.0; furthermore that much more extreme pH values, possibly below 4.0 and above 10.0 can be tolerated for long periods by more resistant species and for shorter periods by less resistant ones. At localities 34 and 35 water pH frequently rose above 9.0 at stations towards the end of the streams. At locality 34 (see Appendix E) fish have been trapped in water at pH 10.0 on two occasions, (30.VI.68, 26.VII.68), at pH 9.2 - 9.8 on three occasions (28.V.68, 30.VI.68, 31.VIII.68), but not in water above pH 10.0 on the two occasions these levels were recorded (30.VII.68, pH 11.0; 31.VIII.68,pH >10.0). At locality 35 (see Appendix) fish have been trapped in water at pH 9.1 - 9.6 on four occasions (24.I.69, 13.XI.69, 27.IX.69, 31.X.70).

(c) Comparisons of Inhabited Waters with Non-inhabited Waters.

The localities I inspected from which *C. eremius* was absent included both artesian fed pools and streams and permanent and ephemeral water bodies of meteoric origin. An initial comparison of the analyses for these non-inhabited localities (see Tables 36 and 37) indicate a similar range of ions (including pH) ion proportions and salinity as recorded from inhabited waters, so there is no obvious correlation of such parameters with the presence or absence of *C. eremius*.

Prompted by Hedgpeth's (1959) bio-aquatic classification of inland waters based on certain anionic proportions, a closer examination of ionic proportions shows a partial correlation with the known occurrences of *C. eremius*. Hedgpeth (1959) distinguished between waters in which SO_4^- or CO_3^- ion content exceeds Cl^- ion content and those in which Cl^- exceeds either SO_4^- or CO_3^- ion content. Tables 42 and 43 list the relavent ionic values for those permanent waters (artesian and meteoric) for which detailed analyses are given in Table 36 . In 13 of the 14 inhabited waters (see Table 42) Cl^- ion exceeds both SO_4^- and CO_3^- respectivelly, while in the remaining water mass Cl^- ion exceeds the SO_4^- but is less than the CO_3^- content. Similarly, in 8 of the 15 non-inhabited (see Table 43) waters Cl^- content exceeds both SO_4^- and CO_3^- respectivelly, and in 6 exceeds SO_4^- only; in the remaining sample the Cl^-

content is less than CO_3^- content and equals SO_4^- content. Thus in all permanent habitats of C. eremius the Cl^- content of the water exceeds either or both, more usually both, the SO_4^- and the CO_3^- contents. However since in all but one of the non-inhabited waters cited Cl^- content similarly exceeds at least one or other of the two ions, it does not appear that there is a chemical barrier, in terms of Hedgpeth's ionic criteria, preventing the occurrence of C. eremius.

A partial correlation exists between the species distribution and Jack's (1923) hypothetical neutral line (see figure 17) dividing the South Australian portion of the Great Australian Artesian Basin into eastern and western parts. Jack (1923) established this line on the basis of the proportion of SO_4^- to CO_3^- content in artesian waters and suggested that the differences either side of the line were due to different areas of intake. West of the neutral line SO_4^- content is greater than CO_3^- content whereas east of it SO_4^- content is less than CO_3^- content. As figure 17 shows the general eastern limit of C. eremius is almost Jack's (1923) neutral line with three apparent exceptions; Dalhousie Springs (locality 1/1) approximately 1km east of the line, localities at or near Coward Springs (localities 33, 34, 35) approximately 24km east of the line and Clayton Bore (locality 44) 10km east of the line.

However, all my chemical analyses disagree with Jack's (1923) data to some extent (see Table 40) and there are some quite large discrepancies in total salinity figures (total dissolved salts) at some localities, in particular localities 18, 29, 36, 54, and 60. In addition, individual ion contents are different in most cases and in two instances (localities 1/1, 33) the proportions of SO_4^- and CO_3^- are actually reversed, and quite markedly, so that whereas according to Jack's (1923) data CO_3^- is in excess of SO_4^-, in my data SO_4^- is in excess of CO_3^-. It therefore appears that the composition of outflowing artesian water can change quite drastically over a period to time (see p. 86) if both sets of data are correct. Assuming the accuracy of my data, Jack's (1923) neutral line now lies further east than he showed it so as to encompass Dalhousie Springs (locality 1/1) and Coward Springs proper (locality 33). It is unlikely that either Jack's (1923) data or my own would be so inaccurate as to account for at least the larger differences and for the large reversal in dominance of certain ions. A possible reason for the difference in the data may be due to different sampling techniques. At least my results are internally consistent since, wherever practicable, I sampled as near as possible to the outflow point of the spring or bore. The samples from which Jack's (1923) data were obtained may not necessarily have been collected in such a fashion and, as has been seen (see p. 73), quite marked gradients in water composition and changes in ion content can occur along artesian surface flows.

Although there appears to be a tendency for permanent C. eremius population to occur most frequently in waters in which SO_4^- is greater than CO_3^- content, there are, as we have seen, some exceptions. Thus it does seem that the relative proportions of SO_4^- and CO_3^- ions might not, within the values recorded in the central Australian region, necessarily have any direct limiting effect on the occurrence of the species.

The apparent correlation between the distribution of the fish and the ion content ratios of the waters west of Jack's (1923) line may be a fortuitous accident of geological and biological history rather than an indication of any direct biological dependence of the fish on the ion ratios of their aquatic environment.

In order to determine whether natural populations living in water in which SO_4^- is greater than CO_3^- content are so adapted to these ionic proportions that they are unable to survive reversed ratios in their aquatic environment I carried out the following test. Selecting 20 of the smallest available individuals (20-25mm SL) from laboratory stock (these presumably being more susceptable to environmental changes than larger fish) collected at Nunn's bore (locality 27), where water SO_4^- exceeds CO_3^- content by 472.5 p.p.m., I placed 10 subjects in a tank containing 2 litres of artesian water collected at Gason's Bore (locality 51) in which SO_4^- is less than CO_3^- content by 311.9 p.p.m. The other 10 subjects were placed in a similar tank containing an equal quantity of artesian water from Nunn's Bore (locality 27) to act as a control. The subjects were introduced into the respective tanks on 4.II.71 which were set side by side in the laboratory, fed an equal quantity of tubifex worms every second day and a fresh supply of the respective waters provided every 7 days. Thus both batches of fish were exposed to virtually identical environments except for the differences in the ion proportions of the two sets of waters. The tanks were inspected every day to see if any deaths had occurred. The test continued for a period of 28 days at the end of which no deaths had occurred in either tank. It was concluded that C. eremius is able to tolerate without apparent harmful effect exposure to water whose Cl^-, SO_4^- and $(H)CO_3^-$ ion proportions are the reverse to the water in which it is bred, at least for a limited period of time. Whether they could withstand prolonged exposure or would be able to establish a breeding population in water of this composition cannot be stated on the available evidence.

Whereas Hedgpeth (1959) regards anionic proportions, in particular Cl^- with respect to SO_4^- and CO_3^-, of at least partial significance as a limiting factor in inland waters, Beadle (1943, 1959) emphasises the importance of total salinity. Table 44 lists the total salinities of the same localities given in Tables 42 and 43.

Since the salinities of both inhabited and non-inhabited waters of the central Australian region are of the same range, it does not appear that this factor either has any direct influence on the occurrence of C. eremius within the Lake Eyre drainage system. However, as Bayly (1967) states, the relative biological significance of ionic proportions and total ionic concentration as limiting factors in inland saline waters has yet to be clearly established. In the case of C. eremius, ionic proportions and total salinities do not appear to be of direct significance in limiting the species occurrence within its present known total range. Other factors at least undoubtedly are involved in limiting distribution including the ability to disperse, accessibility of other waters, food availability, competitiveness and predatory pressure. In fact, as Kinne (1960) believes, the complexity of environmental factors that interact to limit faunal distribution may well be almost infinite. Undoubtedly further information on the occurrence or absence of the species and the accummulation of environmental data from aquatic habitats outside the areas so far surveyed will assist in establishing the limiting factor/s involved but I believe the most productive line of study would be to introduce sample populations of C. eremius into some carefully selected permanent waters both within and outside the Lake Eyre drainage system and establish in which, if any of them, the species is able to survive and subsequently reproduce.

(d) Salinity Tolerance in *C. eremius*.

In order to gauge the tolerance of *C. eremius* to salinities well below and above the range normally inhabited by the species experimental material for these and other live observations was collected from the Nunn's bore (locality 27) population by means of wire mesh traps (see Appendix) and transported by road to the laboratory in 23 litre capacity plastic drums, approximately three-quarter filled with artesian water collected at the same locality, together with a quantity of aquatic plant (*Cyperus* sp.) to dampen movement during transportation. A total of approximately 50 adult fish could be successfully carried in each container without aerating the water during the average 24 hour return journey to the laboratory, except during the warmer months. In the very warm summer months (November - February) the temperature of the water in the containers usually rose to in excess of 40°C after only a few hours travelling during daylight and resulted in almost a total mortality rate. It was doubtful if aeration would have been of any benefit with temperatures of this order. As a result an alternative technique was employed to transport live material during the hot weather, by placing up to 40 adult fish in a 9 litre capacity canvas water bag attached to the exterior of the vehicle. Filled to half capacity with artesian water and containing aquatic vegetation to dampen movement the temperature of the water within the bag was kept below 20°C and enabled an almost mortality-free return journey on each occasion it was used. Upon return to the laboratory the fish were placed in holding tanks for a minimum period of seven days before being used in experiments. During this period and throughout captivity the fish stock were fed with tubifex worms (*Tubifex* sp.) every second day and the tank water continuously aerated.

Salinity tolerance was tested by directly and immediately transferring batches of 10 fish from the holding tanks to each of several smaller tanks (36 x 18 x 20cm deep) each containing 2 litres of water of different salinities. In selecting the fish an effort was made to ensure that those in each batch covered approximately the same size range. Before placing them into the test solutions each batch was briefly rinsed with distilled water to remove holding tank water from the body surfaces.

The salinity of the test solutions was adjusted by diluting with distilled water or concentrating by evaporation the artesian water obtained at the bore head at Nunn's bore (locality 27). In one test the fish were placed into seawater. With each test a control batch was maintained in "normal" artesian water from Nunn's Bore.

The tests were run for a period of 20 to 60 days duration. Every second day the distilled, diluted and saturated waters were replaced with freshly prepared solutions. The "normal" bore water in the control tanks was only replaced if obvious signs of fouling appeared. During the test periods the fish were fed every second day with tubifex worms (Tubifex sp.) for several hours prior to the replacement of fresh solutions. Concentrations were maintained by regular topping up with distilled water if water levels fell significantly. Since the tests were conducted in a constantly cool room and the fish were not crowded aeration of the test tanks was not considered to be necessary.

During the trials the test tanks were inspected every morning and afternoon and any mortalities noted. Dead subjects were removed from the tanks and their standard lengths noted. The trials were conducted at room temperature and water temperatures were noted daily each afternoon between 1600 and 1700 hours. The maximum recorded temperature fluctuation during any 20 day period did not exceed 4.0°C.

The following series of trials were conducted:-

A. Five trials during each of which one test group was exposed to distilled water, a second group to saturated artesian water, and a third group to "normal" artesian water (the control group).

B. One trial during which a test group was exposed to artesian water diluted by nineteen parts to one with distilled water. This trial was held simultaneously with one of the series A trials.

C. One trial during which a test group was exposed to sea water and a control group to "normal" artesian water.

The data recorded from these trials are presented in Appendix S and the results there-from summarised in **Table 45.** Appendix R details the chemical analyses of the various test mediums used in the trials.

The summarised results of these salinity tolerance trials show that C. eremius is capable of tolerating minimal water salinities approaching zero, far less than any level recorded in the field, for periods of up to a maximum of at least 27 days exposure. More indicative however is the period, ranging between day 9 - day 22, during which 50% of mortalities occurred in each of the trials.

At salinity 147 p.p.m. no mortality occurred up to the time the single trial was terminated after 60 days duration, indicating the extremely low salinity level to which the species will withstand prolonged exposure.

Similarly, at salinity 9797 p.p.m., which was well in excess of the control and 15.9% higher than any field record, only one mortality occurred during the four trials which were terminated after varying periods ranging up to 60 days. Furthermore when exposed to seawater with a total salinity approximately X7 that of the control medium and X4.5 the maximum field record, tolerance was equally remarkable; only one mortality occurring during the single trial which was terminated after 60 days.

These results demonstrate the ability of C. eremius to withstand sudden pronounced changes and prolonged exposure to wide extremes of salinity. However, as Beadle (1943, 1959) points out, salinity tolerance determined in the laboratory does not necessarily give a reliable indication of a species ability to become permanently established under natural conditions. Salinity outside the natural range but within the experimental range may cause it to be less resistant to other environmental factors not present under laboratory conditions. Nevertheless the ability to withstand such extreme changes in salinity, particularly reductions, at least temporarily, undoubtedly constitutes an important factor in survival. As discussed earlier (p. 72) the temporary fluctuations in salinity to which C. eremius is subject in nature are primarily due to rainfall and evaporation.

But salinity of outflowing artesian water also varies from one locality to another and within any one locality (see p. 71) Williams (1967) suggests that the chemical composition and the salinity of water flowing from mound springs and bores probably has as little temporal variation as the lentic waters of the Great Australian Artesian Basin. However a comparison of water analyses of samples taken at different points in time from certain localities (see Table 40) indicates that the composition of artesian water can change significantly and sometimes quite dramatically over a time interval.

It was noted during the course of the tolerance trials that shortly before death, fish in distilled water appeared unable to maintain an upright posture and tended to lie on one side of the tank bottom, simultaneously exhibiting a series of sposmadic body convulsions in the form of momentary twitching movements and with the mouth remaining agape.

3. DISSOLVED OXYGEN LEVELS.

(a) Preamble

A number of studies on other fishes have indicated that a dissolved oxygen concentration of the order of 4-5 parts per million is probably the critical level for most warm water fishes. Ellis (1937), for example, in his study of stream pollution stated that fish faunas were not found in diluted waters containing less than 4 p.p.m. of oxygen. He concluded that 5 p.p.m. is probably the limiting level. Moore (1942) in his study of the oxygen requirements, under field conditions, of various North American freshwater fishes, found that oxygen tensions of less than 3.5 p.p.m. at summer temperatures of 15-26°C were fatal, within 24 hours, to most species. On the other hand oxygen concentrations of 5.0 p.p.m. and over were completely non-lethal to all species tested. Moore (1942) therefore concluded that dissolved oxygen concentrations of at least 3.5 to 5.0 p.p.m. are essential to the survival of most warm water fish at summer temperatures (15-26°C).

On the other hand Brown (1957) pointed out that Ellis (1937) failed to conclusively show that much lower oxygen levels did not in fact occur at any time in the waters studied. In addition Kaetz and Gaufin (1953) in their study of the effects of sewage pollution on fish in mid-western North American streams reported that populations of various warm water species occurred in waters in which widely fluctuating oxygen levels sometimes dropped well below 4 p.p.m. for short periods. Brown (1957) in summarizing experiments on young salmonids (a cold water group) by Townsend and Earnest (1940), Townsend and Cheyne (1944), Graham (1949), Davison (1954) and Shepard (1955) states that whilst oxygen concentrations in the region of 2 p.p.m. may be critical for some forms others may survive concentrations less than 1 p.p.m. for long periods. Furthermore comparative tests by Burdick et al (1954) indicates that warm water fishes are more resistant to low oxygen levels than cold water fishes.

(b) Field Measurements

In the light of the above observations I decided to gauge the order of dissolved oxygen concentrations to which C. eremius is subject. By means of Alsterberg's (1925) method of determining oxygen levels as described by Chamberlin (1967) I made field measurements at several stations at Wobna Springs (locality 35), together with other routine data, and at Nunn's Bore (locality 27). Tables 46-47 presents these data. It will be noted that at Wobna Spring the recorded levels varied between 2.0 and 4.0 p.p.m. and at Nunn's Bore the single reading was 0.8 p.p.m. At all sites at which water was sampled for the purpose of these determinations *C. eremius* was simultaneously present. All these concentrations are quite low when compared, for example, with oxygen concentrations characteristic of the Murray River waters (* of the order of 8 p.p.m.).

Thus it is seen that, in summer at least, *C. eremius* is subject to, and able to tolerate at least temporarily, water with very low dissolved oxygen concentration. However as Brown (1957) pointed out in relation to other studies this does not necessarily indicate the minimum levels that may be present at the localities studied. Pollution (for example by virtue of cattle urine and faeces and putrifying carcasses) may well lower oxygen levels considerably for short periods of time, at least in some sections of the habitat.

Within the range recorded at Wobna Spring there appears to be no relationship between oxygen concentration and the species abundance (see Table 46). Brown

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* A personal communication from J. Johnston Esq., South Australian Engineering and Water Supply Department (Bolivar Laboratories).

(1957) states that avoidance reactions by fish in natural gradients may limit dispersal but with regard to the available data relating to C. eremius I do not necessarily know the full extent of the oxygen concentration gradient that may be present at any one time.

Since C. eremius has shown to be able to withstand at least temporary exposure to otherwise lethal levels of water temperature and salinity it is conceivable that the species can similarly survive exposure to excessively low oxygen concentrations, probably less than the 0.8 p.p.m. recorded at Nunn's Bore.

It has been observed (see p. 143) that C. eremius is apparently able to perform aerial respiration, and thereby able to survive, at least temporarily, low dissolved oxygen levels. This would certainly be an asset to any fish inhabiting waters prone to such low oxygen levels as indicated here.

Table 16

Bottom water temperatures recorded at different water masses, both inhabited and uninhabited by _C. eremius_, in the central Australian region.

In the case of artesian waters, at least one reading was taken at, or as close as practicable to, the outflow point. Where two readings are given the second one was that taken some considerable distance from the outflow point and gives some indication of the range of water temperature at the particular locality.

* _C. eremius_ successfully introduced 2.IX.70.

Table 16

INHABITED				
Loc. No.	Locality	Date Recorded	Ambient temp. °C	Water temp. °C
75	Finke River, Hermannsburg H.S.	12.III.70	-	20.0
14	Peake Creek	30.VII.68	20.0	21.9
12	Algebuckina Waterhole	31.VII.68	12.5	9.0
1/3	Dalhousie Spring 3	5.VIII.68	15.4	36.0
27	Nunn's Bore	11.VIII.68	18.0	48.1-15.0
30	Coward Springs proper	1.XI.68	22.2	26.0-18.7
35	Wobna Spring	1.XI.68	20.1	30.5-22.3
24	Johnson's No. 3 Bore	3.XI.68	13.3	36.5-17.0
34	Coward Springs Bore	15.XI.68	28.9	31.5-22.0
1/1	Dalhousie Main Spring	18.XI.69	--	44.0-21.6
1/4	Dalhousie Spring 4	19.XI.69	24.0	34.5 outlet
7	Forrest's Waterhole	20.XI.69	23.7	18.0
18	Birribirriana Spring	21.XI.69	27.5	24.5
19	Nilpinna Spring	21.XI.69	26.8	25.6
13	Wood-Duck Bore	21.XI.69	29.0	29.5
15	Old Peake H.S. Bore	22.XI.69	32.3	35.6-29.6
16	Freeling Springs	23.XI.69	32.0	27.4-26.4
17	Blyth Bore	23.XI.69	31.8	26.0

NON-INHABITED				
Loc. No.	Locality	Date Recorded	Ambient temp. °C	Water temp. °C
8	Hookeys Waterhole	2.V.69	25.5	19.5
9	Cramps Camp Waterhole	2.V.69	26.0	26.0
5	Alberga Crossing	1.VIII.68	21.0	20.5
36	*Blanche Cup Mound Spring	1.IX.68	17.4	13.7
32	Warburton Springs	2.IX.68	19.0	21.7
62	Mulligan Springs	24.X.69	28.7	25.3
63	Twelve Springs	24.X.69	33.1	25.5
60	Montecolina Bore	29.X.69	27.5	31.0
64	Woolatchi Bore	29.X.69	25.0	30.7-25.1
54	Paralana Hot Springs	30.X.69	21.5	51.5-24.4
	Paralana Overflow	30.X.69	20.0	25.9
55	Balcanoona Creek	30.X.69	23.0	24.8
20	Cardajalbarrana Spring	20.XI.69	26.5	21.6
43	Lake Harry Bore	22.XI.70	36.5	30.0
44	Clayton Bore	22.XI.70	38.0	53.1-34.6
45	Dalkaninna Bore	22.XI.70	33.7	60.0
46	Cannawaukinanna Bore	22.XI.70	36.6	45.5
50	Mirra Mitta Bore	22.XI.70	36.5	81.3-30.5
51	Gason Bore	22.XI.70	34.9	91.0-24.6

		Inhabited Waters	Non-inhabited Waters
Higher temp. range	Range of maximum temperatures (excluding localities 44-51).	44.0-18.0	51.5-21.6
	Mean value of maximum temps. (excluding localities 44-51).	29.0	29.6
Lower temp. range	Range of lower temps. (where more than one temp. recorded and including localities 44-51).	29.6-17.0	34.6-24.4
	Mean value of lower temps. (where more than one temp. recorded and including localities 44-51).	22.0	27.8

Table 17

Comparison of thermal conditions prevailing in Inhabited and Non-inhabited waters (mainly artesian). Based on data recorded during November 1968 and 1969 and October-November 1970 as given in table 16 All values in °C.

Table 18

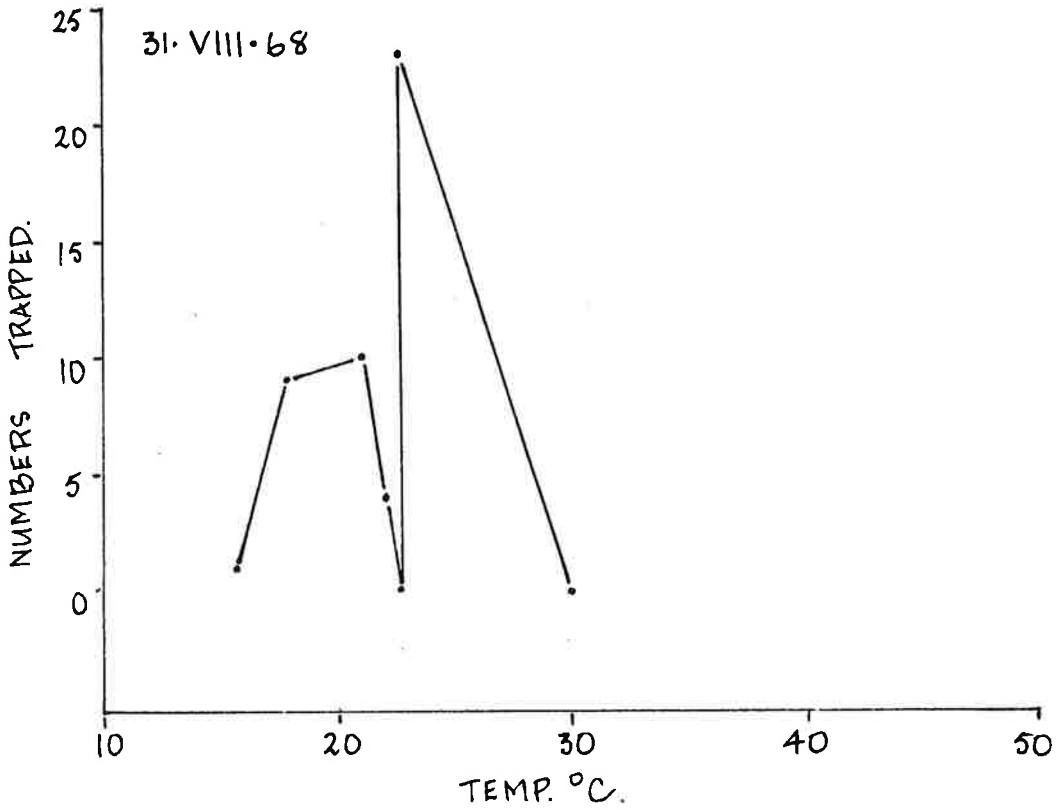
Maximum ranges of bottom water temperature which *C. eremius* has been observed to simultaneously occupy.

Table 18

Locality	Loc. no.	Date recorded	Amb. temp. °C	Max. temp at which *C. eremius* collected or sighted °C	Min. temp at which *C. eremius* collected or sighted °C	Thermal rang occupied C°
Johnson's Bore	24	3.IX.68	?	36.5	14.7	21.8
Coward Springs Bore	34	15.XI.68	28.9	32.0	22.3	9.7
Wobna Spring	35	26.VII.68	19.9	29.9	19.0	10.9

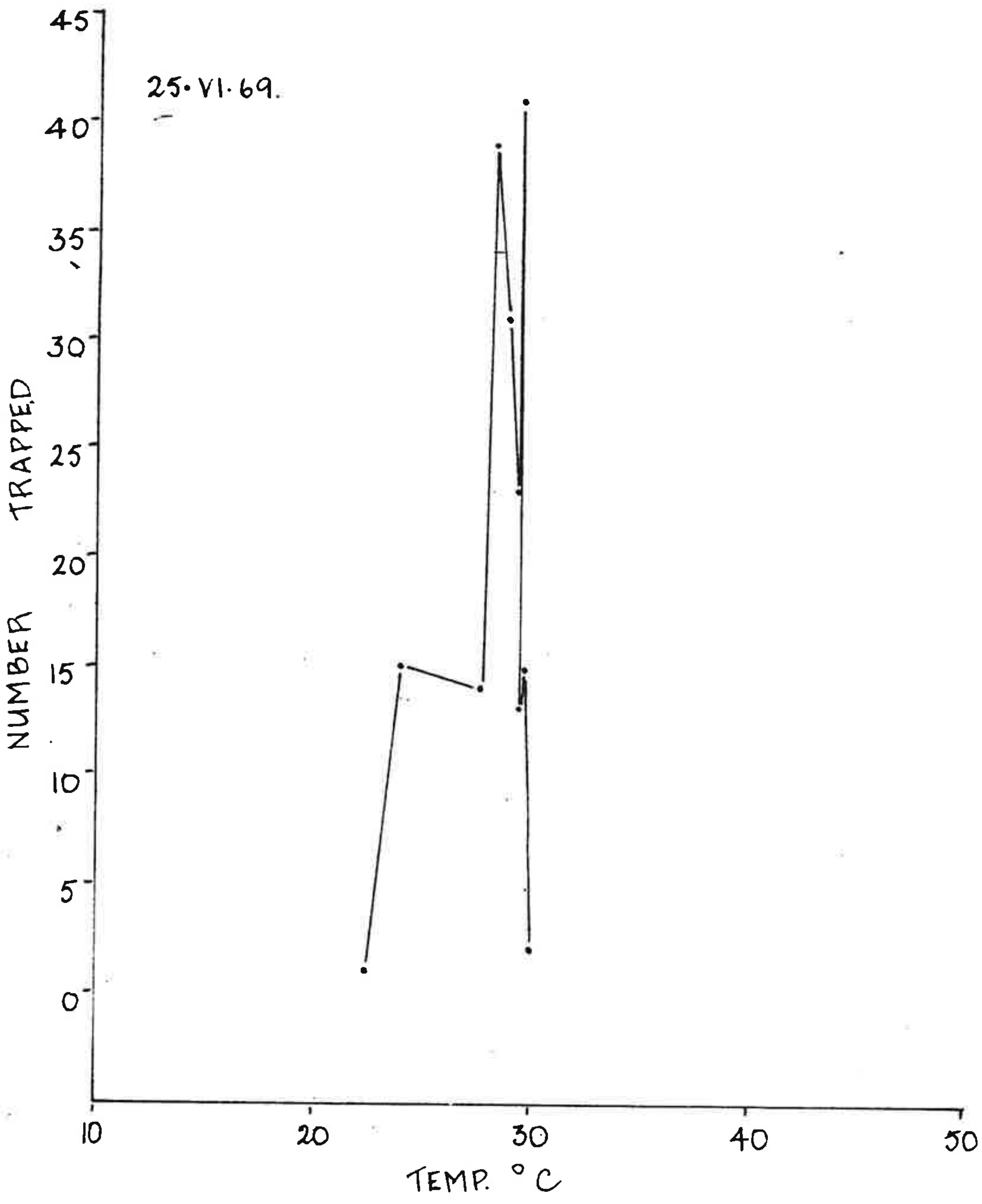
Graph 6

Numbers of *C. eremius* trapped in water at varying temperatures at Coward Springs Railway Bore (locality 34) on 31.VIII.68.


31·VIII·68
NUMBERS TRAPPED.
25
20
15
10
5
0
10
20
30
40
50
TEMP. °C.

Graph **7**

Numbers of *C. eremius* trapped in water at varying temperatures at Wobna Spring (locality 35) on 25.VI.69.

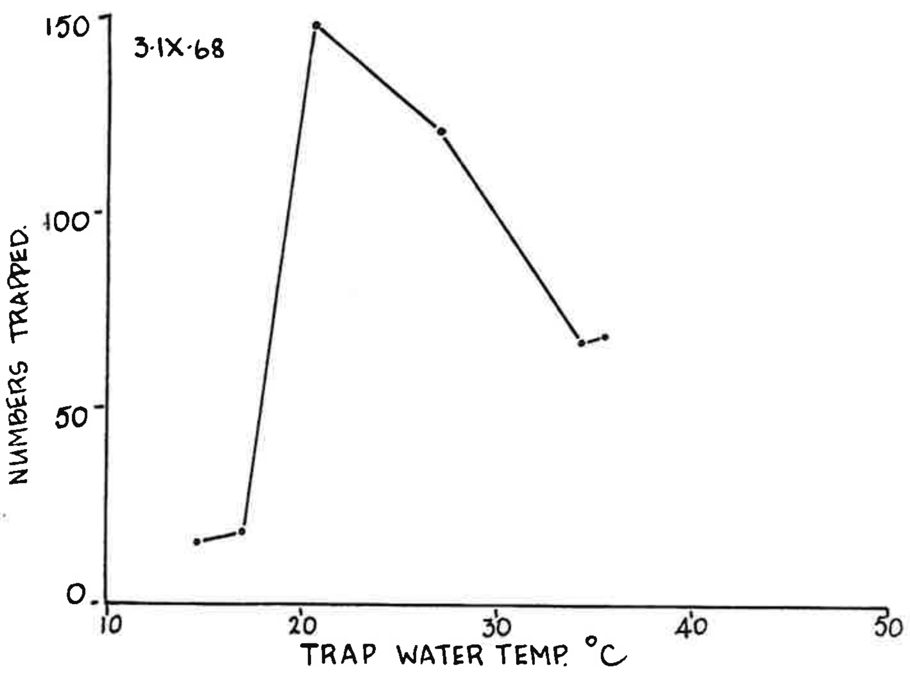

25·VI·69.
NUMBER TRAPPED
45
40
35
30
25
20
15
10
5
0
10
20
30
40
50
TEMP. °C

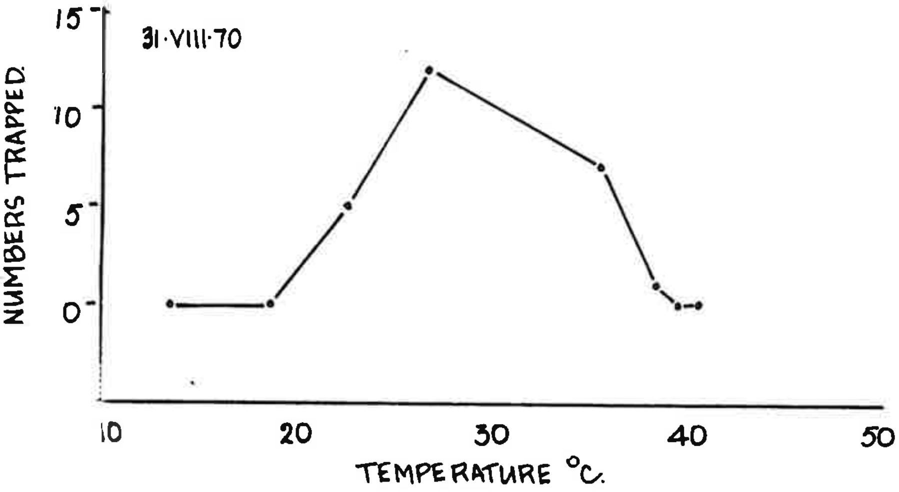
Graph 8

Number of _C. eremius_ trapped in water at varying temperatures at Johnson's No. 3 Bore on 3.IX.68.

Graph 9

Number of _C. eremius_ trapped in water at varying temperatures at Johnson's No. 3 Bore on 31.VIII.70.


3·IX·68
NUMBERS TRAPPED.
150
100
50
0
10
20
30
40
50
TRAP WATER TEMP. °C

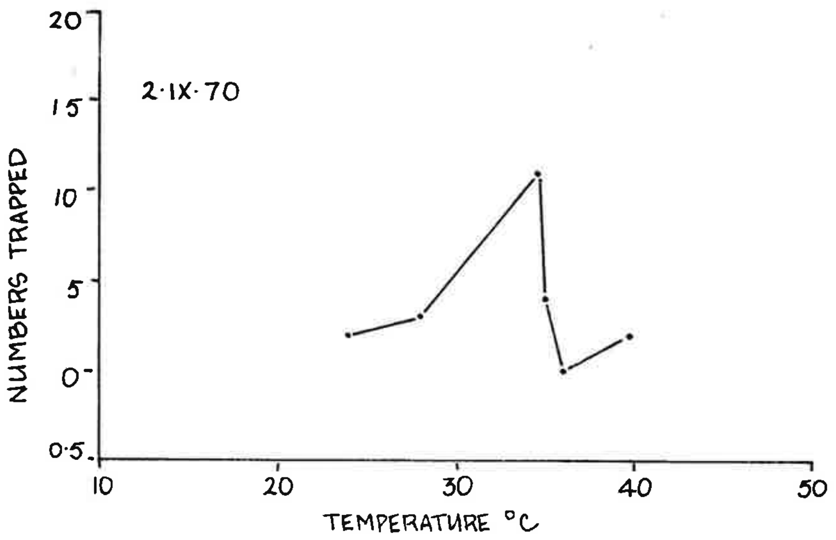

31·VIII·70
NUMBERS TRAPPED.
15
10
5
0
10
20
30
40
50
TEMPERATURE °C.

Graph 10

Numbers of _C. eremius_ trapped in water at varying temperatures at Johnson's No. 3 Bore on 2.IX.70.

Graph 11

Critical thermal maxima of _C. eremius_ trapped in water at different temperatures along the stream at Johnson's No. 3 Bore (locality 24) on 3.IX.68.


2·IX·70
NUMBERS TRAPPED
20
15
10
5
0
0·5
10
20
30
40
50
TEMPERATURE °C

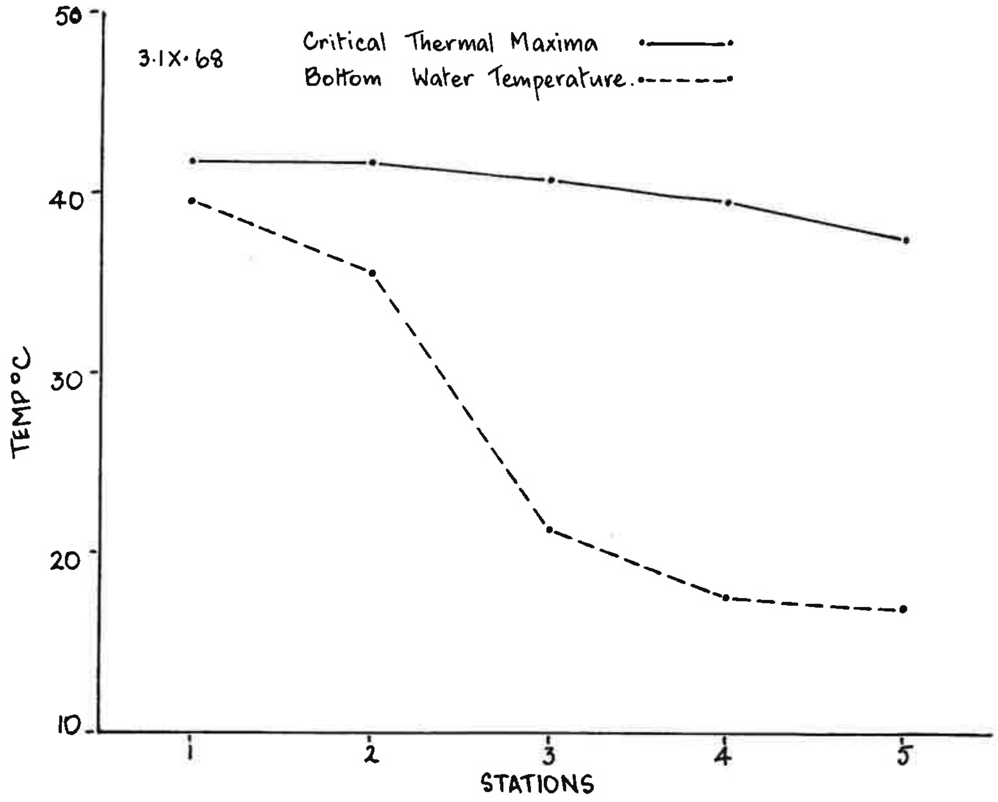

3·IX·68
Critical Thermal Maxima
Bottom Water Temperature
TEMP°C
50
40
30
20
10
1
2
3
4
5
STATIONS

Table 19

Bottom-water temperature and trapping rates recorded at several stations at Johnson's No. 3 Bore (locality 24) on 2.IX.70. Single trap at each station set 20 hours overnight. Temperatures and trapping rates recorded simultaneously 1320 hours 2.IX.70.

Table 19

Station no.	Bottom-water temp. at trap site °C	No. fish trapped
1	35.0	4
2	39.3	2
3	28.0	3
4	34.5	11
5	24.0	2
6	35.9	0

TABLE 20

Temperature, pH and depth transects made across the stream, between open water and algal stands, at Wobna Spring (locality 35) on 30.IV.69.

		Algal Stand adjacent left bank		Open Mid Stream	Algal Stand adjacent right bank	
		Centre of stand	Edge of stand adjacent mid stream		Edge of stand adjacent mid stream	Centre of stand
Station 5	Bottom H_2O temp (°C)	28.5	30.0	30.5	30.0	30.0
	2.5cm. sub-bed temp (°C)	29.0	30.0	30.0	28.8	29.5
	H_2O depth (cm)	10	4	10	1	4
	pH	8.3	7.6	7.5	7.8	8.4
Station 6	Bottom H_2O temp (°C)	28.6	29.9	30.6	30.0	29.9
	2.5cm. sub-bed temp (°C)	28.8	29.8	30.1	29.5	29.7
	H_2O depth (cm)	5	6	13	5	3
	pH	7.9	7.6	7.5	7.7	7.7
Station 7	Bottom H_2O temp (°C)	30.0	30.6	30.7	30.5	26.3
	2.5cm. sub-bed temp (°C)	29.0	30.0	30.0	29.6	26.1
	H_2O depth (cm)	1	5	11	7	4
	pH	7.7	7.6	7.6	7.6	7.7
Station 11	Bottom H_2O temp (°C)	28.9	28.5	28.4		
	2.5cm. sub-bed temp (°C)	28.0	28.5	28.5		
	H_2O depth (cm)	1	1	1		
	pH	8.3	8.1	8.0		

Table 21

Water temperature transects made between mid-stream and adjacent vegetated shallows at several stations at Johnson's No. 3 Bore (locality 24). Recorded 0800 hours 3.IX.68. Single trap set in vegetated shallows adjacent main stream at each station for 14 hours overnight and collected 0900 hours 3.IX.68. All temperatures bottom water readings.

Station 1 situated approximately 1,300m. along stream away from bore outflow; the remaining stations situated downstream from station 1 by the following distances (from station 1), stn. 2, 19m; stn. 3, 55m; stn. 4, 190m; stn. 5, 330m; stn. 6, 485m.

Table 21

Station	Mid open stream water temp. °C.	Distance within veg. stands (cms)				Difference between mid open stream water temp. and minimum water temp. recorded within adjacent veg. stand °C.	Water temp. at trap site °C	Water pH at trap site	No's of <u>C. eremius</u> trapped
		Fringe	5.0	30.0	60.0				
1	41.7	39.5	36.0	36.5	26.5	15.2	36.5	6.8	69
2	40.8	35.5	35.0	33.1	19.7	21.1	34.1	6.6	67
3	26.5	21.3	21.0	21.0	20.0	6.5	27.0	6.6	123
4	21.5	17.5	16.9	16.9	15.4	6.1	20.5	6.6	148
5	14.3			15.1			14.7	6.4	16
6	17.0						17.0	6.7	18

Trap No.	Traps in which all fish col. alive.		Traps in which all fish col. dead.		*Mean bottom water temps.			
	Bottom water temp. oC.	No. of fish trapped	Bottom water temp. °C.	No. of fish trapped	Open pool	Veg. fringe	10cm with-in veg.	20cm with-in veg.
1			43.9	5				
2	41.4	2						
3	38.4	7						
4	38.0	27						
5			41.7	8	40.8	39.4	35.1	33.1
6			41.2	18				
7	40.0	32						
8	39.5	58						
9	40.0	1						

Table 22

Numbers and conditions of *C. eremius* trapped in a pool at Johnson's No. 3 Bore 26.XI.69. Traps set 0800 hours, collected 1200 hours. Water temperatures recorded at collecting time.

* Data from table 23

Table 23

Water temperatures recorded at varying distances into the interior of stands of mixed vegetation and at 1 metre into open water adjacent the respective stands within a large pool at Johnson's No. 3 Bore (locality 24). Recorded 1200 hours 26.XI.69. All values °C.

	Distance within veg. stand (cms)				
Stand	Open pool bottom water temp.	Fringe	10.0	20.0	Difference between open pool bottom water temp. and minimum water temp. recorded within veg. stand °C.
1	43.9	35.5	29.0	27.8	16.1
2	(43.9 (41.4 (41.7	42.8 39.0 41.6	39.5 30.5 40.5	36.5 29.9 37.1	7.4 11.5 4.6
3	(41.7 (41.2 (41.1	39.0 40.0 39.0	34.0 36.1 34.3	35.0 32.1 31.5	7.7 9.1 9.6
4	(41.4 (41.0 (40.0 (38.4	39.1 40.5 38.9 40.0	36.5 38.0 31.5 37.7	34.8 35.5 30.4 36.3	6.6 5.5 9.6 2.1
5	(40.0 (39.5 (39.5	39.2 39.5 38.6	34.5 34.0 34.9	28.5 31.4 34.2	11.5 8.1 5.3
Range	38.0-43.9	35.5-42.8	29.0-40.5	27.8-36.5	2.1-16.1
Mean value	40.8	39.4	35.1	33.1	7.8

Table 23

Stand	Distance within veg. stand (cms).						Difference between mid pool bottom water temp. and minimum water temp. recorded within veg. stand C°.
	Fringe	1.5	5.0	15.0	30.0	40.5	
1	30.5	29.5	28.3				4.2
2	31.5	31.0	30.4				2.1
3	29.9	28.9	26.1	22.7			9.8
4	28.0	26.5	24.2		19.4	19.0	13.5

Table 24

Water temperatures recorded at varying distances into the interior of stands of mixed vegetation situated in a pool at Johnson's No. 3 Bore (locality 24). Bottom water temperature at centre of pool = 32.5°C. Recorded 1330 hours, 21.Vi.70. All values in °C.

Table 25

Water temperature, depth and trapping transects made between mid-stream and the adjacent vegetated shallows at three sites at Johnson's No. 3 Bore locality 24). Recorded 1600 hours 31.VIII.70. Single trap set at each station for 24 hour period.

Table 25

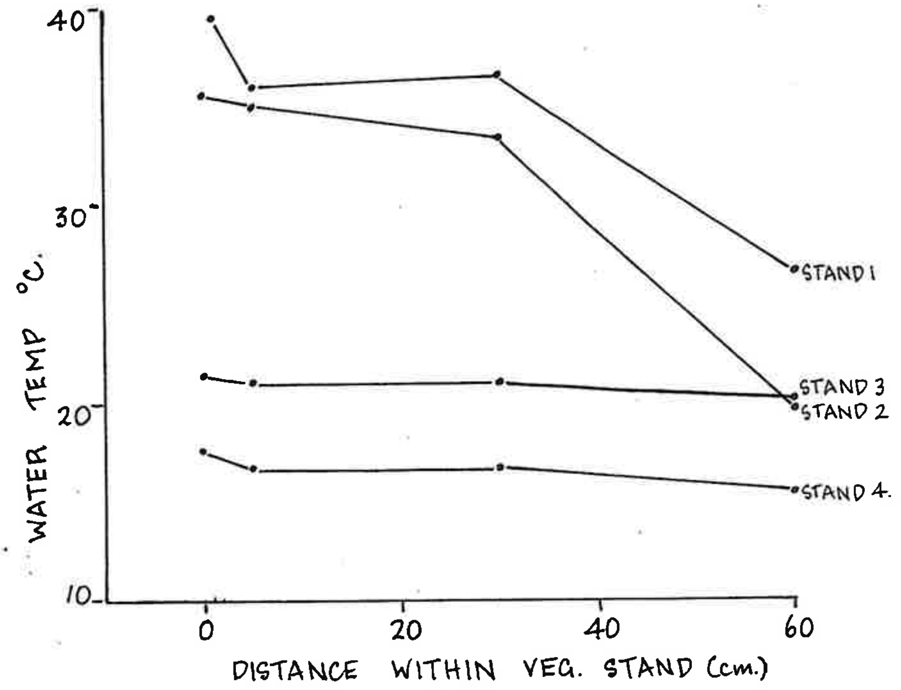
		Transect 1			Transect 2			Transect 3		
		Temp (°C)	Depth (cms)	No's trapped	Temp (°C)	Depth (cms)	No's trapped	Temp (°C)	Depth (cms)	No's trapped
Distance from mid stream (ms)	Mid stream	40.3	6.0	0	39.3	10.0	0	39.5	9.5	0
	1									
	2				37.9	8.0	3			
	3									
	4	35.5	5.0	7	29.0	10.0	11	38.2	10.0	1
	5									
	6				19.4	4.0	1	26.9	6.0	12
	7	22.4	4.0	5				18.5	5.0	0
	8									
	9	13.3	2.5	0						
	10									

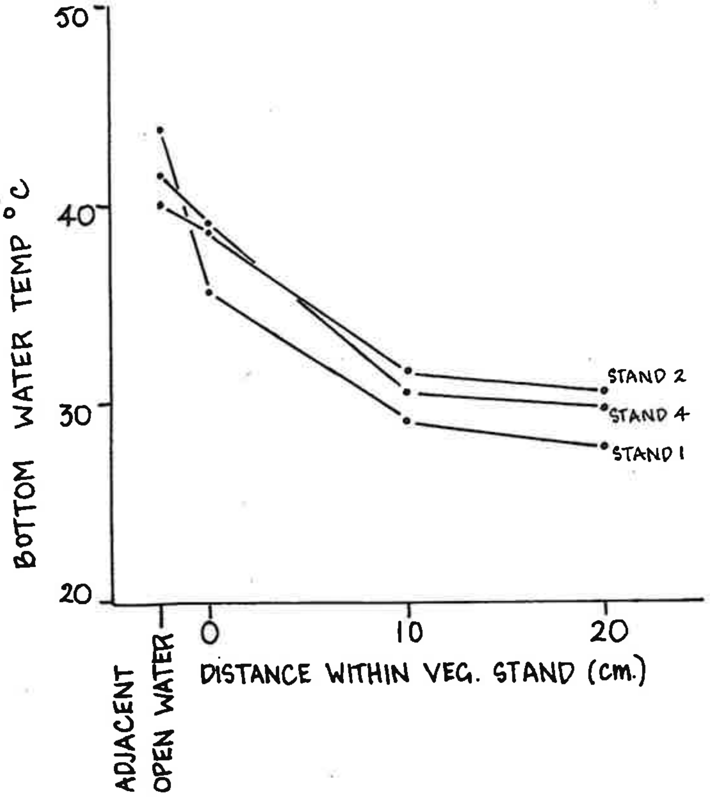
Graph 12

Aquatic thermal gradients between the fringe (0) and the interior of mixed stands of vegetation at 4 stations along the stream at Johnson's No. 3 Bore (locality 24). Mid stream open water temperatures adjacent the stands were as follows: st. 1, 41.7°C; st. 2, 40.8°C; st. 3, 26.5°C; st. 4, 21.5°C.
Recorded 3.IX.68.

Graph 13

Aquatic thermal gradients between the fringe (0) and the interior of 3 stands of mixed vegetation at Johnson's No. 3 Bore (locality 24).
Recorded 26.XI. 69.


WATER TEMP °C
40
30
20
10
0
20
40
60
DISTANCE WITHIN VEG. STAND (cm.)
STAND 1
STAND 3
STAND 2
STAND 4.

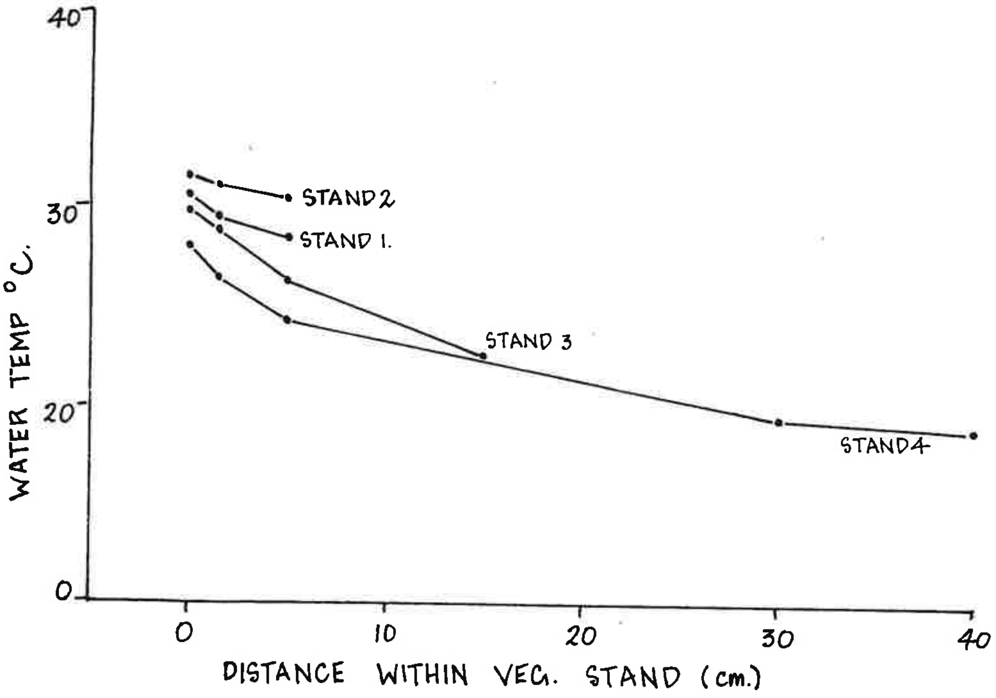

BOTTOM WATER TEMP °C
50
40
30
20
ADJACENT OPEN WATER
0
10
20
DISTANCE WITHIN VEG. STAND (cm.)
STAND 2
STAND 4
STAND 1

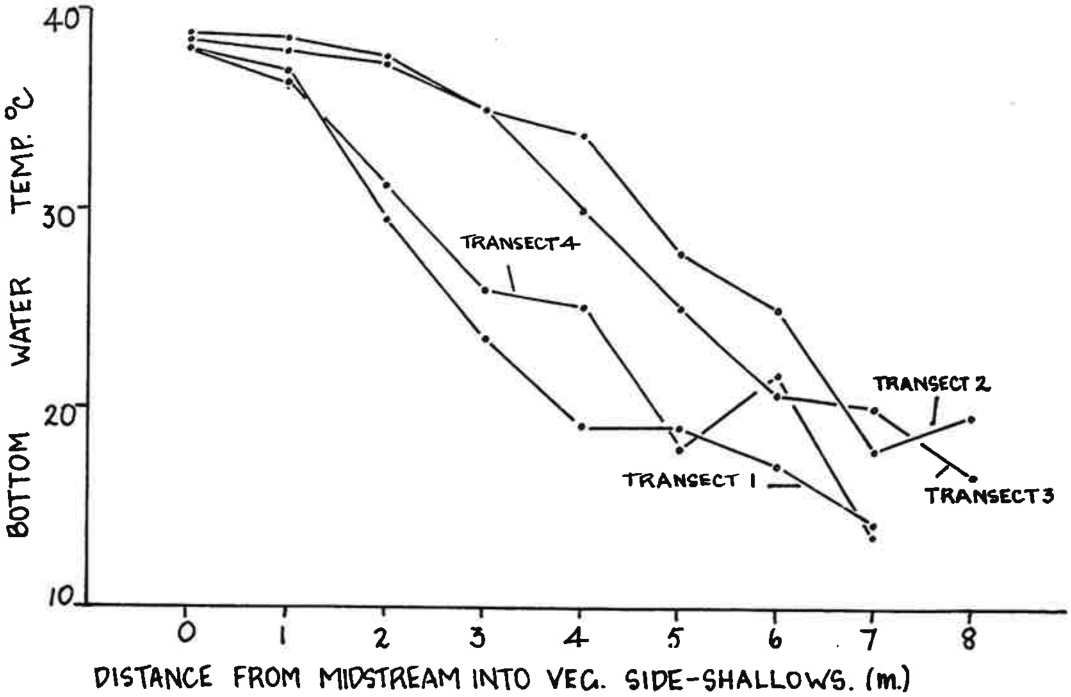
Graph 14

Aquatic thermal gradients between the fringe (0) and the centres of 4 stands of mixed vegetation in a pool at Johnson's No. 3 Bore (locality 24). Recorded 21.VI.70. Mean bottom water temperature at centre of pool = 32.5°C.

Graph 15

Aquatic thermal gradients between mid stream (0) and adjacent vegetated side shallows at 4 transect stations along the stream at Johnson's No. 3 Bore (locality 24). Recorded 2.IX.70. For transects 1 and 4 vegetation fringe is at 1m distance from mid stream; for transects 2 and 3 at 2m distance.


WATER TEMP °C.
40
30
20
0
STAND 2
STAND 1.
STAND 3
STAND 4
0
10
20
30
40
DISTANCE WITHIN VEG. STAND (cm.)


BOTTOM WATER TEMP. °C
40
30
20
10
TRANSECT 4
TRANSECT 2
TRANSECT 1
TRANSECT 3
0
1
2
3
4
5
6
7
8
DISTANCE FROM MIDSTREAM INTO VEG. SIDE-SHALLOWS. (m.)

	Water Temp. °C		
Date and time recorded	Open pool	Vegetated side shallows	Difference
6.V.69 0600 hours	29.5	12.3	17.2
28.XI.69 1100 hours	37.7	24.7	13.0

Table 26

Comparison of the difference in bottom water temperatures in an open pool and adjacent vegetated side shallows at Johnson's No. 3 Bore (locality 24) in winter and summer. Each value is a mean determined from 40 random readings.

Table 27

Mean bottom water temperature and difference between it and mean sub-bed temperature (at 2.5 and 9.0 cm depths) at the various stations at Coward Springs Railway Bore (locality 34) on different occasions between December 1967 and December 1968.

	Mean Water Temp °C		
Date Recorded	Bottom water	2.5 cm sub-bed (mean difference)	9.0 cm sub-bed (mean difference)
14.XII.67	33.5	-0.9	-3.8
21.II.68	24.5	-3.7	-5.1
22.III.68	31.4	-0.6	-1.6
26.IV.68	24.3	-0.4	-0.7
28.V.68	19.9	-0.4	-0.8
30.Vi.68	16.2	+0.3	+0.4
26.VII.68	17.2	-0.9	-1.2
31.VII.68	20.9	-2.4	-3.4
28.X.68	28.1	-1.6	-2.7
15.XI.68	28.2	-2.2	-3.4
19.XII.68	30.8	0	-1.2

Table 27

Graph 16

Mean bottom water temperature and difference between it and mean sub-bed temperature (at 2.5cm and 9.0 cm depths, respectively) at the various stations at Coward Springs Railway Bore (locality 34) on different occasions between December 1967 and December 1968.

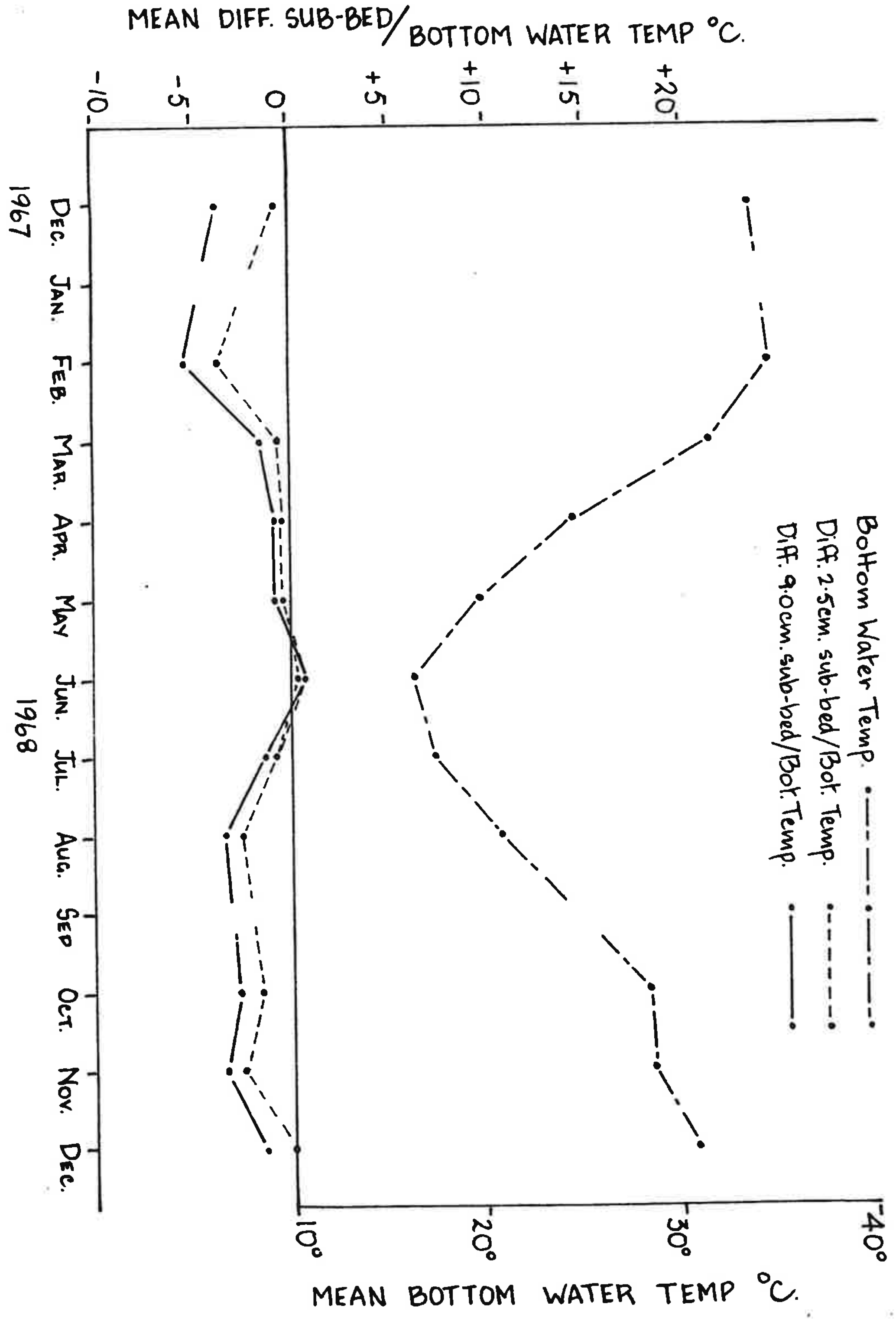

MEAN DIFF. SUB-BED/BOTTOM WATER TEMP °C.
-10
-5
0
+5
+10
+15
+20
1967
Dec.
Jan.
Feb.
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep
Oct.
Nov.
Dec.
1968
Bottom Water Temp.
Diff. 2·5cm. sub-bed/Bot. Temp.
Diff. 9·0cm. sub-bed/Bot. Temp.
10°
20°
30°
40°
MEAN BOTTOM WATER TEMP °C.

Table 28

Mean bottom water and mean difference in sub-bed temperatures recorded at the stations at Wobna Spring (locality 35).

Table 28

Date Recorded	Mean Temperature °C.	
	Bottom water	2.5 cm sub-bed (mean difference)
27.IV.68	29.1	-0.3
29.V.68	24.0	-0.3
30.VI.68	23.5	+0.1
26.VIII.68	25.7	-0.5
1.IX.68	26.5	-0.7
28.X.68	29.5	0
15.XI.68	30.5	-1.5
24.I.69	31.8	-0.8
24.II.69	32.2	-0.3
30.III.69	29.3	-0.8
30.IV.69	29.9	-0.1
25.VI.69	26.4	-0.3
13.XI.69	30.7	-0.1
22.II.70	29.9	+0.3
11.IV.70	28.0	+0.3
10.VI.70	29.4	+0.1
29.VII.70	28.2	+0.1
22.VIII.70	28.8	-0.1
27.IX.70	25.1	-0.2
31.X.70	31.5	-0.4
25.XI.70	30.8	+0.2

Graph 17

Mean bottom water temperature and difference between it and mean sub-bed temperature (at 2.5cm depth) at the various stations at Wobna Spring (locality 35) on different occasions between April 1968 and November 1970.

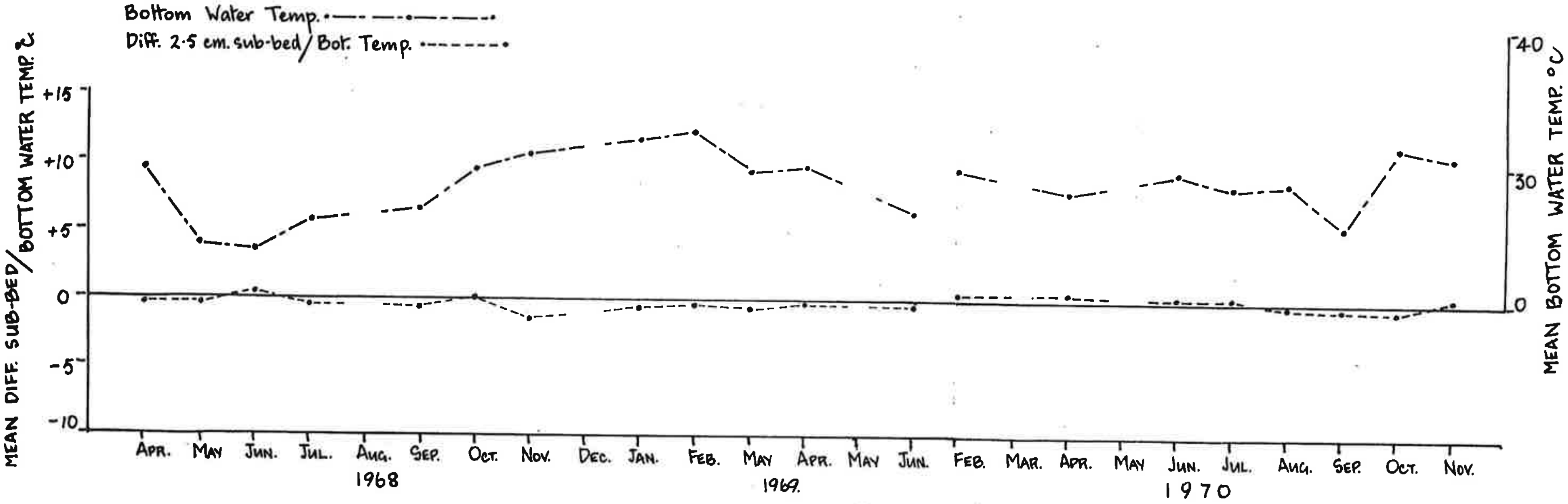

Bottom Water Temp.
Diff. 2·5 cm. sub-bed/Bot. Temp.
MEAN DIFF. SUB-BED/BOTTOM WATER TEMP. °C
+15
+10
+5
0
-5
-10
MEAN BOTTOM WATER TEMP. °C
40
30
0
APR.
MAY
JUN.
JUL.
AUG.
SEP.
OCT.
NOV.
DEC.
JAN.
FEB.
MAY
APR.
MAY
JUN.
FEB.
MAR.
APR.
MAY
JUN.
JUL.
AUG.
SEP.
OCT.
NOV.
1968
1969.
1970

Table 29

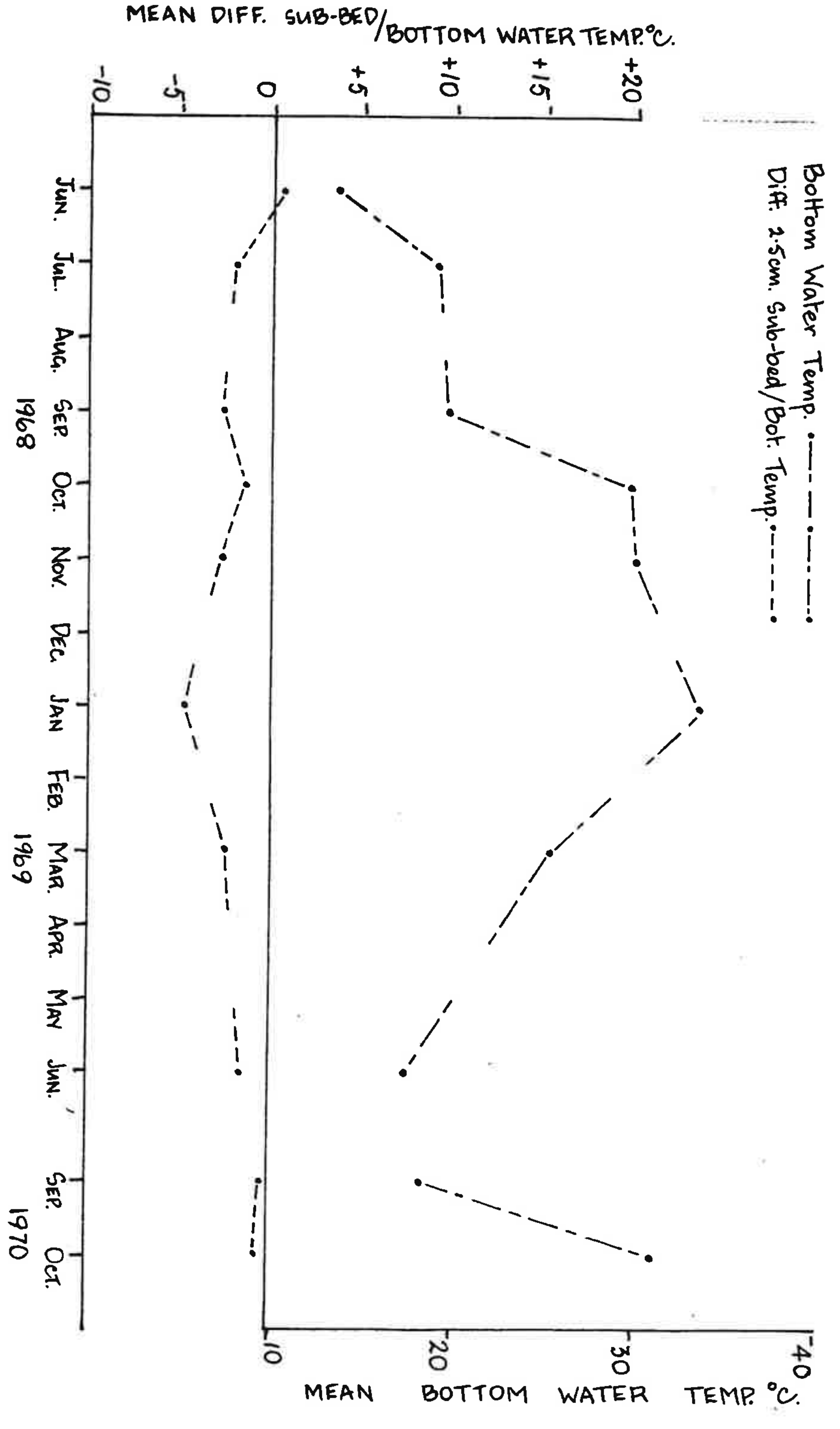
Combined mean bottom-water and sub-bed temperatures recorded at stations 12 and 13 in a side pool associated with the stream at Wobna Spring (locality 35).

Table 29

Date Recorded	Mean Temperature °C	
	Bottom water	2.5 cm sub-bed (mean diff.)
30.VI.68	13.5	+0.5
26.VII.68	19.0	-2.0
1.IX.68	19.8	-2.7
28.X.68	29.7	-1.2
15.XI.68	30.0	-2.8
24.I.69	33.4	-4.8
30.III.69	25.2	-2.2
25.VI.69	17.4	-1.7
13.XI.69	30.5	-0.4
27.IX.70	18.1	-0.1
31.X.70	31.0	-0.5

Graph 18a

Mean bottom water temperature and difference between it and mean sub-bed temperature (at 2.5cm depth) at stations 12 and 13 (ephemeral side pool) at Wobna Spring (locality 35) on different occasions between June 1968 and October 1970.


MEAN DIFF. SUB-BED/BOTTOM WATER TEMP.°C.
+20
+15
+10
+5
0
-5
-10
Bottom Water Temp.
Diff. 2.5cm. Sub-bed/Bot. Temp.
JUN.
JUL.
AUG.
SEP.
OCT.
NOV.
DEC.
JAN
FEB.
MAR.
APR.
MAY
JUN.
SEP.
OCT.
1968
1969
1970
10
20
30
40
MEAN BOTTOM WATER TEMP. °C.

Site	Collecting site's water temp. °C.	Mid stream water temp. °C.	Total No's trapped.	Effect of introduction into mid stream.
1	24.0-35.9	40.7	2	1st death at + 1.5 min. 2nd death at + 3.0 min.
2	28.0-34.5	40.0	14	First two deaths at + 5.0 min. Extreme stress and opercular movements in remainder at + 10.0 min. but alive at + 15.0 min.
3	35.0-39.3	39.9	6	All display stress at + 5.0 min. First death at + 7. Remainder displaying stress but alive at + 15 min.

Table 30

Results of transferring *C. eremius*, trapped (24 hour setting) in cooler water of side shallows, into warmer mid-stream water at Johnson's No.3 Bore 2.IX.70.

Figure 15

Equipment employed to measure critical thermal maxima.

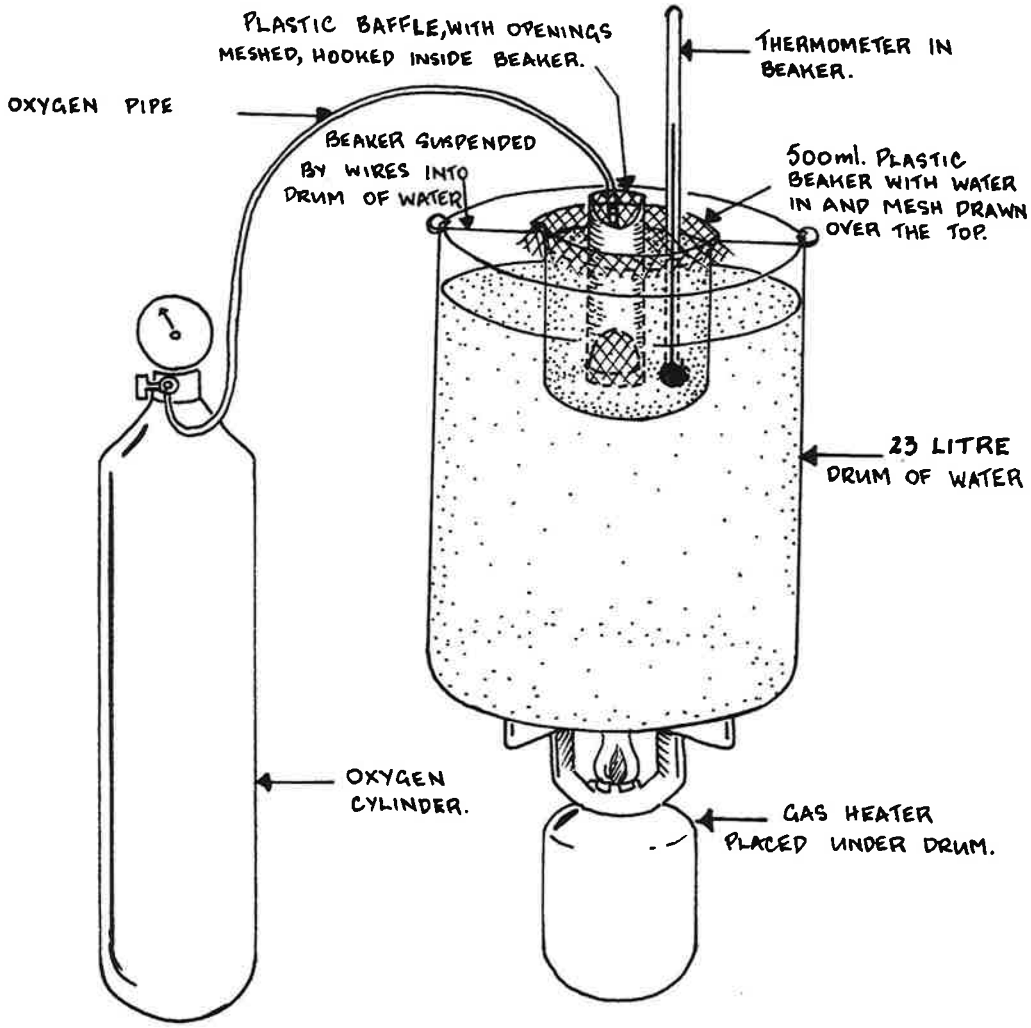
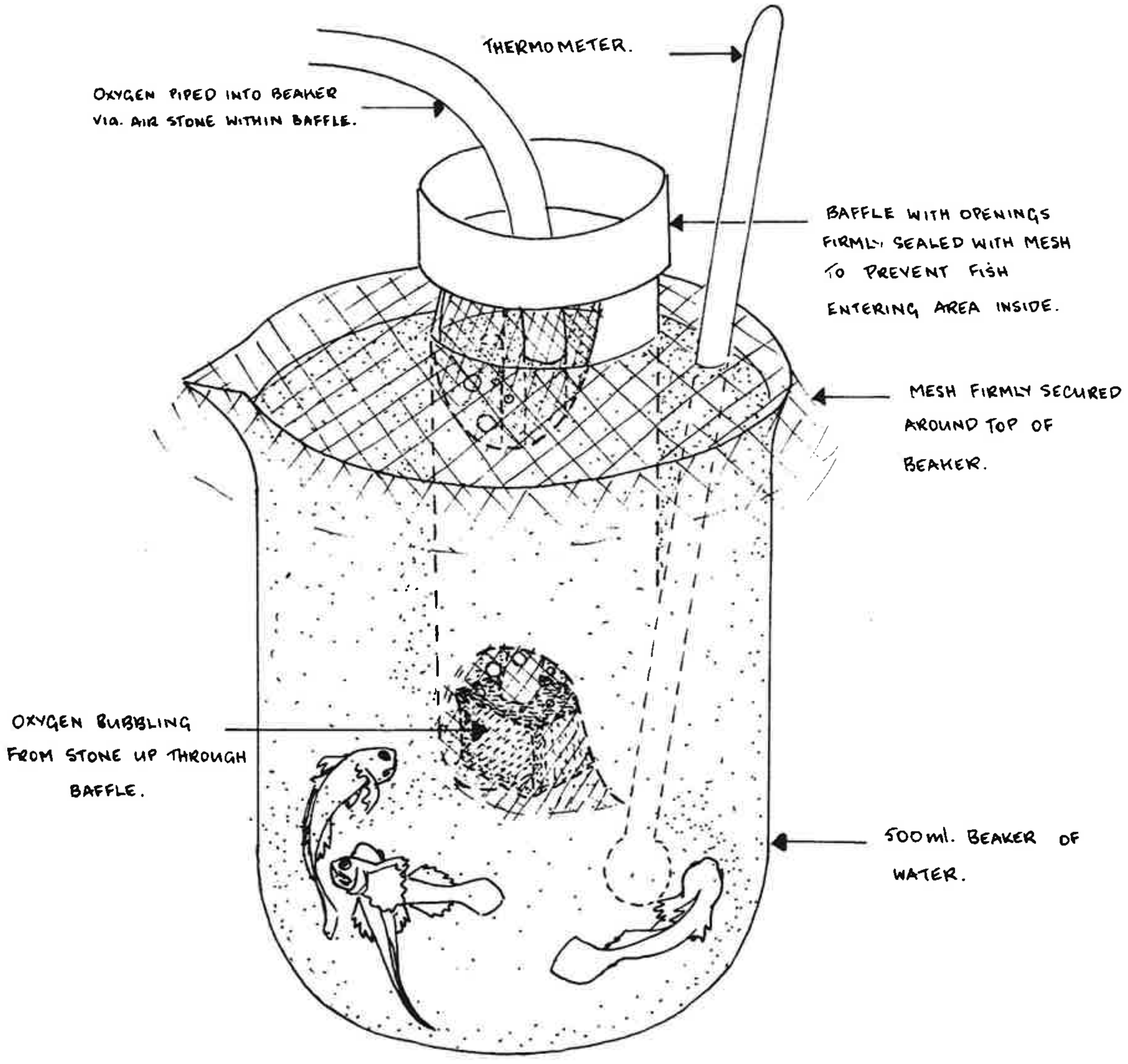

PLASTIC BAFFLE, WITH OPENINGS MESHED, HOOKED INSIDE BEAKER.
THERMOMETER IN BEAKER.
OXYGEN PIPE
BEAKER SUSPENDED BY WIRES INTO DRUM OF WATER
500ml. PLASTIC BEAKER WITH WATER IN AND MESH DRAWN OVER THE TOP.
23 LITRE DRUM OF WATER
OXYGEN CYLINDER.
GAS HEATER PLACED UNDER DRUM.

Figure 16

Equipment employed to measure critical thermal maxima - baffle and airstone arrangement.


THERMOMETER.
OXYGEN PIPED INTO BEAKER VIA. AIR STONE WITHIN BAFFLE.
BAFFLE WITH OPENINGS FIRMLY SEALED WITH MESH TO PREVENT FISH ENTERING AREA INSIDE.
MESH FIRMLY SECURED AROUND TOP OF BEAKER.
OXYGEN BUBBLING FROM STONE UP THROUGH BAFFLE.
500ml. BEAKER OF WATER.

Stn.	Bottom water temp °C.	Subject	c.t.m.	Mean c.t.m.
7	28.9°C	1 2 3 4	40.7°C 41.5°C 41.6°C 41.9°C	41.4°C
12	19.0°C	1 2 3 4	37.1°C 37.4°C 37.5°C 37.8°C	37.4°C

Table 31

Comparison of upper thermal tolerance levels of *C. eremius* sampled from two stations at Wobna Spring (locality 35) on 26.VII.68. Recordings made within an hour of collecting.

Table 32

Comparison of critical thermal maxima (c.t.m.) levels of C. eremius sampled from several stations along the stream at Johnson's No. 3 Bore (locality 24) on 3.IX.68. Recordings made within an hour of collecting.

Table 32

Stn No.	Distance along stream (m)	Bot. water temp. at collecting site	Subject	c.t.m.	Mean c.t.m.
1		39.5°C	1 2 3 4	40.8°C 41.7°C 42.0°C 42.3°C	41.7°C
2	+ 21 metres	35.5°C	1 2 3 4	40.8°C 41.6°C 42.0°C 42.3°C	41.7°C
3	+ 61 metres	21.3°C	1 2 3 4	39.5°C 40.5°C 41.0°C 42.0°C	40.7°C
4	+ 211 metres	17.5°C	1 2 3 4	39.6°C 40.5°C 41.5°C 42.1°C	39.5°C
5	+ 381 metres	17.0°C	1 2 3 4	37.2°C 37.5°C 37.5°C 38.0°C	37.5°C
Range		22.5C°			6.2C°

Table 33

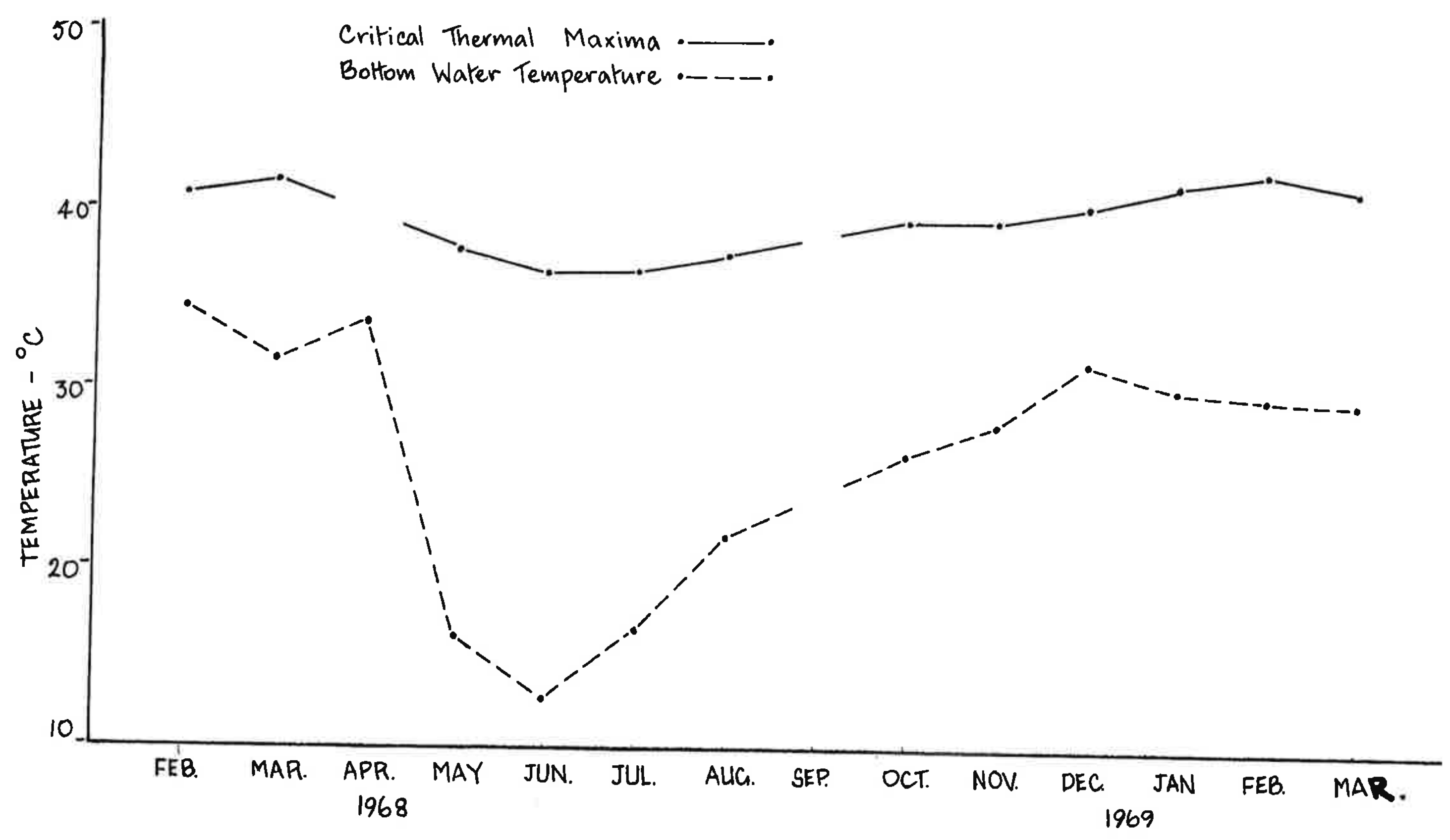
Critical thermal maxima recorded of _C_. _eremius_ sampled from Coward Springs Railway Bore (locality 35) on different occasions between February 1968 and March 1969.

Table 33

Date Recorded	Bottom Water Temp. at Collecting Site.	Subject	c.t.m.	Mean c.t.m.
21.II.68	34.4°C	1 2 3 4	39.6°C 39.6°C 42.0°C 42.0°C	40.8°C
22.III.68	31.5°C	1 2 3 4	41.4°C 41.5°C 41.6°C 41.6°C	41.5°C
26.IV.68	23.7°C		Not Recorded	-
28.V.68	16.0°C	1 2 3 4	36.7°C 37.6°C 37.8°C 38.4°C	37.6°C
30.VI.68	12.8°C	1 2 3 4	35.8°C 35.9°C 36.5°C 36.9°C	36.3°C
26.VII.68	16.5°C	1 2 3 4	35.5°C 36.5°C 37.0°C 37.1°C	36.5°C
31.VIII.68	21.9°C	1 2 3	37.0°C 37.3°C 37.9°C	37.4°C
28.X.68	26.2°C	1 2 3 4	38.5°C 38.5°C 40.0°C 40.0°C	39.2°C
15.XI.68	28.0°C	1 2 3 4	38.0°C 38.5°C 40.0°C 40.0°C	39.2°C
19.XII.68	31.5°C	1 2 3 4	39.5°C 40.0°C 40.5°C 40.5°C	40.1°C
24.I.69	30.0°C	1 2 3 4	41.0°C 41.5°C 41.7°C 42.0°C	41.5°C
24.II.69	29.7°C	1	42.2°C	42.2°C
30.III.69	29.4	1 2 3 4	40.0°C 40.9°C 41.5°C 42.0°C	41.1°C

Graph 18b

Seasonal changes in critical thermal maxima of _C_. _eremius_ and bottom water temperature at Coward Springs Railway Bore, February 1968 - March 1969.


Critical Thermal Maxima
Bottom Water Temperature
TEMPERATURE - °C
50
40
30
20
10
FEB.
MAR.
APR.
MAY
JUN.
JUL.
AUG.
SEP.
OCT.
NOV.
DEC.
JAN
FEB.
MAR.
1968
1969

Time maintained at higher water temperature (hours)	Subject	Standard length (mm)	c.t.m. °C	Mean c.t.m. °C
0	1 2 3 4	29 29 29 36	40.3 40.5 40.5 41.0	40.6
24	1 2 3 4	26 27 29 33	41.5 42.0 42.0 42.0	41.8
48	1 2 3 4	24 26 27 32	40.9 42.0 42.0 42.2	41.7
72	1 2 3 4	28 29 33 34	41.7 42.0 42.0 42.0	41.9

Table 34

Progressive changes in critical thermal maxima of C. eremius directly exposed to and maintained in water (at 31.1°C) ~11C° higher than water kept in for fourteen days previously (19-20°C).

Test conducted 16.III.70.

Time maintained at higher water temperature (hours)	Subject	Standard Length (mm)	c.t.m. °C	Mean c.t.m. °C
0	1	44	41.4	41.6
	2	45	41.4	
	3	46	41.5	
	4	47	42.0	
5	1	40	41.0	41.5
	2	42	41.5	
	3	42	41.5	
	4	49	42.0	
10	1	34	42.5	42.5
	2	47	42.5	
15	1	32	42.2	42.4
	2	41	42.7	
20	1	37	42.5	42.5
	2	41	42.5	

Table 35

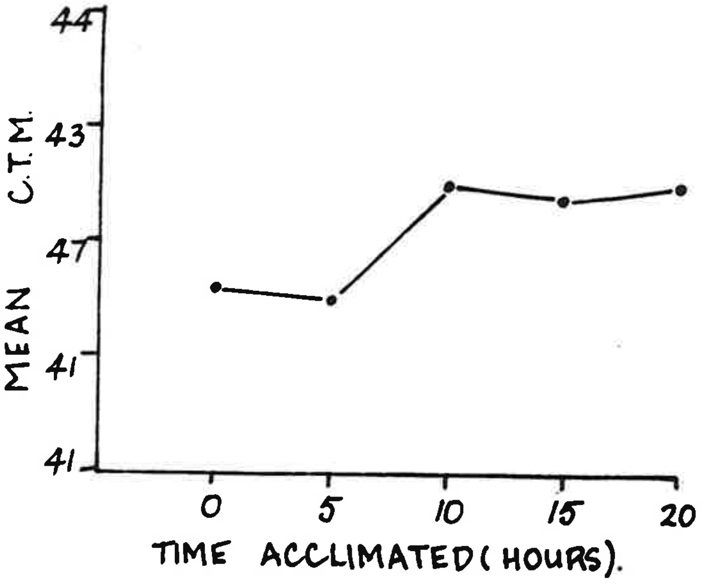
Progressive changes in critical thermal maxima of *C. eremius* directly exposed to and maintained in water (at 33.3°C) ~ 14.0C° higher than water kept in for fourteen days previously (18.0 - 20.0°C). Test conducted 28.IV.70.

Graph 19

Thermal acclimation rate recorded when *C. eremius* was exposed to an ~ 14C° rise in water temperature (from ~ 19°C to 33.3°C).

Graph 20

Thermal acclimation rate recorded when *C. eremius* was exposed to an ~ 11C° rise in water temperature (from ~ 20°C to 31.1°C.


44
43
47
41
41
MEAN C.T.M.
0
5
10
15
20
TIME ACCLIMATED (HOURS).

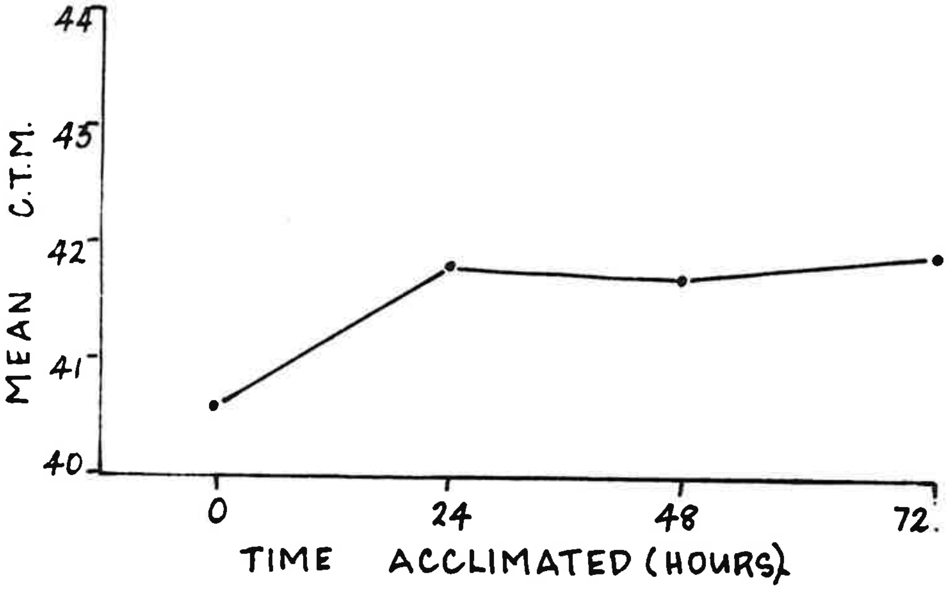

44
45
42
41
40
MEAN C.T.M.
0
24
48
72.
TIME ACCLIMATED (HOURS)

Table 36

Chemical Analyses of water samples taken at various localities principally in the central Australian region. Analyses carried out by Australian Mineral Development Laboratories (see Appendix Q).

* Data from Williams and Siebert (1963).

\+ Uninhabited until _C_. _eremius_ introduced 2.IX.70.

					ANIONS					CATIONS				ASSUMED SALT COMPOSITION												HARDNESS AS CALCIUM CARBONATE							
		Loc. no.	Locality Name	Date Sampled	Cl	SO_4	HCO_3	NO_3	F	Na	K	Ca	Mg	$Ca(CO)_2$	$CaSO_4$	$CaCl_2$	$MgCO_3$	$MgSO_4$	$MgCl_2$	$Na(CO_3)_2$	$NaSO_4$	NaCl	$NaNO_3$	KCl	Total disolved solids	Total	Temporary	Permanent	Due to Ca	Due to Mg	Due to Fe	Total Alkalinity (as $CaCO_3$)	pH
SITES INHABITED BY C. EREMIUS	Artesian water	1/1	Dalhousie Main Spring	6.VIII.68	370	150	140	trace	-	252	-	58	24	186	41	-	-	119	-	-	38	610	-	-	994	245	115	130	145	100	-	115	6.9
		1/3	Dalhousie Spring 3	6.VIII.68	415	180	135	trace	-	280	-	19	55	77	-	-	92	198	-	-	33	684	-	-	1084	270	105	165	45	225	-	105	6.3
		18	Birribirriana Spring	21.XI.69	3350	1770	330	-	-	2515	86	196	188	439	296	-	-	931	-	-	209	5396	-	164	8435	1265	270	995	490	775	-	270	7.5
		24	Johnson's No. 3 Bore	3.IX.68	1600	500	230	-	-	1114	-	162	35	306	292	-	-	173	-	-	230	2640	-	-	3614	550	190	360	405	145	-	190	6.8
		27	Nunn's Bore	(28.XI.69	2625	620	300	-	-	1751	70	211	42	399	381	-	-	208	-	-	274	4224	-	133	5619	700	245	455	525	175	-	245	7.2
				(22.VI.70	2720	600	310	-	-	1815	70	212	37	412	374	-	-	183	-	-	281	4380	-	134	5609	680	255	425	530	150	-	255	6.7
		29	Strangways Springs	(31.X.70	2790	500	445	-	-	1916	31	183	38	591	126	-	-	188	-	-	385	4554	-	59	5903	610	365	245	455	155	-	365	7.1
			Railway Bore	(31.I.71	3320	580	430	-	-	2232	100	200	36	571	200	-	-	178	-	-	439	5319	-	191	6678	650	350	300	500	150	-	350	7.0
		33	Coward Springs proper	3.XI.61	1595	297	836	trace	-	1344	-	64	40	160	-	-	139	-	-	384	440	2630	trace	-	3751	324	324	-	162	162	-	-	-
		34	Coward Springs Railway	(26.IV.68	1310	140	1005	trace	-	1200	-	34	30	138	-	-	181	-	-	1033	207	2160	-	-	3719	210	210	-	85	125	-	825	7.0
			Bore	(April 1969	1305	130	975	30	-	1192	-	33	29	134	-	-	175	-	-	1002	192	2151	40	-	3199	200	200	-	80	120	-	800	-
		35	Wobna Spring	(27.IV.68	1280	135	1045	trace	-	1192	-	36	29	146	-	-	175	-	-	1086	200	2110	-	-	3717	210	210	-	90	120	-	855	7.0
				(31.X.70	1255	115	970	-	-	1126	33	32	28	129	-	-	169	-	-	1008	170	2020	-	63	3044	195	195	-	80	115	-	795	7.3
		44	Clayton Bore	23.XI.70	150	<5	940	-	-	436	12	5.9	0.6	24	-	-	4	-	-	1265	-	229	-	23	1549	17	17	-	15	2	-	770	6.9
	Meteoric water	7	Forrest's Waterhole	20.XI.69	40	35	65	trace	-	38	9	13	5	53	-	-	30	-	-	-	52	53	trace	17	205	50	50	-	30	20	-	50	7.2
		12	Algebuckina Waterhole	31.VII.68	750	435	265	trace	-	643	-	21	67	85	-	-	241	134	-	-	485	1236	-	-	2181	325	215	110	50	275	-	215	7.0
		14	Peake Creek	30.VII.68	3560	415	75	trace	-	1847	-	101	302	99	262	-	-	288	956	-	-	4695	-	-	6300	1495	60	1435	250	1245	-	60	6.8
		31	Beresford Reservoir	31.I.71	80	70	130	-	-	98	9	21	4	85	-	-	24	-	-	63	104	119	-	17	347	65	65	-	50	15	-	105	6.9
		68*	Glen Helen Waterhole	28.IX.62	1114	542	119	3	-	700	25	187	72	-	-	-	-	-	-	-	-	-	-	-	2784	-	-	-	-	-	-	-	6.9
		75	Finke River, Hermannsburg H.S.	12.III.70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12500	-	-	-	-	-	-	-	8.8
SITES NOT INHABITED BY C. EREMIUS	Artesian water	23	Honeymoon Bore	1.II.71	2405	640	235	-	-	1583	60	215	47	312	468	-	-	233	-	-	183	3874	-	115	5064	730	190	540	535	195	-	190	6.9
		30	Strangways Springs mound spring	28.XI.69	2980	585	450	40	-	2009	80	219	48	598	241	-	-	238	-	-	333	473	55	153	6411	740	370	370	545	195	-	370	7.0
		32	Warburton Springs	(1959	1687	300	369	trace	-	1346	-	77	46	193	-	-	159	-	-	247	444	2781	trace	-	3825	381	381	-	193	188	-	-	6.8
				(1.II.71	1755	320	565	-	-	1433	45	9	19	36	-	-	114	-	-	610	473	2827	-	86	3861	100	100	-	20	80	-	465	7.5
		36+	Blanche Cup Spring	(2.XI.61	2110	346	403	trace	-	1726	-	16	53	39	-	-	183	-	-	441	511	3479	-	-	4654	256	256	-	39	217	-	-	7.0
				(1.II.71	2310	375	920	trace	-	1849	45	48	49	194	-	-	295	-	-	727	555	3739	-	86	5131	320	320	-	120	200	-	755	8.1
		43	Lake Harry Bore	23.XI.70	265	<5	1040	-	-	553	5	5.7	0.8	23	-	-	5	-	-	1403	-	429	-	10	1874	18	18	-	15	3	-	855	7.6
		45	Dalkaninna Bore	23.XI.70	110	<5	880	-	-	383	19	5.7	0.7	23	-	-	5	-	-	1182	-	153	-	36	1403	18	18	-	15	3	-	720	8.9
		46	Cannawaukininna Bore	23.XI.70	330	5	775	-	-	473	18	16.2	3.4	65	-	-	20	-	-	977	7	517	-	34	1621	52	52	-	40	12	-	635	7.4
		48	Kopperamanna No. 1 Bore	23.XI.70	130	<5	760	-	-	352	18	6.3	0.9	25	-	-	6	-	-	1014	-	188	-	34	1272	19	19	-	15	4	-	625	9.0
		50	Mirra Mitta Bore	23.XI.70	75	25	675	-	-	294	17	9.4	0.3	38	-	-	2	-	-	887	37	99	-	32	1096	24	24	-	23	1	-	555	8.1
		51	Gason Bore	23.XI.70	70	20	675	-	-	301	12	1.7	0.2	7	-	-	1	-	-	922	30	97	-	23	1080	6	6	-	5	1	-	555	8.1
		54	Paralana Hot Springs	30.X.69	665	145	675	-	-	606	-	70	36	283	-	-	217	-	-	387	214	1096	-	-	2197	325	325	-	175	150	-	555	7.1
		60	Montecolina Bore	29.X.69	3765	125	125	-	-	2387	-	103	23	166	177	28	-	-	90	-	-	6067	-	-	6528	350	100	250	255	95	-	100	7.6
		62	Mulligan Springs	24.X.69	4270	535	510	-	-	2997	-	49	87	198	-	-	433	74	-	-	703	7040	-	-	8448	480	420	60	120	360	-	420	8.9
		63	Twelve Springs	24.X.69	820	175	1095	-	-	1006	-	10	6	41	-	-	36	-	-	1424	259	1352	-	-	3112	50	50	-	25	25	-	900	8.9
		64	Woolatchi Bore	29.X.69	530	15	805	-	-	643	-	10	-	41	-	-	-	-	-	1066	22	874	-	-	2003	25	25	-	25	25	-	660	8.1
	Meteoric water	9	Cramps Camp Waterhole	2.V.69	545	165	160	30	-	333	33	81	31	213	95	-	-	123	24	-	-	819	41	63	1378	325	130	195	200	125	-	130	7.8
		22	Mussel Waterhole	June, 1969	3360	625	35	-	-	1693	-	390	187	47	887	321	-	-	732	-	-	4303	-	-	6290	1745	30	1715	975	770	-	30	-
		42	Callana Reservoir	1.II.71	25	25	75	-	-	45	4	7	1	28	-	-	6	-	-	68	37	35	-	8	142	25	25	-	20	5	-	60	7.6
		55	Balcanoona Creek	30.X.69	210	190	385	-	-	155	-	45	87	182	-	-	297	188	-	-	59	346	-	-	1072	470	315	155	110	360	-	315	7.9
		72	Broughton River	26.XI.70	1350	230	595	-	-	780	20	98	162	396	-	-	356	288	176	-	-	1981	-	38	3235	910	490	420	245	665	-	490	7.0
		73	Light River	26.XI.70	2445	475	445	-	-	1448	39	114	201	461	-	-	118	595	239	-	-	3680	-	74	5167	1110	365	745	285	825	-	365	7.0
		76	Kroehns Landing, Murray River	12.VI.68	265	35	90	-	-	159	-	17	24	69	-	-	46	44	27	-	-	404	-	-	590	140	75	65	40	100	-	75	6.4

Table 37

Range of content of major ions and total salinities of permanent waters known to be inhabited by _C. eremius_ (14 sites) compared with those of some permanent non-inhabited waters (15 sites), all in the central Australian region. Quantities expressed as parts per million and summarized from Table 36.

		Inhabited waters	Non-inhabited waters
Ion	Cl	80 - 3350	25 - 4270
	SO_4	25 - 1770	<5 - 640
	HCO_3	119 - 1045	75 - 1095
	NO_3	0 - 3	0 - 40
	F	0	0
	Na	98 -2515	45 - 2997
	K	0 - 100	0 - 80
	Ca	59 - 211	1.7 - 219
	Mg	0.6 - 188	0 - 201
	Fe	0	0
Total dissolved solids (salinity)		347 - 8435	142 - 8448

Table **38**

Content of major ions and total salinity of water sampled at different stations along the stream flowing from Coward Springs Railway Bore (locality 34) on 26.IV.68. Quantities expressed as parts per million.

Station	Distance from bore head (metres)	Salinity	Anions				Cations			
			Cl	SO_4	HCO_3	NO_3	Na	K	Ca	Mg
1	0	3719	1310	140	1005	trace	1200	-	34	30
2	37	3859	1370	150	1025	trace	1249	-	34	31
6	287	4020	1450	165	1030	nil	1325	-	17	33
8	453	4765	1720	215	1195	nil	1586	-	13	36

Table 39

Content of major ions and total salinity of water sampled at two stations along the stream flowing from Wobna Mound Spring (locality 35) on 27.IV.68. Quantities expressed as parts per million.

Station	Distance from bore head (metres)	Salinity	Anions				Cations			
			Cl	SO_4	HCO_3	NO_3	Na	K	Ca	Mg
1	0	3717	1280	135	1045	trace	1192	-	36	29
7	126	3923	1380	140	1070	nil	1275	-	26	32

TABLE 40

Comparison of major ions and total salinities from samples taken on different occasions from certain artesian waters in the central Australian region.

* Data after Jack (1923)

Loc. No.	Locality	Date Sampled	Sampling time gap (years)	Ion content (ppm)								Total dissolved salts (ppm)
				Cl$^-$	SO$_4^-$	CO$_3^-$	NO$_3^-$	Na$^+$	K$^+$	Ca$^+$	Mg$^+$	
1/1	Dalhousie Spring main spring (probably = Jack's "Dalhousie Hot Spring"	*1913 6.VIII.68	55	340 370	100 150	103 69	- trace	- 252	- -	- 58	- 24	891 994
26	Nunn's Bore	*24.XI.64 22.VI.70	5½	2614 2720	608 600	156 152	nil nil	1797 1815	- 70	208 212	40 37	5423 5609
29	Strangways Springs Railway Bore	8.III.15 31.X.70 31.I.70	54 54¼ ¼	2744 2790 3320	500 500 580	216 445 450	- - -	- 1916 2232	- 31 100	- 183 200	- 38 36	5624 5903 6678
33	Coward Springs proper	*1891 3.XI.61	70	1392 1595	199 297	445 202.1	- trace	- 1344	- -	- 64	- 40	3417 3751
34	Coward Springs Railway Bore	26.IV.68 April 1969	1	1310 1305	140 130	494 494	trace 30	1200 1192	- -	34 33	30 29	3719 3199
35	Wobna Spring	27.IV.68 31.X.70	2½	1280 1255	135 115	514 477	trace nil	1192 1126	- 33	36 32	29 28	3717 3044
36	Blanche Cup Spring	*1891 2.XI.61 1.II.71	70 79 9	1894 2110 2310	149 346 375	417 198 452	- trace trace	- 1726 1849	- - 45	- 16 48	- 53 49	4034 4654 5131
43	Lake Harry Bore	*1896 23.XI.70	74	259 265	nil > 5	505 511	- -	- 553	- 5	- 6	- 1	1315 1874
44	Clayton Bore	30.IV.22 23.XI.70	47	154 150	5 > 5	456 462	- -	- 436	- 12	- 6	- 1	1087 1549
45	Dalkaninna Bore	*1898 23.XI.70	72	117 110	nil >5	428 433	- -	- 383	- 19	- 6	- 1	942 1403
46	Cannawaukininna Bore	*5.X.16 23.XI.70	53	252 330	2 5	406 381	- -	- 473	- 18	- 16	- 3	1226 1621
48	Kopperemanna No. 1 Bore	*1898 23.XI.70	72	143 130	nil >5	314 374	- -	- 352	- 18	- 6	- 1	786 1272
54	Paralana Hot Springs	*1913 30.X.69	56	321 665	151 145	148 675	- -	- 606	- -	- 70	- 36	1110 2197
60	Montecolina Bore	*11.IX.20 29.X.69	48	2237 3765	48 125	144 61	- -	- 2387	- -	- 103	- 23	4005 6528
64	Woolatchi Bore	*12.VII.16 24.X.69	52	? 530	nil 15	800 396	- -	- 643	- -	- 10	- -	2017 2003

Station	Water depth cm.	pH	
		Surface water	Bottom water
1	22	7.0	7.0
2	12	7.2	7.2
3	21	7.2	7.2
4	22	7.0	7.0
5	17	7.0	7.0
6	30	7.8	7.8
7	19	9.4	9.4
8	9	10.0	10.0

Table 41

Surface & bottom-water pH values recorded at Coward Springs Bore (locality 34) on 30.VI.68.

Loc. No.	Locality	Ion content (ppm.)			Cl^- >or< than SO_4^- and CO_3^-	SO_4^- >or< than CO_3^-
		Cl^-	SO_4^-	$*CO_3^-$		
1/1	Dalhousie Springs, main spring.	370	150	68.8	$>SO_4$; $>CO_3$	$>CO_3$
1/3	Dalhousie Springs, spring 3	415	180	66.4	$>SO_4$; $>CO_3$	$>CO_3$
12	Algebuckina waterhole	750	435	130.3	$>SO_4$; $>CO_3$	$>CO_3$
18	Birribirriana Spring	3350	1770	162.3	$>SO_4$; $>CO_3$	$>CO_3$
24	Johnson's No. 3 Bore	1600	500	113.1	$>SO_4$; $>CO_3$	$>CO_3$
27	Nunn's Bore	2625	620	147.5	$>SO_4$; $>CO_3$	$>CO_3$
29	Strangways Springs Railway Bore	2790	500	218.8	$>SO_4$; $>CO_3$	$>CO_3$
31	Beresford Reservoir	80	70	63.9	$>SO_4$; $>CO_3$	$>CO_3$
33	Coward Springs proper	1595	297	202.1	$>SO_4$; $>CO_3$	$>CO_3$
34	Coward Springs Railway Bore	1310	140	494.3	$>SO_4$; $>CO_3$	$<CO_3$
35	Wobna Spring	1280	135	513.9	$>SO_4$; $>CO_3$	$<CO_3$
36	Blanche Cup Spring	2310	375	452.5	$>SO_4$; $>CO_3$	$<CO_3$
44	Clayton Bore	150	5	462.3	$>SO_4$; $<CO_3$	$<CO_3$
68	Glen Helen waterhole	1114	542	58.5	$>SO_4$; $>CO_3$	$>CO_3$

TABLE 42

Cl^-, SO_4^- and CO_3^- ion contents of permanent water masses inhabited by *C. eremius*.

* CO_3^- content values derived from HCO_3^- values given in Table 36 by the conversion $CO_3^- = 0.4918 \times HCO_3^-$

Loc. No.	Locality	Ion content (ppm.)			Cl^- > or < than SO_4^- and CO_3^-		SO_4^- > or < than CO_3^-
		Cl^-	SO_4^-	$^*CO_3^-$			
23	Honeymoon Bore	2405	640	115.6	$>SO_4$;	$>CO_3$	$>CO_3$
30	Strangways Springs Mound Spring	2980	585	221.3	$>SO_4$;	$>CO_3$	$>CO_3$
32	Warburton Springs	1687	300	181.5	$>SO_4$;	$>CO_3$	$>CO_3$
42	Callana Reservoir	25	25	36.8	$=SO_4$;	$<CO_3$	$<CO_3$
43	Lake Harry Bore	265	<5	511.5	$>SO_4$;	$<CO_3$	$<CO_3$
45	Dalkaninna Bore	110	<5	432.8	$>SO_4$;	$<CO_3$	$<CO_3$
46	Cannwaukininna Bore	330	5	381.1	$>SO_4$;	$<CO_3$	$<CO_3$
48	Kopperamanna No.1 Bore	130	<5	373.7	$>SO_4$;	$<CO_3$	$<CO_3$
50	Mirra Mitta Bore	75	25	331.9	$>SO_4$;	$<CO_3$	$<CO_3$
51	Gason Bore	70	20	331.9	$>SO_4$;	$<CO_3$	$<CO_3$
54	Paralana Hot Springs	665	145	331.9	$>SO_4$;	$>CO_3$	$<CO_3$
60	Montecolina Bore	3765	125	61.5	$>SO_4$;	$>CO_3$	$>CO_3$
62	Mulligan Springs	4270	535	250.8	$>SO_4$;	$>CO_3$	$>CO_3$
63	Twelve Springs	820	175	538.5	$>SO_4$;	$>CO_3$	$>CO_3$
64	Woolatchi Bore	530	15	395.9	$>SO_4$;	$>CO_3$	$>CO_3$

TABLE 43

Cl^-, SO_4^- and CO_3^- ion contents of permanent water masses not inhabited by *C. eremius*.

* CO_3^- content values derived from HCO_3^- values given in Table 36 by the conversion $CO_3^- = 0.4918 \times HCO_3^-$

Figure 17

Jack's (1923) 'neutral' line, Lake Eyre basin (after Williams, 1967).

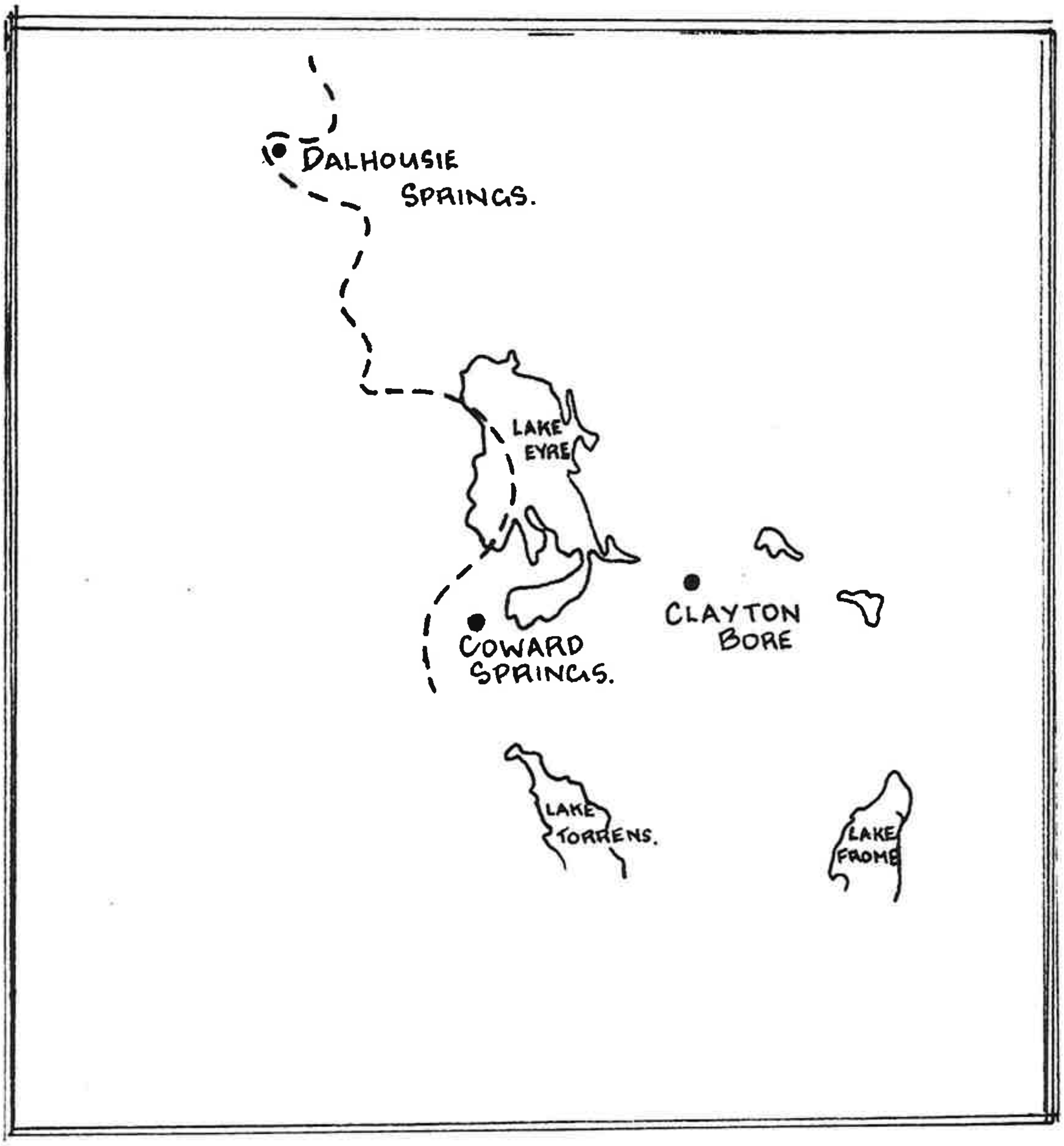

DALHOUSIE SPRINGS.
LAKE EYRE
CLAYTON BORE
COWARD SPRINGS.
LAKE TORRENS.
LAKE FROME

Table 44

Total salinities (expressed as parts per million) of some permanent waters in the central Australian region, both inhabited and un-inhabited by *C. eremius*.

Inhabited Waters		
Loc. No.	Locality	Salinity
1/1	Dalhousie Main Spring	994
1/3	Dalhousie Spring 3	1084
12	Algebuckina Waterhole	2181
18	Birribirriana Spring	8435
24	Johnson's No. 3 Bore	3614
27	Nunn's Bore	5619
29	Strangways Springs Railway Bore	6678
31	Beresford Reservoir	347
33	Coward Springs Proper Bore	3751
34	Coward Springs Railway Bore	3719
35	Wobna Spring	3717
36	Blanche Cup Spring	5131
44	Clayton Bore	1549
69	Glen Helen Waterhole	2784
Range		347-8435
Mean		3543

Non-inhabited Waters		
Loc. No.	Locality	Salinity
23	Honeymoon Bore	5064
30	Strangways Spring Mound Spring	6411
32	Warburton Springs	3825
42	Callana Reservoir	142
43	Lake Harry Bore	1874
45	Dalkaninna Bore	1403
46	Cannawaukinna Bore	1621
48	Kopperamanna No. 1 Bore	1272
50	Mirra Mitta Bore	1096
51	Gason Bore	1080
54	Paralana Hot Springs	2197
60	Montecolina Bore	6528
62	Mulligan Springs	8448
63	Twelve Springs	3112
64	Woolatchi Bore	2003
Range		142-8448
Mean		3071

Table

Table 45

Summarized results of salinity tolerance trials upon _C_. _eremius_. (from Appendix **S**).

Medium	Salinity (Total dissolved salts in ppm)	No. of trials conducted	Duration of trial (days)	Period elapsed to first mortality (days)	Period elapsed to 50% mortality (days)	Period elapsed to 100% mortality (days)	Remarks
Distilled Water	>1.25 <8.3	5	13-60	1-12	9-22	17-27	
Diluted 1:19 Artesian Water	147	1	60	-	-	-	No mortalities recorded up till time trial discontinued
Control Artesian Water	5,609	6	13-60	6-46	-	-	Total of 11 mortalities recorded in 6 trials.
Saturated Artesian Water	9,797	5	13-60	5	-	-	1 mortality recorded throughout all 5 trials.
Sea Water	37,580	1	60	1	44	-	8 mortalities recorded up till time trial discontinued.

Table 46

Dissolved O_2 concentrations of water samples taken at several stations along the stream at Wobna Spring (locality 35) together with other simultaneously recorded data, made 22.II.70.

Table 47

Dissolved O_2 concentration and water temperature recorded in shallows at Nunn's Bore (locality 27) on 22.II.70.

TABLE 46

Ambient temp. = 31.0°C Readings commenced 1615 hrs.

Stn.	Bott. water temp. °C	2.5 cm. sub-bed temp °C	Diff. sub-bed bottom temp °C	pH	Water depth (cm)	Stream width (cm)	Relative abundance of veg.		Trapping rate	Dissolved O_2 concentration p.p.m.
							Cyperus sp.	*Spirogyra* sp.		
1	30.9	30.9	0	7.0	3	900	1	1	0 (but *C. eremius* present)	3.0
2	30.5	30.9	+0.4	7.2	5	117	1	2	0	-
3	30.4	-		7.2	6	90	3	1	-	-
4	30.1	30.3	+0.2	7.2	5	75	1	1	13	
5	30.2	30.4	+0.2	7.3	6	160	0	4	10	3.0
mid-way between 5 & 6	31.0	-	-	-	-	-	0	4	-	2.0
6	30.1	30.4	+0.3	7.4	6	180	0	4	20	3.0
7	30.0	30.1	+0.1	7.5	6	90	0	2	19	3.0
8	29.5	30.0	+0.5	7.7	8	43	0	1	3	-
9	29.5	30.0	+0.5	7.7	9	50	1	3	6	-
10	29.2	30.0	+0.8	7.8	6	100	½	3	14	-
11	29.0	29.1	+0.1	7.9	6	73	1	2	4	4.0

TABLE 47

Sampling Station	Water temp. °C	Dissolved O_2 concentration p.p.m.	Comment
In shallows (2-3 cms) depth amongst vegetation	35.8°C	0.8	*C. eremius* present

VII THE ENVIRONMENT - NON-PHYSICAL PARAMETERS

CONTENTS

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1. FOOD

To establish what C. eremius eats and the relative importance of the different components of diet I examined and scored the contents of the alimentary canals of 100 fish (40-50mm standard length) selected from a collection made at Nunn's Bore (locality 27) on 31.V.71 (see Table 48). These fish were killed and preserved immediately upon being retrieved from traps (set for 15 hours overnight) by placing them in 5% formalin in order to halt digestion.

It is clear from Table 48 that, at the adult stage at least, C. eremius is omnivorous. Insects, ostracods and unidentified eggs constituted the main animal diet (at the time of collecting); filamentous algae the main vegetable diet.

As Haines (1968) reports for Ellogobius olorum (Sauvage, 1880), filamentous algae were found in the majority of the C. eremius and direct laboratory observation showed that it was deliberately eaten.

The presence of detritus and small rock particles in many instances correlates with the fish's demeral habit and the laboratory observation that it sifts bottom silt, taking silt into the mouth and ejecting it, presumably in search of detritus. With regard to the fish scales located amongst the gut contents, laboratory observations have shown that C. eremius is necrophagic.

Diatoms have also been found in the alimentary canals of fish collected from Johnson's No. 3 Bore (locality 24); at least 16 diatom species (see Table 49), mainly benthic or periphytic forms, were identified amongst the gut contents of a C. eremius collection made in March 1969.

In the laboratory C. eremius readily feeds upon Tubifex sp.

2. AQUATIC VEGETATION

(a) Influence on the geographic distribution of C. eremius.

Although small numbers of C. eremius have been encountered at some sites devoid of aquatic vegetation these have always been ephemeral waters and therefore do not represent permanent habitats.

A characteristic plant community is associated with all artesian waters in the Lake Eyre basin. This usually consists of one or more species of filamentous green algae and the spear grass, Cyperus laevigatus L. In addition one or more species of the following may also be present - bull rush, Typha sp.; reed, Scirpus sp.; Potamogeton pectinatus L. and Chara sp. Table 50 indicates the aquatic plants located at some localities where C. eremius is either present or absent. It will be noted that the plant communities of both inhabited and non-inhabited waters usually possess both filamentous green algae and spear grass, Cyperus laevigatus L.. Further, there are no plant species which are consistantly found in inhabited waters and not in non-inhabited waters, or vice versa. Thus within the known range of C. eremius it appears there is little difference in aquatic plant communities to influence the presence or absence of the species at particular permanent habitats.

(b) Influence on the occurrence and abundance of C. eremius within the habitat.

i. As Protective Cover.

Within the individual habitat C. eremius is most frequently found amongst or in close proximity to aquatic vegetation. The marked preference of the species for algae as a habitat rather than open water has been demonstrated in the laboratory (see p. 129). Individuals disturbed in open water, either in the field or the laboratory, swiftly seek cover amongst the nearest available vegetation. It is thus apparent that vegetation is at least important in that it affords protective cover.

It has become apparent from field observations and trapping rates that the distribution and local concentrations of C. eremius within the individual waterway tends to correlate with the occurrence and local abundance of vegetation, in particular algae, along the waterway. I attempted to correlate the species abundance with vegetation during the observations at Wobna Spring (locality 35). Since it was difficult to objectively measure the extent of plant stands with any degree of accuracy I decided to subjectively score the relative abundance of algae and spear grass at the various stations. Taking an arbitary scale of 0 to 5 I scored the approximate area each form of plant covered within an overall area of approximately 0.5 square metre within the stream at each station. These estimates together with associated trapping rates are presented in Appendix F. Graphs 21 to 26 are of the more obvious correlations derived from these observations. From these graphs it can be seen that greater numbers of *C. eremius* tend to occur where there is relatively more plant cover, particularly of algae.

ii. As a Thermal Refuge

In addition to providing protective cover there is considerable evidence (see pp. 54 - 62) to show that aquatic vegetation provides a thermal refuge during summer months. Steep thermal gradients in water temperature have been recorded between lethally warm open water and cool shallows within and at the base of stands of aquatic vegetation at Johnsons No. 3 bore (locality 24). As discussed on p. 55 when such steep thermal gradients exist the species appears to concentrate amongst the vegetated shallows and except for occasional brief excursions out into open water to remain within the confines of the stands.

iii. As a Platform to perform Aerial Respiration

When specimens were crowded in warm water in a container (see p. 143), and therefore under conditions of oxygen depletion, individuals were observed to leap out of the water and attach, usually via the section disc formed by the ventral fins, to the walls of the container or to the surfaces of plant leaves (Phragmites communis) suspended into the water. Whilst attached these fish were observed to vigorously perform aerial respiration until they dropped back into the water after a short time of up to 115 seconds.

Reference has been made elsewhere (see p. 145) to the fact that in laboratory tanks, during warm weather, C. eremius has been observed to withdraw at least the forepart of the body from the water and rest it on the emerged root base of plant stands (Cyperus laevigatus L.) and perform, what appears to be, aerial respiration.

Thus aquatic plants are capable of acting as out-of-water attachment surfaces upon which the fish can perform aerial respiration. However this has not been observed to occur in field observations.

iv. As a Food and Habitat for Animal Prey

From gut examinations and laboratory observations of feeding activity it is evident that filamentous green algae are deliberately eaten and constitute a substantial part of the fish's diet (see p. 92).

In addition, an examination of a sample of live algae (Spirogyra sp.) from Wobna Spring (locality 35) showed that it harboured a variety of small fauna in abundance. Table 51 lists the forms found in this examination and their relative abundance. Ostracods at least have been confirmed amongst the fish's gut contents and it is probable that the soft bodied oligochaetes are also ingested, if only incidentally.

Thus not only does algae appear to constitute a major food item in itself but it also harbours a variety of fauna which is either confirmed as a dietary item or is potentially capable of being eaten by the species.

3. OTHER FISHES IN ASSOCIATION WITH *C. eremius*.

Table 52 lists some of the localities where permanent populations of *C. eremius* have been found and indicates these other fish species, if any, which have been found at the same time in the same habitats.

It is seen that the species most commonly associated with *C. eremius* are those of the genus *Craterocephalus*. Since this genus is typically pelagic in habit whereas *C. eremius* is demersal it would seem that the latter would be subject to little, if any, direct competition from the Craterocephalids. On the other hand whether a clear distinction can exist between demersal and pelagic niches in the relative shallows of artesian surface waters is open to question.

As indicated in Appendix A it is seen that except at Mulligan Springs (locality 62) and possibly several of the springs at Dalhousie Springs (localities 1/2, 1/3, 1/7) no other *artesian* habitat has apparently been located in the central Australian region that is inhabited by any other species to the exclusion of *C. eremius*. Even at Dalhousie Springs main spring (locality 1/1), where *Neosilurus* sp. (a demersal inhabitant) and *C. stercusmuscarum* are both present in overwhelmingly greater abundance, *C. eremius* has been able to maintain a small population. It is possible that the species does in fact inhabit, in small numbers, the other springs at Dalhousie Springs (localities 1/2, 1/3, 1/7) from which it was not collected.

4. PREDATION

The main predatory force acting upoon *C. eremius* appears most likely to be from aquatic birds. Table 53 lists the various species of birds sighted on one occasion at Coward Springs railway bore (locality 34) and indicates which of these are confirmed or potential fish predators. This list demonstrates the abundant variety of predatory bird life that characteristically inhabits the vicinity of permanent waters in the central Australian region for a considerable period each year. Of a total of 17 aquatic or semi-aquatic bird species at least 9 are either confirmed or potential fish eaters. *Porzana fluminea* has actually been observed feeding on *C. eremius* at Johnson's No. 3 bore (locality 24) on 2.IX.70, a lone *P. fluminea* foraging in shallows at the base of reed stands was seen to eat a dead fish lying in shallow water.

Other fishes are possibly predacious on *C. eremius*. I have found *Craterocephalus stercusmuscarum* in the stomachs of *Mogurnda mogurnda*, *Madigania unicolor* and *Neosilurus* sp. collected at Dalhousie Springs (localities 1/1, 1/3, 1/4). However at no locality where *C. eremius* has been found in conjunction with any other fish have I found any identifiable remains of *C. eremius* in the stomachs of the other species. *Neosilurus* sp. because of its similar demersal habitat possibly preys on *C. eremius* where the two species occur together, e.g. at Dalhousie Springs main spring (locality 1/1) the uncharacteristically small *C. eremius* population may be due, in part, to a direct predatory and competitive influence from the overwhelmingly abundant Neosilurus sp. population.

Field and laboratory observations have shown that C. eremius is necrophagic upon its own species but it does not appear to be actually cannibalistic.

The larger aquatic insects and insect larvae may be predators, in particular the larger beetles (Families Hydrophilidae and Dytiscidae) and dragon fly nymphs (Order Odonata), which are at least partially demersal in habit and occur in abundance at many localities inhabited by C. eremius, for example, Johnson's No. 3 Bore (locality 24), Nunn's Bore (locality 27) and Coward Springs railway Bore (locality 34).

Item	No. of alimentary canals in which identified
nothing	0
filamentous algae	64
plant fragments	56
diatoms	15
Insecta (chitinous fragments)	54
eggs (unidentified)	12
Cladocera (daphnid)	4
Copepoda	6
Ostracoda	12
fish scales	6
*detritus	92
rock particles	38

TABLE 48

Contents of alimentary canals of 100 C. eremius (40 - 50 mm. standard length) collected at Nunn's Bore (locality 27) on 31.V.71.

* detritus = pulped, brown coloured mass.

Diatom Species

- *Navicula rhyncocephala* Kütz. var.?
- *Anomoeoneis sphaerophora* (Ehr.) Pfitz. var.?
- *Nitzschia fonticola* Grun.
- *Gomphonema parvulum* var. *micropus* Kütz. Cleve
- *Navicula aikenensis* Patr. var.?
- *Fragilaria construens* (Ehr.) Grun.
- *Nitzschia hungarica* Grun. var.?
- *Mastogloia smithii* Thwaites ex W. Sm.
- *Gymbella pusilla* Grun.
- *Nitzschia amphibia* Grun.
- *Cyclotella meneghiniana* Kütz.
- *Stauroneis anceps* Ehr. var.?
- *Navicula cryptocephala* Kütz.
- *Diploneis smithii* (Breb.) Cleve
- *Navicula* spp.
- *Cymbella* spp.

Table 49

Diatom species identified in the alimentary canals of a collection of *C. eremius* made at Johnson's No. 3 Bore (locality 24) on 31.III.69.

TABLE 50

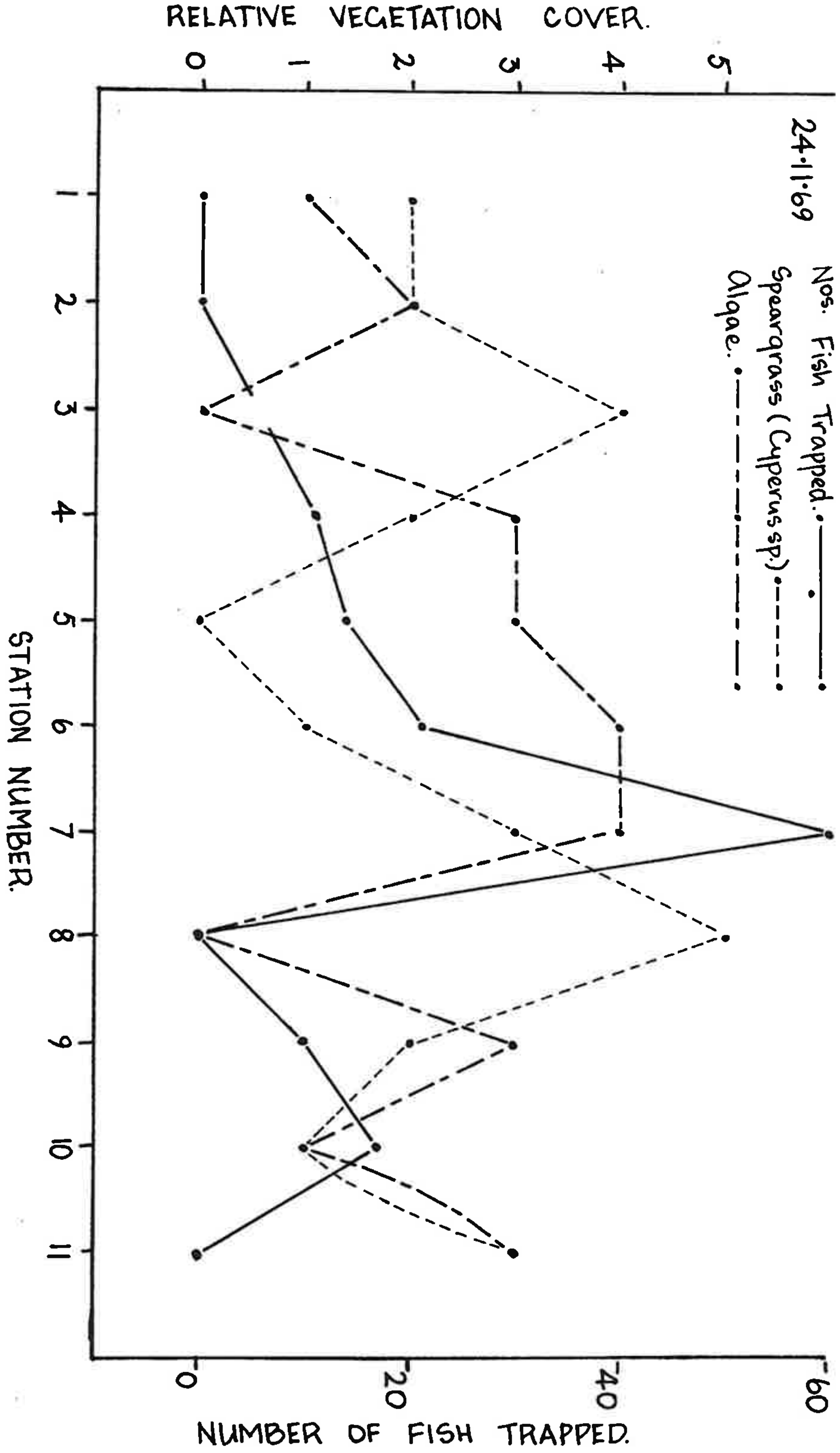
Aquatic vegetation found present at various localities in the central Australian region.

Table 50

	Localities														
	C. eremius present									*C. eremius* absent					
Type of vegation	1/1	19	24	27	33	34	35	75	36	30	32	54	55	63	64
Algae (filamentous green)	?	*	*	*	*	*	*	*	*	*	*	*		*	*
Chara sp.			*	*											*
Cyperus bulbosus VAHL												*?	*?		
Cyperus distachys							*								
Cyperus gymnocaulos STEUD.	*	*	*										*		
Cyperus laevigatus L.	*	*	*	*	*	*	*		*	*	*		*	*	*
Phragmites australis (CAV). TRIN. ex STEUD	*														
Phragmites communis						*									
Polypogon monspeliensis (L.) DEDF.													*		
Potamogeton pectinatus L.						*	*?								
Ruppia spiralis L.			*												
Scirpus litoralis SCHRAD.													*		
Scirpus validus VAHL				*						*	*				
Typha sp.			*									*			
Typha angustifolia L.						*									
Typha domingensis L.						*									

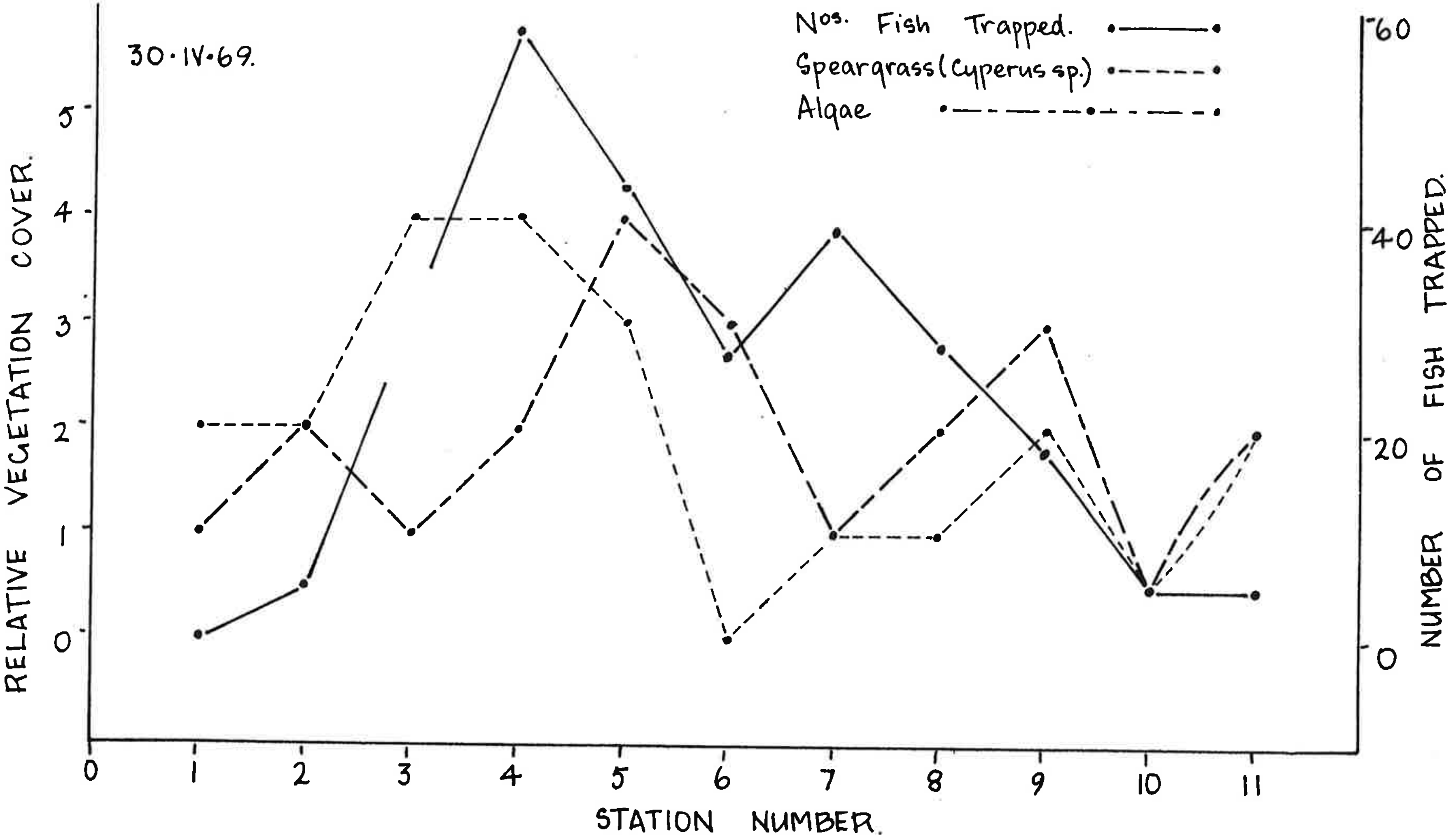
Graph 21

Correlation between number of *C. eremius* trapped and aquatic vegetation cover at the various stations in the main stream at Wobna Spring (locality 35) as recorded on 24.II.69.


24.11.69
Nos. Fish Trapped.
Speargrass (Cyperus sp.)
Algae.
RELATIVE VEGETATION COVER.
0
1
2
3
4
5
STATION NUMBER.
1
2
3
4
5
6
7
8
9
10
11
NUMBER OF FISH TRAPPED.
0
20
40
60

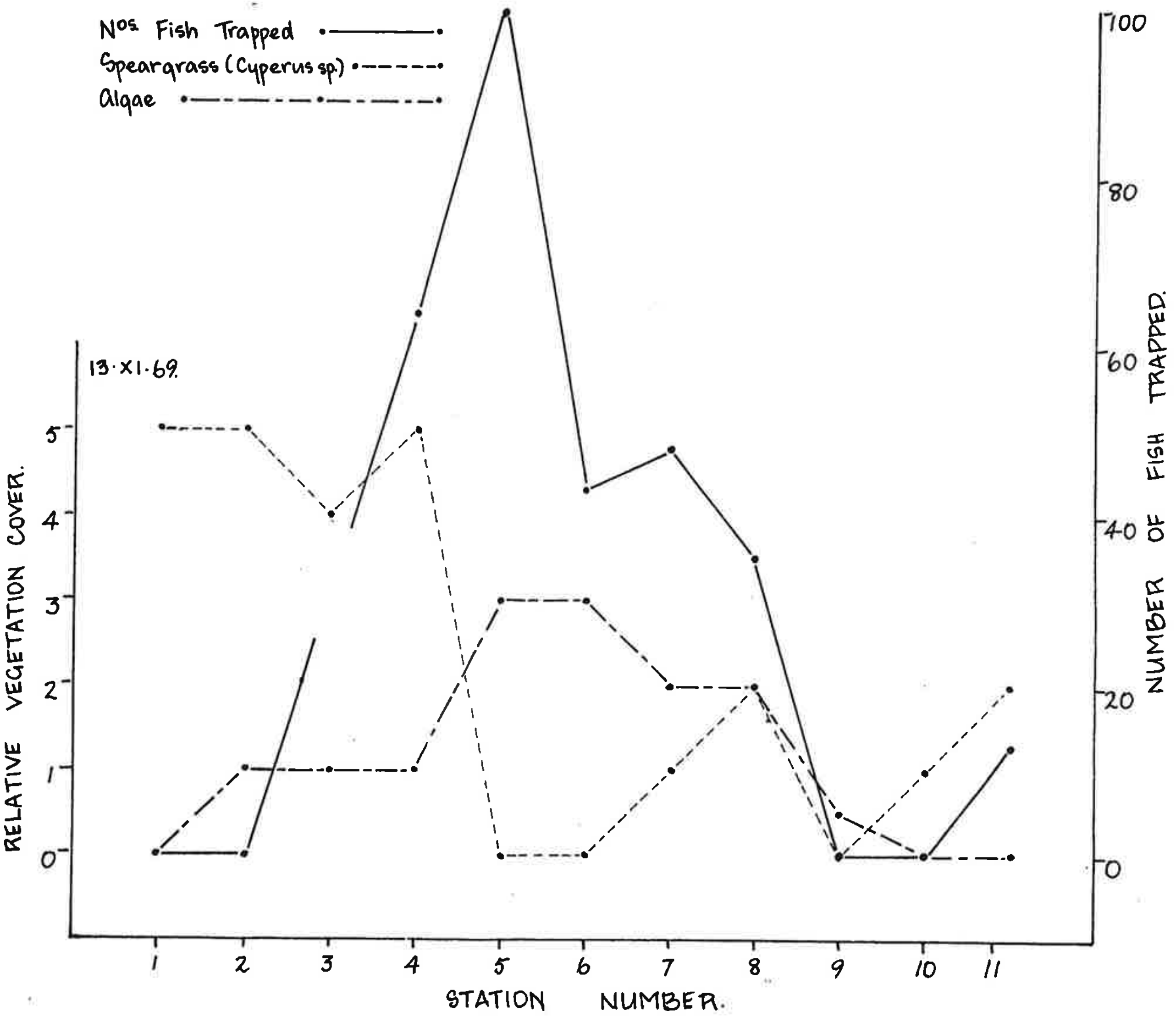
Graph 22

Correlation between number of *C. eremius* trapped and aquatic vegetation cover at the various stations in the main stream at Wobna Spring (locality 35) as recorded on 30.IV.69.


30·IV·69.
Nos. Fish Trapped.
Speargrass (Cyperus sp.)
Algae
RELATIVE VEGETATION COVER.
0
1
2
3
4
5
NUMBER OF FISH TRAPPED.
0
20
40
60
STATION NUMBER.
0
1
2
3
4
5
6
7
8
9
10
11

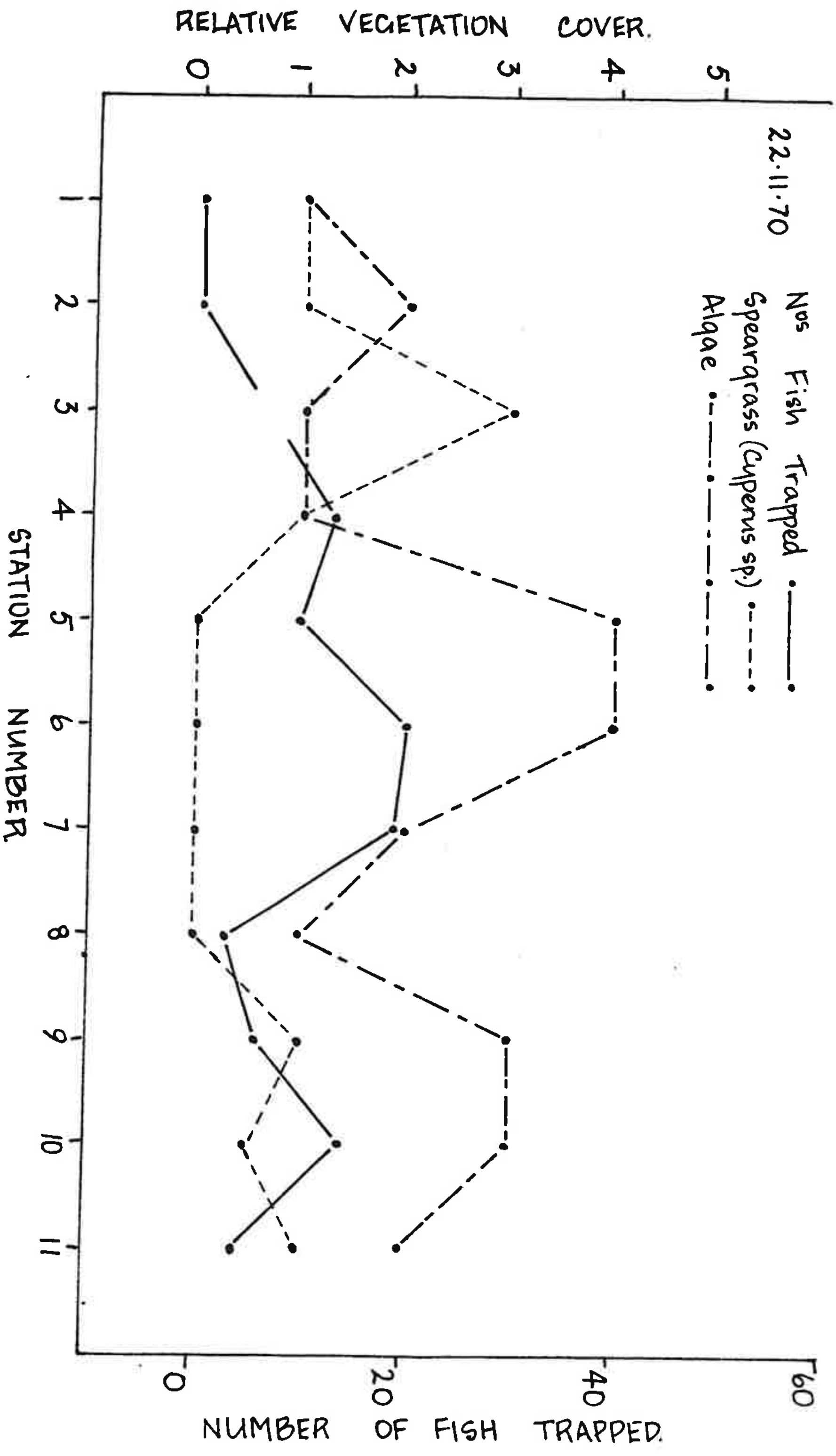
Graph 23

Correlation between number of *C. eremius* trapped and amount of aquatic vegetation cover at the various stations in the main stream at Wobna Spring (locality 35) as recorded on 13.XI.69.


Nos. Fish Trapped
Speargrass (Cyperus sp.)
Algae
13·XI·69.
RELATIVE VEGETATION COVER.
0
1
2
3
4
5
NUMBER OF FISH TRAPPED.
0
20
40
60
80
100
1
2
3
4
5
6
7
8
9
10
11
STATION NUMBER.

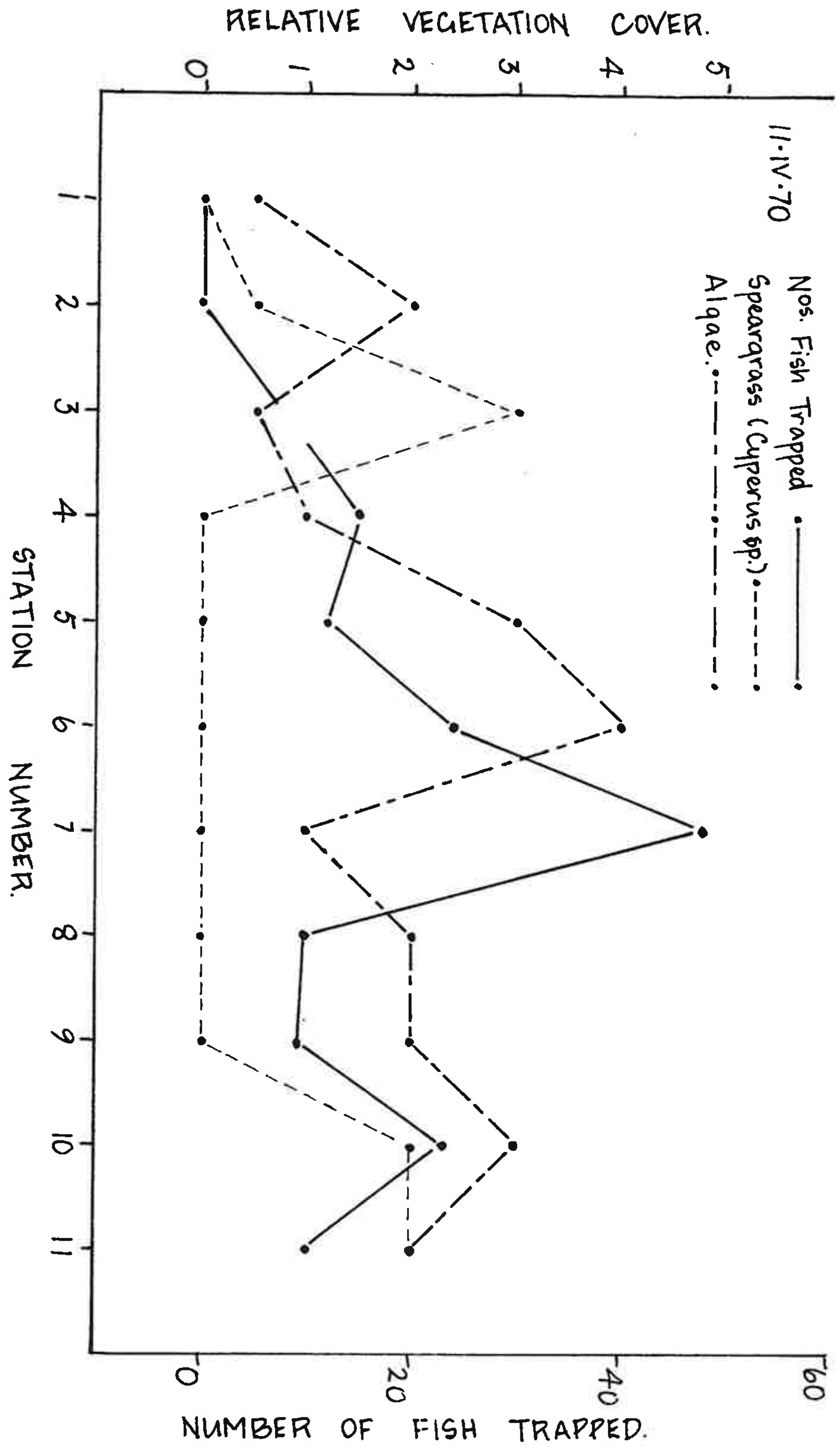
Graph 24

Correlation between number of C. eremius trapped and aquatic vegetation cover at the various stations in the main stream at Wobna Spring (locality 35) as recorded 22.II.70.


RELATIVE VEGETATION COVER.
0
1
2
3
4
5
22.11.70
Nos Fish Trapped
Speargrass (Cyperus sp.)
Algae
1
2
3
4
5
6
7
8
9
10
11
STATION NUMBER
0
20
40
60
NUMBER OF FISH TRAPPED.

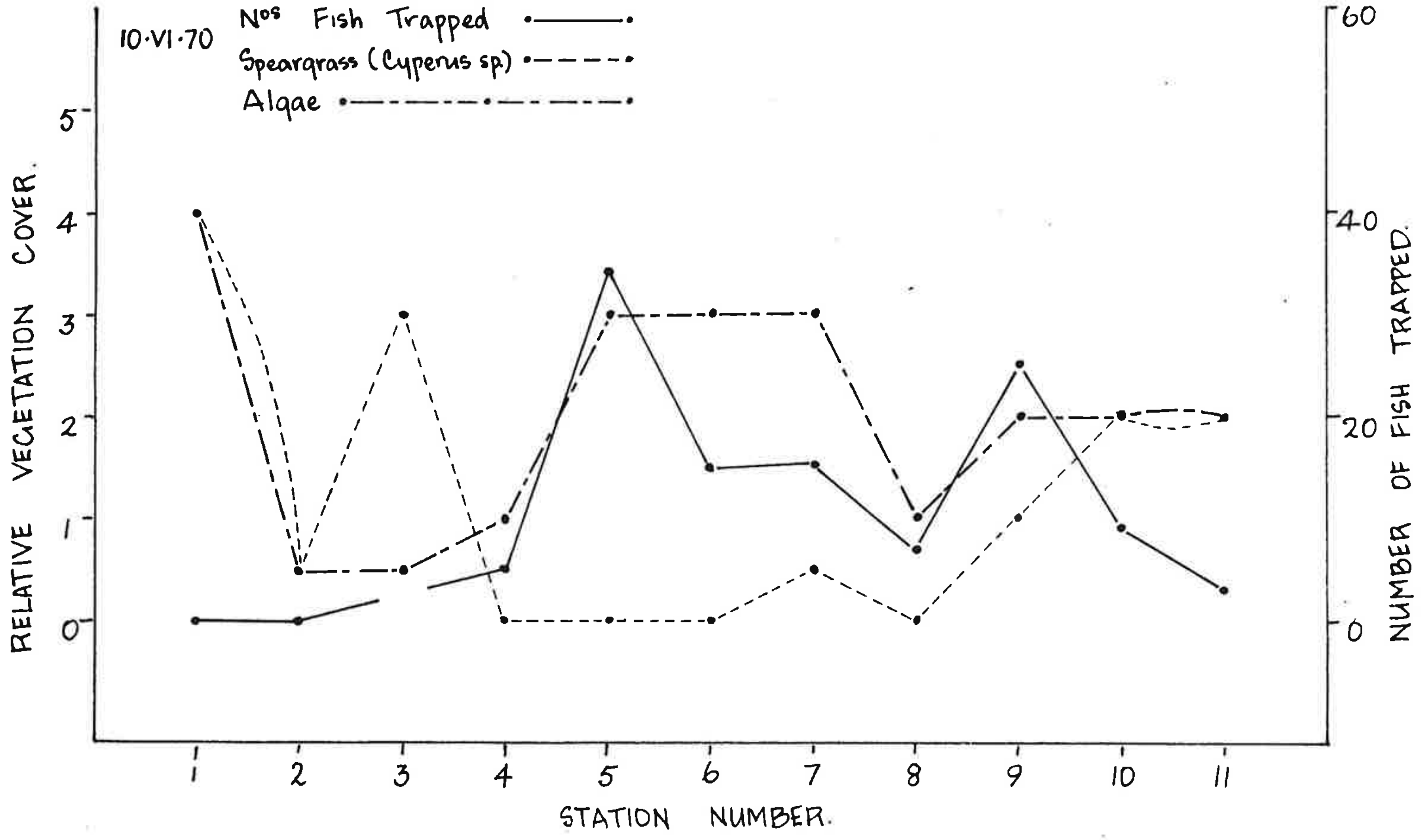
Graph 25

Correlation between number of C. eremius trapped and aquatic vegetation cover at the various stations in the main stream at Wobna Spring (locality 35) as recorded on 11.IV.70.


RELATIVE VEGETATION COVER.
0
1
2
3
4
5
11·IV·70
Nos. Fish Trapped •———
Speargrass (Cyperus sp.)•- - - -
Algae.•-—-—-
1
2
3
4
5
6
7
8
9
10
11
STATION NUMBER.
0
20
40
60
NUMBER OF FISH TRAPPED.

Graph 26

Correlation between number of *C. eremius* trapped and aquatic vegetation cover at the various stations in the main stream at Wobna Spring (locality 35) as recorded on 10.VI.70.


10·VI·70
Nos Fish Trapped
Speargrass (Cyperus sp)
Algae
RELATIVE VEGETATION COVER
0
1
2
3
4
5
NUMBER OF FISH TRAPPED
0
20
40
60
STATION NUMBER
1
2
3
4
5
6
7
8
9
10
11

Fauna	Relative abundance
Gastropoda (fam. Hydrobiidae)	Numerous
Oligochaetae	Abundant
Ostracoda	Abundant
Phreatoicus latipes	Not abundant

Table 51

Contents of a sample of algae (Spirogyra sp.) taken from Wobna Spring (locality 35) on 24.II.70.

Table 52

Other fishes found in conjunction with some permanent populations of _C_. _eremius_.

* Sighting only.

Locality	Loc. No.	Other fishes present (in addition to *C. eremius*).	Remarks
Dalhousie Springs, Main Spring	1/1	*Neosilurus* sp. *Craterocephalus stercusmuscarum*. *Mogurnda morgurnda*	*Neosilurus* sp. and *C.stercus muscarum* by far the most dominantly abundant
Dalhousie Springs Spring 3	1/3	*Neosilurus* sp. *Craterocephalus stercusmuscarum* *Mogurnda mogurnda*	As above
Dalhousie Springs, Spring 4	1/4	*Neosilurus* sp. *Craterocephalus stercusmuscarum* *Mogurnda mogurnda*	As above
Algebuckina waterhole	12	*Craterocephalus eyresii* *Madigania unicolor*	
Wood Duck Bore	13	Nil	*C.eremius* abundant
Old Peake Homestead Bore	15	Nil	As above
Freeling Spring	16	*Craterocephalus stercusmuscarum*	Both species approximately equally abundant.
Blyth Bore	17	*Craterocephalus fluviatilis* **Madigania unicolor* (?)	*C.eremius* and *C.fluviatilis* approximately equally abundant.
Birribirriana Spring	18	*Craterocephalus stercusmuscarum*	Both species approximately equally abundant.

Locality	Loc. No.	Other fishes present (in addition to *C. eremius*).	Remarks
Nilpinna Spring	19	*Neosilurus* sp. *Craterocephalus stercusmuscarum*	*C.eremius* and *C.stercusmus-* approximately equally abundant and dominant over *Neosilurus* sp.
Johnson's No. 3 Bore	24	*Craterocephalus eyresii*	*C.eremius* by far the most dominantly abundant.
Nunn's Bore	27	*Craterocephalus eyresii*	As above
Strangways Springs Railway Bore	29	Nil	*C.eremius* abundant
Coward Springs proper	33	Nil	As above
Coward Springs Railway Bore	34	Nil	As above
Wobna Spring	35	*Craterocephalus eyresii*	*C.eremius* by far the most dominantly abundant. A small school of *C.eyresii* sighted in the vicinity of Stn. 5 on 29.V.68. Four specimens trapped at Stn. 12 on 1.IX.68. A total of twenty seven specimens trapped at Stns.12&13 on 15.XI.68. No *C.eyresii* trapped or sighted since.
Clayton Bore	44	Nil	*C.eremius* abundant

Table 53

Bird species recorded at Coward Springs Railway Bore (locality 34) 27 - 28.V.68 by Wm. J. Merilles Esq. (Australian Antarctic Division).

Common name	Scientific name	Confirmed fish predator	Potential fish predator
White-faced Heron	*Ardea novaehollandial* Latham 1970	*	
Mountain Duck	*Tadorna tadonoides* Jard. & Selby 1828		*
Black Duck	*Anas superciliosa* Gmelin 1789		*
Grey Teal	*Anas gibberifrons* Mueller 1842		*
Nankeen Kestrel	*Falco cenchroides* Vigors & Horsfield 1827		
Dusky Morhen	*Gallinula tenebrosa* Gould 1846		*
Spotted Crake	*Porzana fluminea* Gould 1842	*	
Spur-winged Plover	*Lobibyx novaehollandiae* (Stephens) 1819		*
Red-capped Dotteral	*Charadrius alexandrinus* Linn. 1758		
Black-fronted Dotteral	*Charadrius melanops* Vieillot 1818		
Red-kneed Dotteral	*Charadrius cinctus* Gould 1838		
White headed Stilt	*Himantopus* (Linn.) 1758		*
Silver Gull	*Larus novaehollandiae* Stephens 1826	*	
Crested Pigeon	*Ocyphaps lophotes* (Temminck) 1822		
Galah	*Cacatua roseicapilla* Vieillot 1817		
Welcome Swallow	*Hirundo tahitica neoxana* Gould 1842		
White-backed Swallow	*Cheramoeca leucosternum* (Gould) 1840		

Common name	Scientific name	Confirmed fish predator	Potential fish predator
Australian Pipit	*Anthus novaeseelandiae* (Gmelin) 1789		
Blue and white Wren	*Malurus leuconotus*		
White-fronted Chat	*Epthianura albifrons* (Jard & Selby) 1828		
Singing Honeyeater	*Meliphaga viriscens* (Vieillot) 1817		
White-fronted Honeyeater	*Phylidonyris albifrons* (Gould) 1841		

VIII BEHAVIOUR

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BEHAVIOUR

1. LOCAL MOVEMENTS

(a) General

Between 1968 and 1970 regular observations have been made of various sized groups of C. eremius maintained in several laboratory tanks. The tanks contained water varying in depth between 2cm and 20cms, had a surface area of 0.01-1.72 m^2 and a silt bedding in the bottom 1-2cms deep. Under these conditions the species behaviour is characteristically demersal and solitary. When initially introduced into a tank the members of the population quickly isolated themselves at random, although when cover was provided (vegetation or rocks) the fish showed a preference for sites under or in close vicinity to such cover. The fish spent most of their time resting on the tank beds in one position interspersed with infrequent and brief independent short range excursions of an apparently foraging/exploratory nature, usually culminating in a return to the general area previously inhabited. No behavioural response has been noted between individuals except when food is located by one or more individuals, all other individuals are occasionally attracted and congregate round it. The fish may then compete for portions of the food by shaking it free from the mouths of their fellows.

Sudden hand movements over the water surface or heavy vibrations invariably alarm individuals, particularly those in open areas. They respond by rapid and erratic independent scattering movements until they either settle down or reach cover, which ever happens first.

Field observations upon the populations at Wobna Spring (locality 35) and Johnson's No. 3 Bore (locality 24) revealed a similar pattern of behaviour to that displayed by the laboratory populations. At least during daylight, individuals spend a considerable period of time in the cover of aquatic vegetation making brief independent excursions into open water where, if they are disturbed, they scatter to cover.

Table 54 , prepared from the trapping data given in Appendix P and from direct observations, indicates the range and relative abundance of the C. eremius population along the stream at Wobna Spring (locality 35) on various occasions between April 1968 and May 1971. The fluctuation of the maximum trapping frequency between Stations 4 and 10 (a range of 210m) and the sporadic appearance of specimens in large numbers at Station 1 (the spring head) and Stations 12 and 13 (a side pool) initially suggests a periodic movement of the population as a whole, back and forth along the stream. However the presence or absence of the species at Station 1 has been observed to correlate with the presence or absence respectively of aquatic vegetation which is periodically totally eaten out by cattle upon moving into the vicinity of the spring during drought periods. It seems then, that these movements of the fish merely reflect migrations to or from certain sections of the stream which periodically become more or less favourable for habitation through the appearance or fall-off of suitable stands of vegetation (see p. 94).

The occasional appearance of large numbers of fish in the side pool (Stations 12 and 13) where no aquatic vegetation has ever been observed has on each occasion been preceeded by seasonal rainfall. It would, therefore, appear that the occupation of this pool (which is usually dry) is due simply to the flushing action of flood waters carrying individuals across from the adjacent main channel.

(b) Range of Movement

Several attempts had been made to measure the range of movement of individuals within the field habitat but these have proved somewhat unsatisfactory, largely due to the inadequacy of the marking techniques employed (see p. 37). Nevertheless, at Wobna Spring (locality 35) when 16 males and 27 females collected midway between Stations 5 and 6 on 4,IX.70 were marked by removing their ventral fins with surgical scissors and reintroduced at the collecting point the same day; 23 days later on 27.IX.70 a single marked female was trapped at Station 4 and another at Station 5, 12.5 and 30.5 (metres) respectively upstream from the capture/release point. On 31.X.70 a third marked female was trapped at Station 4.

At Johnson's No. 3 Bore (locality 24), 68 specimens collected by trap on 30.X.68 at the centre of the pool approximately 10m in diameter were marked by means of impregnating fluorescent pigment particles beneath the body surface (see p. 37), and subsequently released at the capture point after 6 traps were scattered randomly and up to 9m distance about the capture/release point; after a period of 13 hours the traps were withdrawn and it was found that 5 visibly marked subjects had been recovered at the release point and a further 2 recovered from a trap 9m distance.

On the basis of these limited observations it is deduced that within its habitat an individual may move over distances of at least 30m.

(c) Orientation in a Water Current

Observations at Wobna Spring (locality 35) have shown that individuals make brief excursions into open midstream where the flow rate is greatest. Although there was no evidence of any particular orientation to the direction of water flow the fact that all the re-captured marked individuals at Wobna Spring (locality 35) mentioned in the previous section were taken upstream from their release point did suggest that *C. eremius* might exhibit a tendency to orientate into a water flow and swim upstream. Fishes adapted to living in small streams frequently exhibit such a positive rheotaxis which helps prevent them being carried downstream.

Stream flow rates were measured at different sections along the stream at Wobna Spring (locality 35) to gauge the order of magnitude of flow rates to which C. eremius is subject. Flow rate was determined by measuring the time taken for a small weighted plastic phial to float with the current over a distance of 4m. The cap of the phial was coated with iridescent orange paint to facilitate observations. The results, presented in Table 55 show that the rate of water flow ranges from zero in side shallows and standing bodies of water, up to approximately 0.7m per second in certain mid-stream sections.

To establish how the species responds to a water current, a fibre glass raceway was constructed (see figure 18) consisting of an open chamber 10.5cm wide 12.5cm deep with a mean circumferance of 251.5cm. The chamber was filled to a depth of 10.0cm with artesian water and water flow was created by means of a Braun pump set in a side compartment. The water in the raceway and the compartment connected via a window covered with fine plastic mesh to prevent fish being drawn into the pump inlet. The water jet created by the pump enabled a stream flow of 0.3m per second to be attained. The direction of flow was controlled by reversing the direction of the rubber pipeing in the raceway.

Four adult male subjects, 40-45mm SL, was placed in the raceway and allowed to adjust for 24 hours in stationary water at room temperature. A series of observations were then made in which the orientation and behaviour of the subjects were noted when the water in the raceway was (1) stationary, (2) flowing clockwise, and (3) flowing anti-clockwise.

When flow was commenced or reversed a period of 1 minute was allowed to elapse to enable maximum flow to be established before an observation was made. The results, shown in Table 56, indicate that C. eremius responds very markedly with a positive rheotaxis, at least when the flow is at a rate of 0.3m per second.

In a second set of observations the ventral fins of the same 4 subjects were cut-off and after allowing a settling down period of 24 hours the tests were repeated. The results of these observations, also shown in Table 56, demonstrate that a similar orientation into the current was effected. Nevertheless the subjects could only achieve this for brief periods by maintaining vigorous swimming movements either in contact with or off the bottom. Without the aid of the ventral fins they were presumably unable to attach to the bottom of the raceway and soon tired and were then swept along with the current. Clearly the ventral fins are necessary to the fish in enabling it to maintain itself stationary and to have control of its movements in a flowing stream for any prolonged period of time. Since nearly all populations of C. eremius inhabit waters incorporating a flowing stream the typical Gobiidae suction disc formed by the united ventral fins is clearly an important functional structure in the species.

To determine whether C. eremius can orientate in a water flow without the aid of vision I selected 5 adult subjects 50-55mm SL, and eliminated their power of vision by destroying their eyes with a heated dissecting probe. Immediately following this operation a bacteriostatic and antifungal agent (Dichlorohydroxyquinaldine 5% w/w) in the form of cream was applied to the wounded eye sockets to prevent infection developing.

In order to establish that vision had been effectively destroyed I placed the fish (after a recovery period of 24 hours) together with 5 others of similar size with vision intact (to act as a control group) in a half-illuminated half-darkened tank (see p. 124) and carried out a series of hour long trials during which I scored, every 5 minutes, the location of the fish i.e. whether in the open illuminated section of a tank or under the masked section in darkness. Thus any difference in phototactic response between the two groups would be due to lack of vision on the part of the test subjects. The results of the 5 trials conducted are presented in Table 57 . The vision-intact control group, as expected (see p. 125), exhibited a pronounced negatively phototactic response with a combined score of 85.9% time spent in darkness and only 14.1% under illumination. On the other hand the test group exhibited what approach a neutral phototactic response with a total score of 55.4% time spent in darkness and 44.6% under illumination. Thus it appeared that not only were these latter fish displaying little if any phototactic response, but also that vision in the members of this group had been effectively destroyed. There is a statistically significant difference between the time spent in the light and dark sections of the tank by the test and control fish (see Appendix V , report G). It was noted that all 5 of the test fish moved approximately equally as often back and forth between the illuminated and darkened sections of the tank i.e. none showed an obvious preference for a particular section; it was therefore deduced that vision has been effectively destroyed in each fish.

The 5 blinded fish and the 5 vision intact control group were then placed in the raceway already described. Following the same procedure as before observations were then made of the responses of the subjects to clock-wise and anti-clockwise flowing water. The results of these observations, presented in Table 58, indicate that the subjects lacking vision responded in the same way as those that were able to see i.e. when either swimming or remaining stationary they orientated head-on against and parallel-to the direction of flow. Thus it is concluded that C. eremius can orientate in flowing water by the tactile sense alone. It was noted that for the duration of the trial all fish, including the blind subjects, maintained contact with the bottom of the raceway.

Findings that some fishes when not in contact with the ground were guided solely by optical stimuli and that blinded fish released in a stream were unable to orientate until they touched the bottom were reported by Lyon (1904). Although it has been repeatedly stated that fish out of contact with solids can orientate by means of the friction of the water alone, Dykgraff (1933) in fact confirmed Lyon's (1904) results as Fraenkel and Gunn (1940) point out. Dykgraaf's (1933) confirmation was based on the discovery that blinded Phoxinus laevis Agassiz, out of contact with solids, were unable to orientate in flowing water; but if such fish made contact with the bottom the frictional stimulation enabled them to orientate.

Since all the blinded C. eremius were in continuous contact with the raceway bottom where they maintained orientation in the flowing water it is probable that they too required to be in actual contact with the bottom to orientate, though this was not specifically tested.

C. eremius is typically demersal in habit and therefore in close contact with the bottom most of the time. It is therefore reasonable to expect that it would be an advantage to be able to readily maintain orientation in a flowing stream when vision is not possible.

In order to establish whether C. eremius displays a preference for flowing water an artificial stream was generated in a large tank in the laboratory during July

1970. This was done by placing a 60cm length of 10cm diameter split earthenware pipe, which was on a slight slope in a depression in the side of a small plastic bucket within the tank (see figure 19). A flow of water down the pipe was maintained from an overflow generated by a Braun pump pumping water from the main tank into the bucket.

A population of 40 adult fish maintained in the tank was regularly observed whilst the artificial stream was operating for a period of 5 days. None of the fish were obviously attracted to the vicinity of the outflow into the tank during this period and when individuals did occasionally approach the outflow region it was only briefly and apparently in the course of random exploratory movements. No fish were observed attempting to swim up the pipe against the flowing water stream.

Although I have not demonstrated what maximum flow rate individuals are able to successfully resist and swim against, the occasional upstream migration to Stations 1 and 2 at Wobna Spring (locality 35) from Station 4 (see p. 104) implies that individuals are able to swim against flow rates of at least 0.7m per second which is the flow rate recorded upstream of Station 3 on 10.VI.70 (see Table 55). On the other hand it may well be that actual movement upstream takes place in shallows at the extreme side of the channel where the rate of flow is considerably less than in the middle of the channel where the flow rates were recorded.

2. FEEDING

(a) Preamble

As indicated on page 92 C. eremius is omnivorous and ingests a variety of plants and animal foods, predominantly filamentous green algae and detritus together with various small fauna including insects and eggs, ostracods, copepods, and diatoms. This wide range of diet suggests that little selectivity is exercised in feeding, but much that is consumed is fortuitous and the species feeds upon whatever suitably sized matter is available. In contrast, Haines (1968) has reported that filamentous algae are deliberately eaten by, and that it is a major food item of, another of the Gobiidae, Ellogobius olorum (Sauvage). Subsequent laboratory observations showed that C. eremius also deliberately eats algae and that it sifts bottom silt by taking it into the mouth and ejecting it.

(b) Feeding Activity

Laboratory observations have shown that in captivity C. eremius will feed on tubifex worms (Tubifex sp.) lying on the bottom of tanks. In contrast, little attempt is made to sieze mosquito larvae at the water surface although some fragments of mosquito larva have been identified amongst stomach contents of a few individuals collected in the field (3 specimens) and therefore are eaten on occasions. In a laboratory experiment 10 adult fish were kept in a tank (36 x 18 x 20cm deep) containing 10.0cms depth of water for 3 days without being fed. On the morning of the 4th day (23.VIII.71) a cluster of approximately 50 live tubifex worms held by a suspended pair of small forceps were presented to the fish just below the water surface (see figure 28). From the time of presentation the fish were continuously observed for a 2 hour period (1200-1400 hrs.); during this time only 3 brief individual approaches and accompanying biting motions by 2 different fish were made to the suspended food. None of the other fish showed any interest in the suspended tubifex but they readily approached and ate the few tubifex that broke free from the suspended cluster once they had dropped to the bottom of the tank. In the second trial period the following day a fresh cluster of tubifex were similarly presented; during this trial no approaches were made by any of the fish to the suspended food. It is therefore concluded that C. eremius is predominantly a demersal feeder.

Since C. eremius will readily feed on tubifex worms these were used as food in the series of feeding experiments to be described.

The large numbers of C. eremius trapped during both day and night hours (see p. 138) suggested that the species feeds during the day and the night. In order to establish whether this is in fact the case, 10 subjects (25-40mm SL) from laboratory stock were placed in the tank (36 x 18 x 20cm deep) filled to a depth of 4.0cm with artesian water. The stock had been maintained in a room in which windows ensured a regular day/night cycle of light intensity within the room. Placed near a window where this cycle of illumination would continue, the test subjects were allowed to settle down for a period of 24 hours prior to the experiment commencing. The first series of observations were carried out in daylight on two successive mornings. On both occasions 20 tubifex worms were placed at random into the tank and a 2 hour period allowed to elapse before an inspection was made of the number of tubifex remaining. Then, on two successive evenings, in darkness, commencing the following day, 20 tubifex worms were again introduced into the tank and after a 2 hour period an inspection made to see how many tubifex remained uneaten. The results of these tests shown in Table 59 indicated that all available tubifex were consumed during both daylight hours and at night. It is therefore concluded the species will feed both by night and day.

(b) Sensory factors involved in Food Location and Feeding

To determine the relative importance of the various senses in locating food and stimulating feeding activity, a series of comparative feeding tests, using tubifex, were carried out to deduce, by a process of elimination, the primary sense/s involved. Laboratory observations on feeding subjects had indicated that not until the forehead is in very close proximity to food, usually less than 1cm, does a subject display any form of feeding activity or give any indication that it is aware of presence of food, unless it has been alerted and attracted by the feeding activity of other individuals (see p. 103). This suggested that whatever sense/s were involved in food location and feeding they normally operate only at short range.

(i) Vision

The results of the day and night feeding experiments discussed on p. 114 suggested that vision plays no special role in the location of food. Nevertheless a specific experiment was undertaken to examine this. Four pairs of subjects, all of similar size (40-45mm SL), were placed in 4 separate tanks (36 x 18 x 20cm deep) filled to a depth of 4cm with artesian water. Feeding tests were carried out during the late morning of the dates shown in Table 60, by placing 20 tubifex in each tank for a period of 2 hours and noting how many were consumed at the end of this period. One pair of tanks was illuminated by the means of a 'Planet' fluorescent lamp suspended 25cm immediately above the water surface whilst the other pair was covered with a thick black cloth so that the subjects were in darkness (see Fig. 21). Although no water temperatures were recorded it is unlikely that there was any significant difference between

the different tanks since all were kept in the same laboratory room in close proximity to each other and the heat emitted from the fluorescent lamp was considered to be insignificant.
After 2 hours, an inspection was made of the number of tubifex remaining in each tank. As a control, for each suceeding test the illumination conditions were reversed so that the subjects who had previously been fed under illumination were then subject to feeding in darkness and vice versa.

There is no consistent difference between the comparative results given in Table 60 so it is concluded that in C. eremius vision is not essential in locating food and that the capacity to locate food is dependent on other factors. There is no statistically significant difference between the quantities of tubifex eaten in light and dark (see Appendix V , Report C).

(ii) Movement

A further series of tests were carried out to determine if movement of the food assisted in its location. Eight different subjects were employed, housed in pairs in each of 4 tanks similar to those used in the previous experiment. Into each of one pair of tanks 20 live tubifex were introduced whilst into each of the other pair 20 dead tubifex were placed. These were killed immediately prior to the test by being momentarily immersed in boiling water. During a feeding period of 2 hours all tanks were illuminated equally by a 'Planet' fluorescent lamp set 25cm above the water surface. At the end of the feeding period the number of tubifex remaining in each tank were counted. In the following trial the live and dead tubifex were placed in the opposite pair of tanks so that subjects previously fed live tubifex were fed dead tubifex and vice versa. Since the previous experiment had demonstrated that vision has no influence on the capacity to locate tubifex any significant difference in the number of dead or alive tubifex consumed in this present experiment would suggest that sensory vibrations set up by moving prey are significant in enabling C. eremius to locate food.

The results of this experiment are presented in Table 61. Since there is no significant difference in the two sets of readings, it is concluded that movement of the prey are not important in the location of food. There is no statistically significant difference between the quantities of live and dead tubifex eaten (see Appendix V, Report D).

Another similar experiment was conducted in which two groups of subjects were alternately fed live tubifex under illumination and dead tubifex in darkness, i.e. two separate pairs were each tested for the number of live tubifex consumed under illumination and compared against another two separate pairs being fed dead tubifex in darkness. The results from this experiment, as shown in Table 62, confirm the conclusions of the previous two series of experiments that neither vision or movement play any important role in the location of food. Again there is no statistically significant difference between the quantity of illuminated tubifex eaten and the quantity of dead tubifex eaten in darkness (see Appendix V, Report E).

(iii) "Touch" Sense via Ventral Fins.

Since Haines (1968) observed in Ellogobius olorum that the ventral fins appeared to be adapted as a sense organ used to detect food by actual contact with food, I examined whether this was the case with C. eremius, especially as sense receptors have been located in the fins of a number of bottom-living fishes including Trigla sp. (von Frische, 1950), (Scharrer, 1935).

Observations upon C. eremius feeding on tubifex did not indicate that the ventral fins were employed in food perception. Nevertheless an experiment was carried out, because any sensory receptors present in the ventral fins need not necessarily require actual contact to detect food.

Using two tanks (36 x 18 x 20cm deep) filled to a depth of 4.0cm of artesian water, I selected two batches of 10 subjects each, each representing a similar size range (30-45mm SL). From one batch I removed the ventral fins of each individual by means of surgical scissors and left those of the other group intact as a control. Each batch was placed in separate tanks and left 24 hours to allow the subjects from whom fins had been removed to recover. At the conclusion of this period 20 live tubifex were introduced into each of the tanks. These were kept in darkness by placing a black cloth over both to eliminate any possible use of the visual sense. After 2 hours the tanks were inspected to see how many tubifex had been eaten in each. Two similar feeding trials were run with the same subjects on a later occasion.

The results of these trials are presented in Table 63 . The marked discrepancy in the results of the first trial and the final two trials suggests that the test group had not fully recovered after their fins were removed at the time of the first trial. Assuming this to be the case it is concluded that since in the two final trials an equal number of tubifex were consumed by those subjects devoid of ventral fins as those with intact fins that the ventral fins are not employed to any sifnificant extent in locating food.

(iv) Olfaction/Gustation

Having eliminated vision, vibration recognition and food recognition by the ventral fins as significant factors assisting in the location of food, I then examined the role of the olfactory/gustatory senses.

An experiment was designed in which a tank (36 x 18 x 20cm deep) in size was employed. Small swabs, approximately 5mm in diameter, were prepared from tightly compressed lint bound in cotton thread and attached to short lengths of platinum wire. Before each trial the tank was filled to a depth of 4.0cm with artesian water. A single fish was put into the tank and allowed to settle down for 1 hour. The tank was illuminated by a 'Planet' fluorescent lamp set 25cm above the water surface while the rest of the laboratory room was darkened.

For a period of 15 minutes before the start of the trial one swab was immersed in freshly macerated tubifex. Immediately before the trial commenced the swab was removed and briefly washed with distilled water to remove tissue fragments. A control swab had previously been immersed in macerated tubifex in order that it would acquire the slight pigmentation imparted by the macerated tubifex but was then washed in several changes of hot distilled water to remove as much odour as possible. Immediately prior to the trial the two swabs were introduced into the water in the tank, one at either end, 1cm above the tank bottom, and fixed in position by looping the attaching wires over the rim of the tank (see figure 22).

Sitting at a distance of several metres from the tank in the darkened room in order not to disturb the subject in the illuminated tank, I proceeded to score the number of close approaches and biting motions made by the subject during a 1 hour period. At the conclusion of this interval, the 2 swabs were removed, the test swab being reintroduced into freshly macerated tubifex shortly before the next trial and the control swab again washed in several changes of hot distilled water.

The artesian water was replaced with a fresh supply, the same subject was reintroduced for a second trial which was run after a 1 hour settling down period, but the position of the control and test swabs were reversed. This procedure was repeated with a further 3 different subjects.

Since the test and control swabs were similar in all respects, except that the test one was infused with macerated tubifex solution, any differences in response elicited by the 2 swabs would presumably be due to different stimuli on the olfactory/gustatory senses. The results presented in Table 64 clearly indicate that the prepared swab stimulated a significantly greater number of approaches and biting responses than the neutral control swab. It is therefore concluded that the olfactory and/or gustatory sense is the predominant factor enabling <u>C. eremius</u> to locate food, and in stimulating feeding action. The pronounced drop in response to both the trial and control swab (in most instances) during the second trial run for each subject suggests that a learning process may be occurring due to inability to complete the feeding action during the initial trial run. There is a highly significant statistical difference between the number of approaches to the prepared and control swab (see Appendix V, REPORT F).

3. RESPONSES TO CERTAIN ASPECTS OF THE ENVIRONMENT.

(a) Preamble

In each of the following series of experiments the test subjects were housed in a transparent perspex tank (40 x 31 x 5cm deep) in 3cms depth of water. Each experiment was a habitat preference trial in which the fish were observed over a period of time to establish their preference (if any) for one or other of the pair of environments presented to them, one in each half of the tank. The trials were scored by recording every 5 minutes the number of fish present in each half of the tank, thus getting an overall measure of the relative time the members of the test group spent under each of the alternative conditions over the total period of the experiment.

(b) Light

To establish if and how *C. eremius* responds to light I conducted a series of trials to determine the preference shown by individuals for illumination versus darkness. In each trial 10 fish were placed in the tank described. Black matt paper was attached to the underlying surface of the tank to reduce light reflections. Half the tank was illuminated with white light from a 'Planet' fluorescent lamp placed 25cm above the surface of the water whilst the other half of the tank was maintained in darkness by means of a blackened wood mask (see fig. 24). The heat from the lamp was negligible, therefore water temperature was virtually uniform throughout the tank. When a group of test fish were placed in the tank a settling down period of 1 hour was allowed to elapse before a trial commenced. During each trial, every 5 minutes over a 1 hour period the numbers of fish in the open and darkened sections of the tank respectively were noted. At the end of each trial the darkened and illuminated halves of the tank were reversed and a settling down period of 1 hour was allowed to elapse before the next trial. Different fish were used for each pair of trials.

The results of the 12 trials conducted are presented in Table 65. It is clear that C. eremius is strongly negatively phototactic, spending more than 70% of its time in the darkened part of the tank.

(c) Background Reflectivity

To determine whether C. eremius is selective in regard to the amount of light reflected from the background over which it moves I conducted a series of trials scoring the preference shown for a dark background versus a light background on the same basis as before.

Again employing the same tank as before I attached to the underlying surface two different coloured papers. Thus one half of the tank had a matt black background, the other half a matt yellow background. A 'Planet' fluorescent lamp was set longitudinally 25cm above the water surface. Two trials, each of 2 hours duration, were conducted employing the same 10 fish in each trial. At the end of the first trial the background colours were reversed to the opposite ends of the tank and a 1 hour settling down period allowed to elapse before the next trial.

The results of the 2 trials are presented in Table 66 from which it appears that C. eremius has only a very slight preference, if any, for a dark coloured background. There is no statistically significant difference between the time spent over the black and yellow backgrounds (see Appendix V , report H).

(d) Background Texture

To determine whether C. eremius has any preference for the texture of the bed over which it settles I conducted a series of trials in which I compared the preference for a coarse-textured bed versus a smooth-textured bed.

In the test tank I fitted a wooden (3 ply) bed. The surface of one half of the wood bed was left smooth whilst the other half was coarsened by means of a stout nail brush to break up the surface. To all intents the colour of the two sections was the same, but the smooth surface did reflect somewhat more light. A 'Planet' fluorescent lamp was set longitudinally 25cm above the water surface. A series of 6 trials, each of 1 hour duration, were conducted. Five fish were used in each trial and the same fish were employed in all trials. At the end of each trial the 2 different beds were reversed to opposite ends of the tank and a period of at least 1 hour allowed to elapse before the next trial commenced.

The results of the 6 trials are presented in Table 67. It is seen that the species exhibits a very strong selectivity of some 86% for a smooth-textured bed in preference to a coarse-textured bed. Since in the previous experiment C. eremius showed no significant preference for a far less reflective matt black surface it seems reasonable to assume that the effect of the slightly less reflective coarse-textured bed in this experiment is negligible.

(e) Background Medium.

In the natural habitat of C. eremius stream beds are frequently encountered consisting in one section of light coloured coarse-textured sand and in another section dark coloured fine-textured silt, for example, as at Johnson's No. 3 Bore (locality 24), Nunn's Bore (locality 27) and Wobna Spring (locality 35).

On the basis of the previous 2 laboratory experiments it appears that the species would show, with regard to texture, a strong preference for fine-textured beds, but with regard to reflectivity no perceivable preference. Thus with regard to coarse sand and fine silt it would be expected that the species would show a preference for silt rather than the sand, irrespective of the difference in reflectivity of the two mediums.

In order to establish which of these media are preferred I conducted 2 trials to determine the relative preferences of the species. Again employing the same tank I prepared 2 different beds, one silt the other sand, from material collected at Wobna Spring (locality 35). Thus one half of the tank contained a light coloured coarse sand bed, the other half a dark fine silt bed, both of a uniform depth of 1cm. A 'Planet' fluorescent lamp was placed longitudinally 25cm above the water surface. During each 1 hour trial using 10 fish, the number of fish over the sand and the silt respectively was scored every 5 minutes. At the conclusion of the first trial the tank was turned around so that the beds were facing opposite ends of the laboratory and a period of 1 hour allowed to elapse before the second trial was commenced using the same 10 subjects.

The results of the 2 trials presented in Table 68 show that there is a strong preference for the fine dark silt as shown by the time spent over it. This preference is what was expected on the basis of the earlier experiments but the degree of preference is not as great as anticipated though this is possibly due to a greater degree of difference in textures between those of the artifically prepared beds and those of the natural beds. There is a statistically significant difference between the times spent over each of the two different beds (see Appendix V, reportI).

(f) Aquatic Vegetation.

Field observations (see p. 95) indicate that greater numbers of C. eremius tend to be trapped in those sections of a stream where aquatic vegetation, particularly filamentous green algae, is abundant rather than in poorly vegetated areas.

To measure the degree of preference shown for the algal environment I conducted a series of comparative trials scoring the time spent amongst algae as opposed to open water. With matt black paper attached to the bottom of the test tank to reduce light reflection I placed a quantity of live green algae (Spirogyra sp.) collected from Wobna Spring (locality 35) uniformly and densely throughout one half of the tank and left the other half as open water. A 'Planet' fluorescent lamp was placed longitudinally 25cm above the water surface.

During each 1-hour long trial the number of fish, of a total of 10 (different subjects for each trial), on top and beneath the algae and in the open water section respectively, were scored every 5 minutes. At the conclusion of each trial the fish were removed and the algae replaced in the opposite end of the tank. New subjects were then introduced and a period of 1 hour allowed to elapse before the next trial commenced.

Table 69 presents the results of the 3 trials conducted. It is apparent that members of the species spend much longer amongst aquatic algae than in open water.

Since, overall, the fish occurred in about equal numbers lying on top of the surface of the algae as beneath it, it appears that little of the preference for the algae in this experiment can be directly attributable to the characteristic negatively phototactic response demonstrated previously (see p. 124). In fact there appears to be no phototactic response, either positive or negative, indicated by the results of this experiment. It is possible that the algae were packed so densely that the fish were unable to remain beneath its surface for any prolonged period without impeding respiratory activity.

4. BODY COLOUR CHANGES.

C. eremius has the ability to undergo changes in body colour between light yellow and black. I observed in the field that individuals inhabiting bodies of water with predominantly light coloured beds, for example, Wobna Spring (locality 35) invariably have minimal development of dark pigmentation so that the characteristic transverse banding of the dorsal surface (see p. 9) is barely apparent. On the other hand individuals inhabiting waters with predominantly dark coloured beds, for example, Johnson's No. 3 Bore (locality 24) and Nunn's Bore (locality 27) are usually very darkly pigmented and are often almost uniformly dark over the dorsal and lateral surfaces, with little indication of banding. This adaptation to background colour would seem likely to constitute a protective asset against predators, in particular birds.

Fry (1957) has pointed out that in fish the time required for movements of pigments to occur from one extreme to the other is highly variable. In Crenilabrus sp. for example, change can occur within a few seconds, in Fundulus sp. in 1-2 minutes, in Ameiurus sp. 1-35 hours, whilst Anguilla sp. takes 20 days.

In the course of handling laboratory stock it became evident to me that C. eremius may respond to different intensities of background colour relatively quickly but that individuals vary in their rapidity of response and in the extent to which they respond. A series of tests was, therefore, conducted to measure the time taken to respond to changes in background colour. Fourteen fish were placed in a small glass-bottomed tank (36 x 18 x 20cm deep) containing 4cm depth of water. The tank was set on a black matt paper background and illuminated by a 'Planet' fluorescent lamp placed longitudinally 25cm above the water surface. The heat emitted from the lamp was negligible. The subjects were kept continuously illuminated for 24 hours over the black background when there was an increase in the density of visible dark pigment. At the end of this period the fish were placed, one at a time, by means of a small dab net, into an adjacent tank of the same size, also illuminated from above but with a matt white paper background beneath the bottom of the tank. Using a stop watch the time that elapsed between introduction into the second tank and the first discernible change (a lightening) in body colouring was measured, by two observers, for each individual. The fish were then retained under continuous illumination over a white background for 24 hours, when there was a marked reduction in the apparent density of the pigmentation. The fish were then replaced in the first tank over the black background and the times noted for the first discernable darkening to occur in each subject, two observers again taking part. These tests were then repeated. Table 70 presents the times taken in these tests. It can be seen that the time taken for an initial response to be recorded varied between 2.0 and 29.0 seconds.

Although no specific tests have been conducted to measure the time for maximum change to occur, several very darkly pigmented subjects when placed on an illuminated white background in the laboratory completed the change to a light sandy yellow within a period of 60-120 seconds. Such rapidly completed extreme changes in pigmentation are not, however, typical of the species.

Since the change in pigmentation that occurred when each fish was transferred to a different background colour may have been due to factors other than the background colour, a second series of control tests were run in which the same fish used in the above tests were first placed for 24 hours in an illuminated tank over a white background and then transferred individually into a similarly illuminated adjacent tank, also with a white background. Following this the tank was placed over black paper and the fish were then kept for 24 hours over a black background and then transferred individually into another tank also with a black background. In no instance did any of the fish display any perceivable change in body colour upon being transferred to a background colour similar to the one they had been held over for the previous 24 hours. Thus it is concluded that the change in body colour that occurs when subjects are transferred to a different background colour is due primarily to the background colour itself and not to any difference in temperature, water conditions or an emotional factor induced by handling.

Fry (1957) has also pointed out that although colour changes generally depend on visual stimulation and that usually a blinded fish becomes dark and remains so while illuminated, regardless of changes in background colour, a number of fishes, including two species of Gobius, continue to respond to changes in illumination after blinding. Fry (1957) states that responses to background colour may also be initiated by photoreceptors in the skin (possibly by direct or reflex activation of chromatophores), the pineal complex and possibly by other nervous structures not yet identified.

To determine if body pigments respond to changes in background colour in blind C. eremius, 5 fish rendered and confirmed blind in a previously described experiment (see p. 109) were placed with 5 vision-intact fish of similar size in a tank under illumination over a black background for 24 hours. The fish, which were all now darkly pigmented, were then transferred individually to a tank with an illuminated white background when a colour lightening occurred and the pigment response times noted. The fish were then held over a white background for 24 hours after which they were transferred back into the tank over the black background where a darkening occurred and response times were again recorded. From the results of these observations (see Table 71) it is seen that both the blind and the vision-intact fish responded to changes in background colour. That is, blinding had not abolished the pigment response in changes to background colour.

Thus it appears that in C. eremius chromatophores respond to stimulation other than via the optical system, although this probably is the principal effector when it is intact. In fact, because the mean time taken by the blind fish to respond was somewhat greater than that taken by the vision intact fish this implies that the pigment response does depend in part on visual stimulation since it is effected more rapidly by this means than via extra-optical photoreceptors alone.

An analysis of the data in Table 71 indicates a statistically significant difference between the mean response times of blind and vision-intact fish when transferred from white to black backgrounds (see Appendix V, report J). However, there is no significant difference in the mean response times of the two groups of fish when transferred from black to white backgrounds (Appendix V, report K). These differences in significances could well be due to errors caused by the subjective method of recording the responses. It was intended that this factor would be minimised by employing two observers. A larger volume of data, employing greater numbers of fish, would undoubtedly enable more conclusive results to be made.

The differences in the mean times taken (in both groups) when transferred from black to white backgrounds from when transferred from white to black backgrounds could be due to either (a) differences in detecting colour changes against different coloured backgrounds, or, (b) a genuine response time difference, that is, the change from dark to light colour might be effected more rapidly than the change from light to dark colour.

5. ACTIVITY PATTERNS

As previously demonstrated, C. eremius feeds both by night and by day in laboratory tanks (see p. 114). This suggests that in the natural habitat the species is similarly active night and day. In order to measure the relative day/night activity pattern of the species I conducted a series of trappings of the population at Johnson's No. 3 Bore (locality 24) on different occasions between December 1968 and September 1970.

The main day/night trappings (Series 1A - 6A) were made in a large side pool approximately 6 metres in diameter whose depth ranged between 15 and 30cm. Each trapping consisted of 9 non-baited wire mesh traps (see Appendix D for description). Set in a cross pattern 1 metre apart (see figure 20), placed in position from the side of the pool by means of a 2 metre long pole with attached line and hook, so as to disturb the pool as little as possible (see figure 25). On the occasion of the first 4 series of trappings (See Table 72) the traps were set alternately one or more times for 8 hours of darkness followed by 8 hours of daylight (or vice versa) that is, the first setting was made at night, the second setting in daylight (or vice versa) and so on and at similar times. Counts were made of the number of fish in each trap at the conclusion of each setting but they were not sexed. The final 2 series of trappings (Series 5A and 6A) were conducted as straight runs, that is, a number of successive night trappings of 8 hours duration each, followed by an equal number of day trappings (or vice versa) and on these occasions counts were made of each sex. The results of all these trappings (Series 1A to 6A) together with the phases of the moon are presented in Tables 72 and 73.

Another series of similarly conducted trappings (Series 1B to 4B) were made in a second smaller pool at Johnson's No. 3 Bore (locality 24), employing 2-4 traps for each setting. The first 3 of these series were alternate day/night trappings; the fish were not sexed. The 4th in these series of trappings comprised 3 successive day trappings followed by 3 successive night trappings; in this series the fish were sexed and their standard lengths noted. The results of these trappings (Series 1B to 4B) are presented in Tables 74 and 75.

Series 1A and 2A (see Table 72) show a pattern in which peak activity occurs during night hours. Series 3A did not however follow this pattern, and indicated neither a day or night activity peak; the progressive drop in numbers with each successive trapping suggests that disturbance of the habitat through setting and removing traps had possibly interfered with normal activity on this occasion. Series 4A is again inconclusive and if anything suggests equal activity in both night and day. Series 5A and 6A in which the settings were made at successively similar times indicate that activity is 20-30 per cent greater during daylight than at night. The difference in proportion of the numbers of males and females trapped day and night may be due to greater activity on the part of females, but more probably, to a difference in the populations sex ratio (see p. 40). However males appear to display relatively less reduction in activity at night than females. It will be noted that in Series 5A and 6A that the order in which the trappings were conducted was different, that is, in Series 5A the day trappings were made first whilst in the Series 6A the night trappings were made first; this was in order to counteract any effect on the trapping rates due to the habitat being disturbed during the early settings on each occasion.

The results of Series 1B - 4B conducted in the smaller pool (see Tables 74-75) are also conflicting in that whilst the data from Series 1B suggest a peak activity rate during daylight hours the results of Series 2B suggest a night peak. It will be noted that the results of Series 2B are similar to those obtained with the simultaneously conducted trappings in the larger pool, that is, Series 1A (see Table 72).

These results are fairly conflicting in that though the species always displayed some activity, both night and day, there were occasions when there was an exceptional preponderance of night activity and others when this occurred during daylight hours.

The possibility that these enhanced levels of day or night activity may be influenced by the degree of moonlight, and therefore lunar phases, has been considered. Taking the total counts from all the comparable night trappings conducted at Johnson's No. 3 Bore (locality 24) and Wobna mound Spring (locality 35) (see Table P) respectively, I separated them according to the lunar phase prevailing on the night of trapping as shown in Tables 76 and 77 . I then determined the mean trapping rate during each phase and compared one with the other. On the basis of the limited number of data available it can be seen that, at both localities, the tendency appears to be for greater numbers to be trapped (=greater activity) during the new moon phase than during either quarter or full moon phases; also, for greater numbers to be trapped during quarter moon than full moon phases. Thus an increasing amount of moonlight appears to progressively depress the numbers trapped and hence indicates a lower level of activity.

However, only at Johnson's No. 3 Bore (locality 24) is there a statistically significant difference between the trapping rates during full moon and the other lunar phases (see Appendix V , report L). This significant difference applies between full moon and all the other phases but reservations are held about the comparison between full moon and new moon since the new moon data comprises only two observations.

As pointed out by McDowall (1969) lunar rythms have been reported in several fishes but only a very few, well authenticated, cases involving non-marine species have been found. Regarding one of the latter, (Galaxias attenuatus (Jenyns), Burnet (1965) found that mature adults migrate downstream to esturine spawning grounds just before full moon. Deelder (1954) concluded that in Anguilla anguilla L. migration to the sea is influenced by the phase of the moon but that this is not through the direct influence of moonlight as migrations are known to occur regardless of night sky conditions. Lowe (1952) on the other hand found that the same species will migrate only when water is turbid but that lunar influence is disrupted by cloud cover and suggested that light quality may be a critical factor. Savage and Hodgson (1934) found a lunar rythmn in the quantity of herring (species not specified) caught commercially, a peak catch occurring about full moon, and Moore (1958) reported lunar rythmns in the commercial species Pagallus centrodontus Cuv. & Val. However Blaxter and Holliday (1963) have shown that it is difficult to establish if apparent lunar rythumns based on commercial catch data indicate true fish activity rhythms.

With C. eremius the picture is confusing but it is possible that a lunar influenced activity pattern operates; careful analysis of considerably more data will be necessary to establish whether this is so or not.

I have evidence from trapping data to suggest that C. eremius possesses a characteristic annual pattern of fluctuating activity levels. The most complete set of trappings made at one locality over an extended period has been at Wobna Spring (locality 35). The total counts from each series of trappings made at this locality between September 1968 and November 1970 (see Appendix P) are plotted in Graphs 27-28 Although far from complete, a similarity is noted between approximately corresponding time periods, notably September-December 1968 with September-November 1970 and December-June 1968-69 with November-August 1969-70, which does suggest that a regular cycle of activity is operating. What trapping data is available from Johnson's No. 3 Bore (locality 24) (see Tables 76 and 77) and Nunn's Bore (locality 27) (see Appendix O) for the same period is also plotted in Graphs 27-28, and although sparse, what is represented, does appear to present a somewhat similar pattern, though out of phase with those from Wobna Springs (locality 35).

Graph 29 was obtained by combining the trapping data available for each month at Wobna Springs (where more than one set of data available by calculating a mean) from different years into a single year. I have in this way attempted to provide as complete a picture for a hypothetical year as is possible with the scattered data available. It will be noted that in this form of presentation, the correlations between Wobna Springs (locality 35) and the other two localities are somewhat more similar than in Graph 28 , though still out of phase.

This apparent activity pattern may be due to the influence of lunar phases as discussed earlier. It is however possible that this form of presentation may conceal a component due to varying water temperatures attributable to seasonal changes in ambient temperature. If there is such a seasonal temperature effect on activity this is more likely to occur with fish inhabiting standing or slowly moving bodies of water than those in swiftly flowing streams where water temperature remains fairly constant.

6. AERIAL RESPIRATION.

C. eremius has been seen lying in open shallows of less than 1cm depth with the forepart of the body out of water during the middle of the day in warm summer weather at the Old Peake Homestead bore (locality 15) on 21.XI.69 : ambient temperature = 32.3°C, water temperature = 29.6°C - 35.6°C. Vigorous movements of the opercular of these fish suggested they were breathing air.

At Coward Springs railway bore (locality 34) on 22.II.68, during the early afternoon, 60 fish that had just been collected were placed in 5cm depth of water (water temperature = 30.5°C) in an enamel bucket in the shade. After 15 minutes under these crowded conditions the fish displayed signs of distress. Individuals approached the water surface with gaping mouths, air bubbles formed at the water/air interface, several fish soon collapsed and ceased all movement. Shortly thereafter fish began to leap repeatedly out of the water and to throw themselves against the wall of the bucket to which they remained attached for varying periods of time.

The fish were mostly attached to the wall by their ventral surface, presumably, principally by means of the suction disc formed by the united ventral fins. Some however attached by the sides of their bodies and held on by capillarity or by mucous adhesion. Whilst out of water such fish exhibited very active opercular movements and it appeared that they were breathing air.

The fish in the bucket leapt between approximately 1 and 15cm above the water surface and remained out of the water for periods varying between 25 and 115 seconds before returning. Clocked times of individual periods spent out of the water by some of the fish were as follows, 25, 40, 45, 85, 105, 115 seconds. On occasions some fish that leapt only a short distance out of water remained with the tail still immersed.

Upon returning to the water the fish usually slid back down the bucket wall but some actively threw themselves off the wall.

Several blades of a reed common at Coward Springs bore, _Typha angustifolia_ L., were later suspended into the bucket and subsequently several fish were observed to leap on to and attach to the surface of the blades. However the fish appeared to show no particular preference for the surface selected for attachment, whether bucket wall or reed blade.

All the fish in the bucket suddenly collapsed, ceased respiration and died 75 minutes after being introduced, presumably due to excessive depletion of the quantity of dissolved oxygen in the water.

On a subsequent visit to Coward Spring railway bore on 22.III.68, 20 freshly collected fish were placed in the same bucket in 2.5cm depth of water (water temperature = 28.5°C). Graph paper was placed around the internal wall of the bucket in order to measure the heights to which the fish were expected to leap from the water. After a period of 1 hour the fish had not behaved as on the previous occasion and attached themselves to the wall, although a few did leap a short distance of up to 5cm out of the water but immediately fell back. Water temperature however was 2.0°C lower on this occasion and the fish appeared less crowded. There was therefore probably a lower rate of dissolved oxygen depletion on this occasion and assuming that a certain critical oxygen level is the stimulus causing the fish to leap from the water this would account for the difference in behaviour on this occasion.

Fish maintained in laboratory tanks during warm weather and exposed to sun-light near windows, have been observed to lie for prolonged periods with the head and forepart of the body out of water resting on the surfaces of emerging clumps of silt and plant roots (Phragmites communis). Active opercular movements by these fish again suggest that aerial respiration is being performed in response to depleted dissolved oxygen levels.

The water in a laboratory tank (36 x 18 x 20cm deep) containing 5 fish was allowed to evaporate without being replaced during a 6 week period in January-February 1970. When the water depth reached zero the fish were observed, alive, lying on the surface of the damp silt. Whilst lying out of the water the fish continually opened and closed their mouths and operculae. This suggested that aerial respiration was being performed. The fish survived in this situation for 4 days until the silt bed dried out, whereupon they died, presumably due to dessication. These fish were not observed to attempt to burrow into the silt in response to the water level dropping to zero (see p. 58).

The ability to respire direct from the atmosphere is clearly an appropriate adaptation for fish inhabiting waters of high mineral content which are subject to relatively high temperatures and also to severe seasonal reduction through high evaporation rates in summer. Such factors must cause the aquatic environment to be subject to periods of quite low oxygen tension, a condition further exaggerated by cattle urine, faeces, decaying carcasses and the disruption of water beds by movement of the cattle. This latter effect is particularly prevelent in the Central Australian region, especially in the summer months when cattle converge on bores and springs. Aerial respiration would clearly constitute a useful and possibly important survival mechanism for any fish living in such circumstances.

Brown (1957) has pointed out that many fishes have been claimed to breath air on insufficient evidence and that in many instances air breathing has been ascribed on the basis of biological rather than physiological evidence. Nevertheless Brown (1957) does accept that non-physiological evidence may be convincing. I consider that the observations I have described here are strongly indicative of aerial respiration on the part of *C. eremius*.

Furthermore as Brown (1957) states, accessory air breathing organs may occur in almost any part of the alimentary canal or in the gill chamber, but that the use of gills themselves for aerial respiration is rare. I have examined the internal walls of opercular chambers of living *C. eremius* and have not noted any particular vascularization of the epithelium. This suggests that the opercular chambers can be disregarded as accessory air-breathing organs in this instance.

Aerial respiration nevertheless appears to be a possibly significant aspect of the biology of *C. eremius* and one which is clearly worthy of more detailed investigation.

Table 54

Range of Occupation and Relative Abundance of *C. eremius* along the stream at Wobna Spring (locality 35), over the period March 1968 to May 1971.

Data for 22.III.68 - 26.VII.68 inclusive and 1.III.71 - 31.V.71 inclusive, based on sightings only. Remainder based on trappings (see Appendix F) and sightings. The values above the line for each respective date indicates the total number of fish trapped at the particular stations, those below the number of males and females respectively, that is $\frac{10}{7/3}$ = a total of 10 fish comprising 7 males, 3 females; where the total number (above) exceeds the combined sex values (beneath) this is due to one or more immature fish being trapped and which could not be sexed.

Although a trap was regularly set at station 1, it invariably sank deeply into the soft bed present at that point so that it became ineffective. Hence, visual sightings were the only reliable guide to the presence and abundance or the absence of fish at that station.

The X marked along the line for each respective date indicates the station at which maximum number of fish were trapped on these particular dates.

Distance and positions of the various stations along the Wobna Spring (locality 35) stream are given in Appendix

Date Observed/ Trapped.	MAIN STREAM STATIONS											SIDE POOL STATIONS	
	1	2	3	4	5	6	7	8	9	10	11	12	13
22.III.68													
27.IV.68													
29.V.68	abundant												
30.VI.68	abundant												
26.VII.68													
1.VIII.68	2	2		47		101 X	48	8				1	
28.X.68	1					51 X	47						
15.XI.68	absent	2		6	13	36	53 X					4	15
19.XII.68	absent	4		36	71 X	59	31	7					
24.I.69	absent	0		1	5	6	11 X	6	3				
24.II.69	absent	0		11	14	21 X	16	4	10	17			
30.III.69	absent	0		4	6	20 X	4	5	11				
30.IV.69	absent	5		58 X	43	27	39	28	18	5	5		
25.VI.69	abundant 15	2		13	41 X	23	31	39	14	15	1		
13.XI.69	present	0		64	99 X	43	48	35			13	35	88
22.II.70	present	0		13	10	20 X	19	3	6	14	4		
11.IV.70	absent	0		15 7/7	12 6/3	24 6/19	48 18/25 X	10 7/3	9 8/4	23 13/10	10 14/4		
10.VI.70	absent	0		5 2/2 X	34 15/19 X	15 7/8	15 5/10	7 3/3	25 15/10	9 3/6	3 2/1		
23.VI.70	absent	0		16 7/6	17 9/8	37 15/22 X	10 2/8	19 7/7	8 5/3	8 3/5	8 3/5		
30.VII.70	absent	0		7 3/4	14 3/11	11 6/5	19 10/9	22 10/12	24 17/7	35 18/17 X	13 8/5		
23.VIII.70	absent	0		30 19/11 X	17 9/8	23 11/12	4 3/1	18 11/7	0	7 3/3	3 3/0		
27.XI.70	absent	0		18 7/11	19 13/5 X	16 6/9	8 3/5		1 1/0	1	1 1/0		
31.X.70	absent	0		2 0/2	9 3/6	13 6/6 X	4 2/2	3 2/1	3 2/1				
25.IX.70	abundant 5			18 10/8	23 15/8 X	13 7/6	17 10/7	4 2/2					
1.III.71	present			present	present	present							
31.III.71	present			present	present	present							
.IV.71	present			present	present	present							
31.V.71	abundant			present	present	present							

Table 55

Water Flow Rates, Wobna Spring (locality 35)

Flow rates recorded at different sections along the stream at Wobna Spring on 10.VI.70. They were determined from the mean value of six readings of the time a weighted phial took to be carried along a distance of 4 metres at each section.

Table 55

Section of Stream	Water Flow metres/sec.
Station 1. Spring head pool (at side opposite flow exit).	0
Station 2. (run, 2m either side).	0.32
Station 3. (run, 4m upstream of Station 3).	0.70
Midway between Stations 3-4.	0.66
Midway between Stations 4-5.	0.45
Station 5. (run, 2m either side).	0.39
Station 6. (run, 2m either side).	0.36
Station 7. (run, 4m upstream of Station 7).	0.46
Station 8. (run, 2m either side).	0.42
Station 9. (run, 2m either side).	0.56
Station 10. (run, 4m downstream)	0.38
Station 11. (run, 2m either side)	0.36
Side pool adjacent Station 10.	0

Figure 18

Equipment employed to study orientation in a water current.

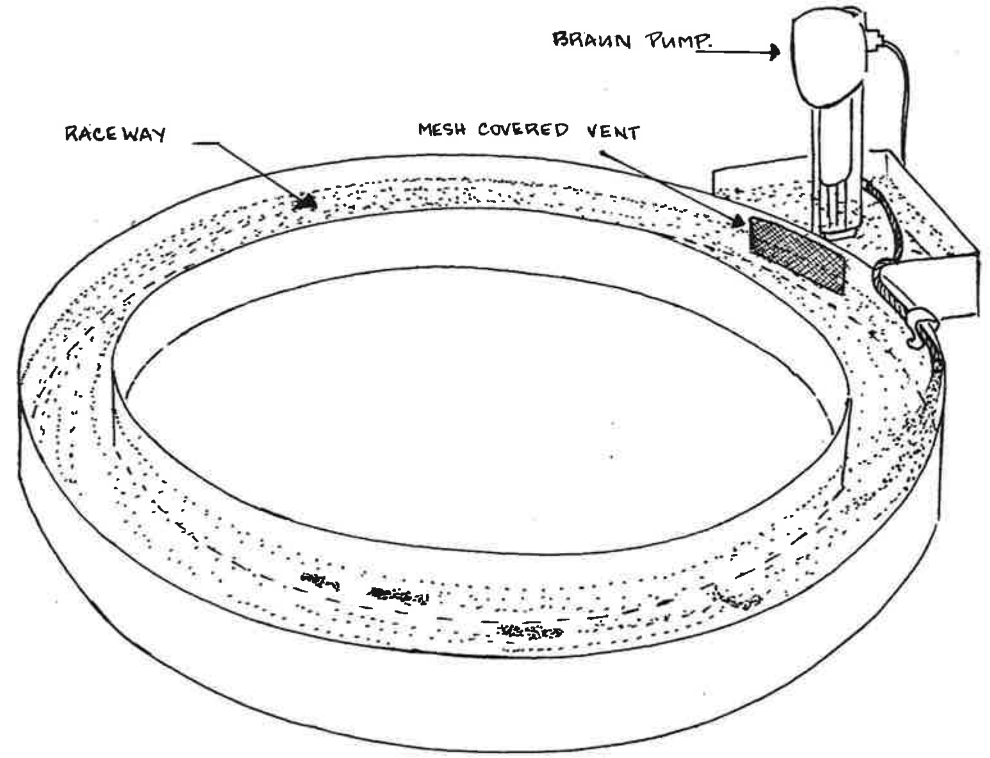

BRAUN PUMP.
RACEWAY
MESH COVERED VENT

Table 56

Response by *C. eremius* to a current of water flowing in a raceway.

→	Indicates subject is facing or swimming in a clockwise direction.
←	Indicates subject is facing or swimming in an anticlockwise direction.

Table 56

	Trial	Direction of Water Flow		
		Nil water stationary	Clockwise →	Anti-clockwise ←
VENTRAL FINS INTACT	1 (control)	← → ← ←		
	2		← ← ← ←	
	3			← → → →
	4		← ← ← ←	
	5			→ → → →
VENTRAL FINS ABSENT	6	← → → →		
	7		← → ← ←	
	8			→ → → →
	9		← → ← ←	
	10			→ → → →

Table 57

Total scores in each of five one hour long trials recording the presence or absence of blinded and non-blinded *C. eremius* under illumination or in darkness in a half masked tank. Scores made every five minutes. Five fish in each group.

Table 57

		Total number of "presences" recorded over a one hour period scoring every five minutes.			
		"Blinded"group		Vision-intact grou	
Trial	Date recorded	In light	In darkness	In light	In darknes
1	5.VIII.71	39	26	18	47
2	5.VIII.71	44	21	13	52
3	6.VIII.71	35	30	4	61
4	10.VIII.70	14	51	7	58
5	10.VIII.70	13	52	4	61
Totals		145	180	46	279
Percentages		44.6%	55.4%	14.1%	85.9%

Table 58

Responses to water flow by 5 blinded and 5 vision-intact *C. eremius* subjects.

Trials conducted 15.VII.71.

→ Indicates subject is facing, either stationary or swimming, in a clockwise direction.

← Indicates subject is facing, either stationary or swimming, in an anti-clockwise direction.

Table 58

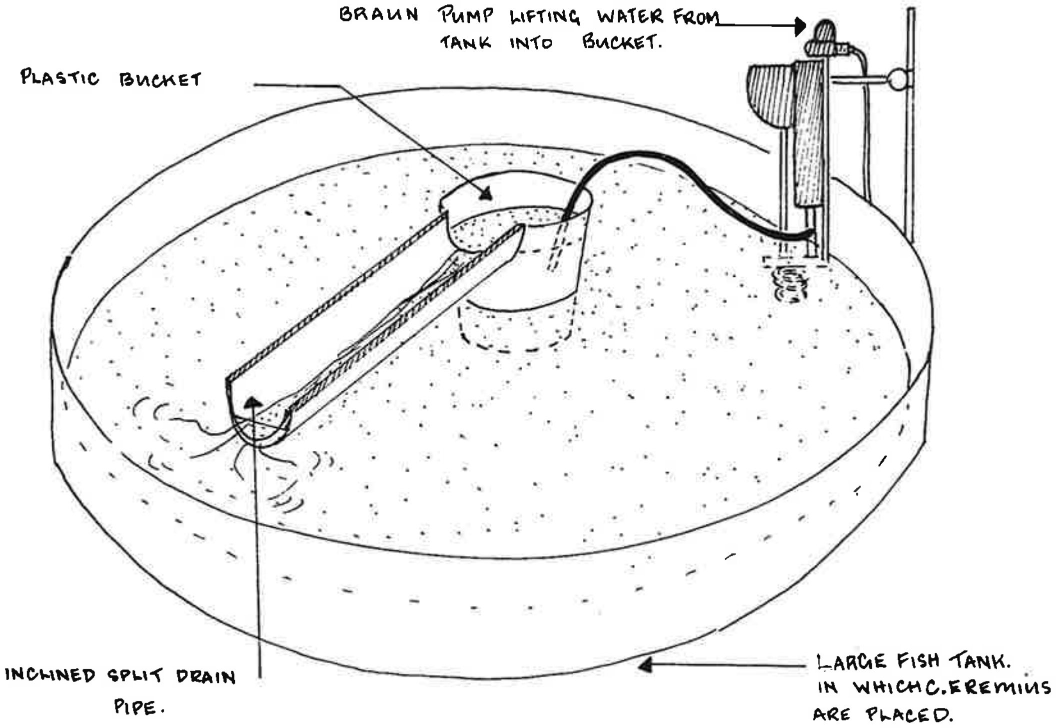
Trial	Nil (water stationary)		Direction of Water Flow			
			Clockwise		Anti-clockwise	
	Vision intact subject	Blind subject	Vision intact subject	Blind subject	Vision intact subject	Blind subject
1 (control)	→ ← → ← →	→ → ← → →				
2			← ← ← ← ←	← ← ← ← ←		
3					→ → → → →	→ → → → →
4			← ← ← ← ←	← ← ← ← ←		
5					→ → → → →	→ → → → →

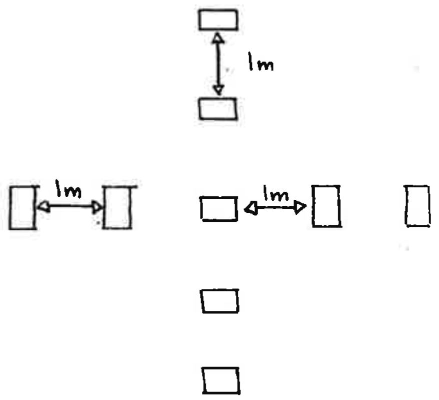
Figure 19

Equipment employed to study response to an artificial stream.

Figure 20

Pattern in which traps were set in pool "A" at Johnson's No. 3 Bore (locality 24).





FISH TRAPS PLACED AT 1metre INTERVALS.

Figure 21

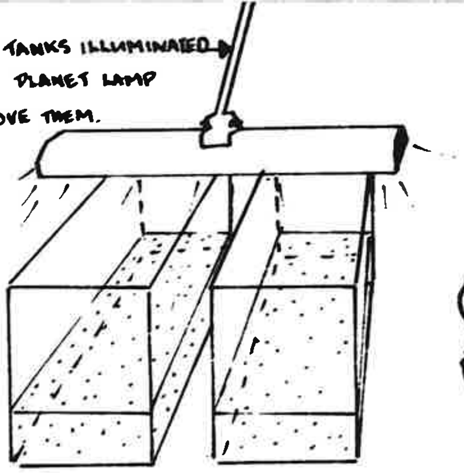
Equipment employed to study role of vision in feeding.

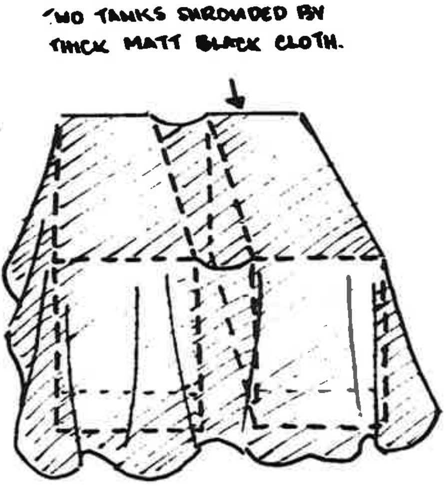
Figure 22

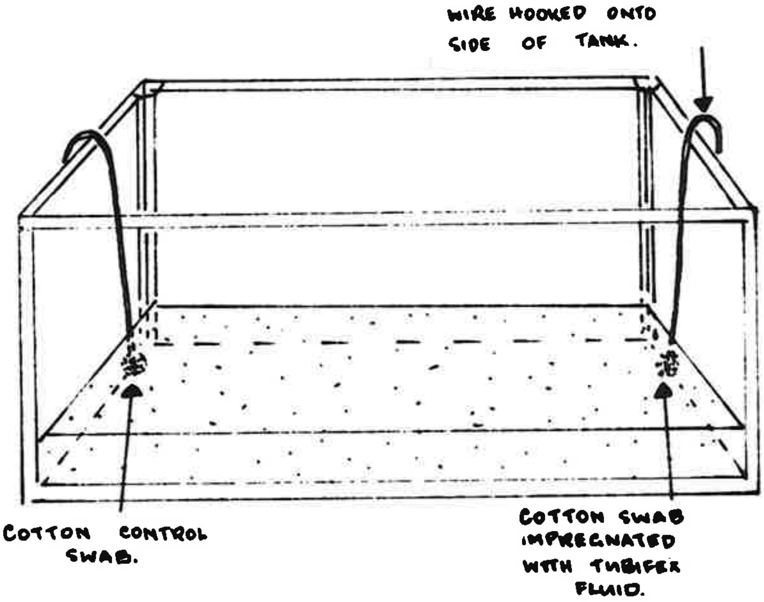
Equipment employed to study role of olfaction/gustation in feeding.

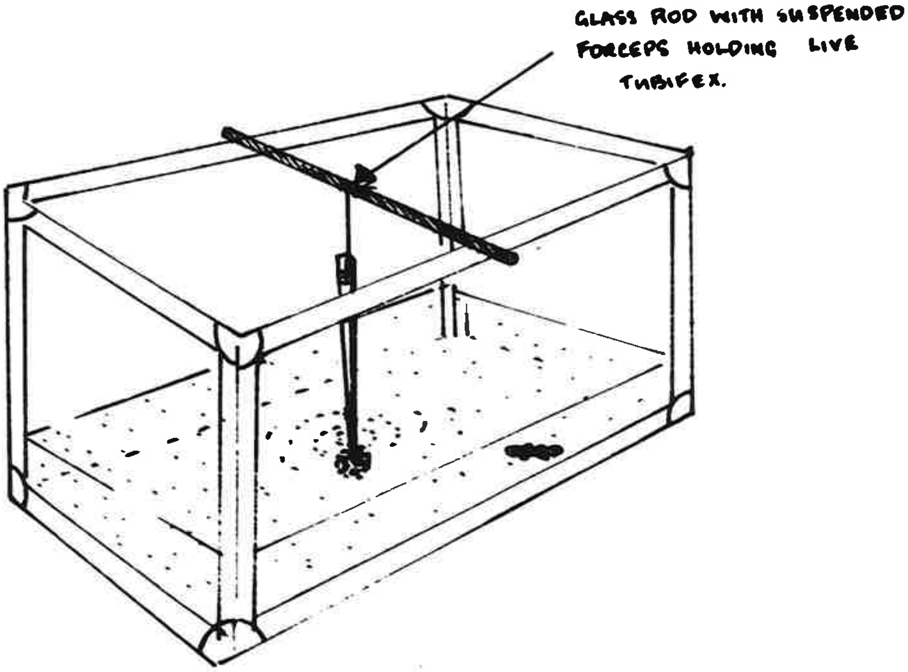
Figure 23

Equipment employed to study surface feeding.


TWO TANKS ILLUMINATED
WITH PLANET LAMP
ABOVE THEM.


TWO TANKS SHROUDED BY
THICK MATT BLACK CLOTH.


WIRE HOOKED ONTO
SIDE OF TANK.
COTTON CONTROL
SWAB.
COTTON SWAB
IMPREGNATED
WITH TUBIFEX
FLUID.


GLASS ROD WITH SUSPENDED
FORCEPS HOLDING LIVE
TUBIFEX.

Trial Date	Duration of expt.	Water Temp ^{0}C	No. of tubifex consumed at end of 2 hour period.
16.vi.71	day (1030-1230 hours	14.5	20
17.vi.71	day (1030-1230 hours	11.4	20
18.vi.71	night (2045-2245 hours	12.5	20
19.vi.71	night (2045-2245 hours	12.7	20

Table 59

Numbers of tubifex consumed, out of a total of 20, by 10 C. eremius during equal periods of time at night and in the day.

Table 60

Number of live tubifex consumed out of a total of 20 by 10 *C. eremius* (a) under illumination, (b) in darkness, during a 2 hour period by 8 *C. eremius*. Some subjects used for all trials.

Trial Date	Group	No. of tubifex consumed at end of 2 hour period	
		Under Illumination	In Darkness
25.ii.69	A	18	
	B	20	
	C		16
	D		20
27.ii.69	A		20
	B		20
	C	20	
	D	20	
6.iii.69	A	18	
	B	20	
	C		19
	D		20
13.iii.69	A	20	
	B	20	
	C		15
	D		19
17.iii.69	A		20
	B		20
	C	12	
	D	20	
26.iii.69	A	20	
	B	20	
	C		20
	D		20
9.iv.69	A		20
	B		20
	C	20	
	D	20	
14.iv.69	A	20	
	B	20	
	C		20
	D		20
TOTAL NO'S	CONSUMED	308	309

Table 60

Table 61

Number of (a) live (b) dead tubifex consumed out of a total of 20 in each instance, under [illegible] illumination, during a two hour period, by 8 *C. eremius*.

Same subjects used for all trials.

Trial Date	Group	No. of tubifex consumed at end of 2 hour period under illumination	
		live	dead
17.IV.69	A	13	
	B	18	
	C		20
	D		19
21.IV.69	A		19
	B		19
	C	20	
	D	16	
23.IV.69	A	20	
	B	20	
	C		19
	D		19
29.IV.69	A	13	
	B	17	
	C		20
	D		20
1.V.69	A		20
	B		20
	C	19	
	D	19	
5.V.69	A	20	
	B	20	
	C		20
	D		20
7.V.69	A		20
	B		20
	C	20	
	D	20	
21.V.69	A	20	
	B	10	
	C		17
	D		12
TOTAL NO'S CONSUMED		285	304

Table 61

Table 62

Number of tubifex consumed out of a total of 20 presented to each of several pairs of C. eremius for a period of 2 hours; two pairs presented with a live tubifex under illumination whilst other two pairs presented with dead tubifex in darkness.

Table 62

Trial	Date	Pair	No. of tubifex consumed	
			Live tubifex and illuminated	Dead tubifex and darkness
1	19.XII.69	A	12	
		B	20	
		C		20
		D		16
2	22.XII.69	A	8	
		B	19	
		C		17
		D		13
3	30.XII.69	A		18
		B		20
		C	18	
		D	12	
4	7.I.70	A		17
		B		11
		C	12	
		D	20	
	Total no's tubifex consumed		121	132

Trial Date	No. of tubifex consumed at end of two hour period.	
	Group devoid of ventral fins	Group with intact ventral fins
3.IV.70	2	14
13.IV.70	20	20
16.IV.70	20	20

Table 63

Number of live tubifex consumed out of a total of 20, in darkness, during a 2 hour period by

(a) 10 *C. eremius* with ventral fins intact,

(b) 10 *C. eremius* with ventral fins removed.

Table 64

Responses by _C_. _eremius_ to (a) tubifex macerate impregnated swab, (b) neutral control swab.

Table 64

Trial Date	Subject	Trial	Prepared Swab		Control Swab	
			No. approaches	No. Biting motions	No. approaches	No. Biting motions
14.v.70	1	a	43	8	60	1
		b	8	3	9	0
21.v.70	2	a	24	11	7	0
		b	20	0	1	0
22.v.70	3	a	27	28	5	0
		b	16	5	2	0
25.v.70	4	a	45	5	21	0
		b	8	0	2	0
Total No's approaches and biting motions			191	60	107	1

Figure 24

Equipment employed to compare response to light and darkness.

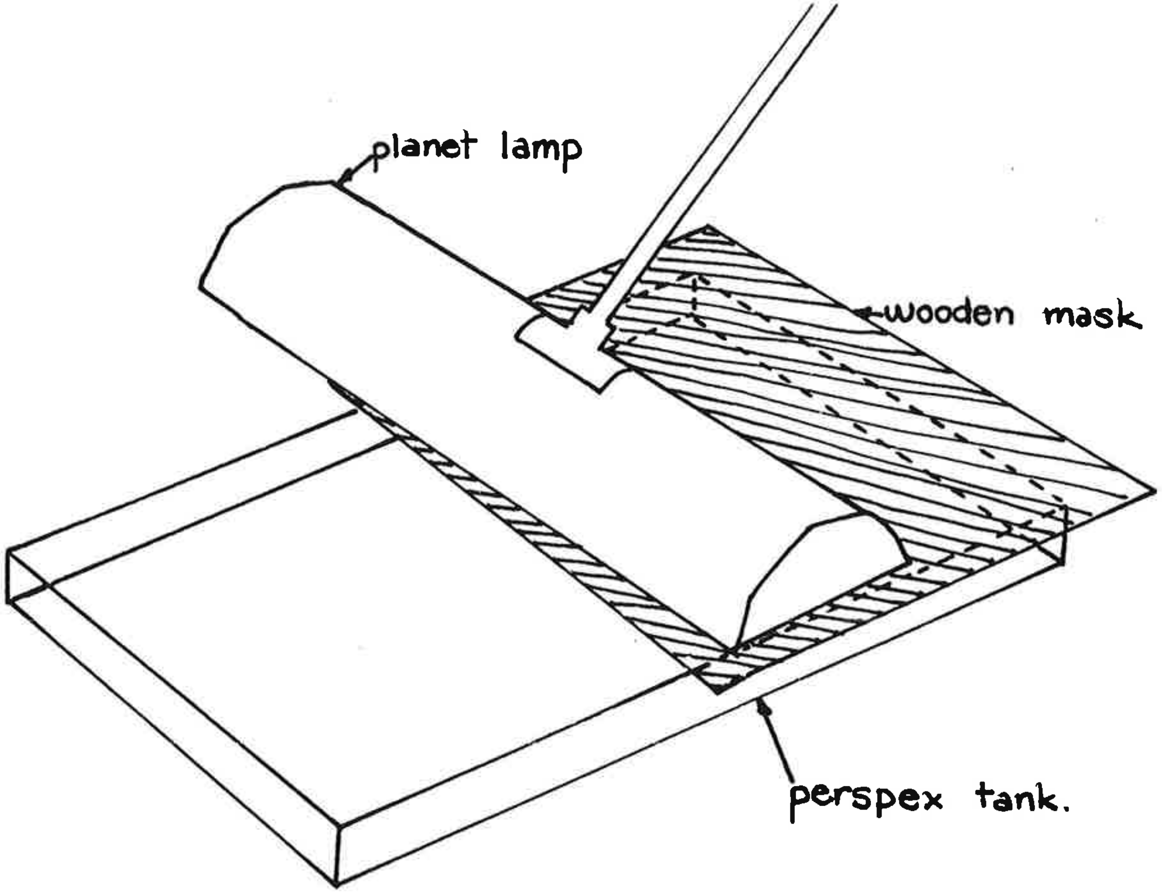

planet lamp
wooden mask
perspex tank.

Table 65

Light/dark preference by C. eremius. Ten subjects per trial. Different subjects for each pair of tirals. Each trial of one hour duration. Scoring every five minutes. In second trial of each pair, same subjects but light/dark sections reversed to opposite ends of tank.

Table 65

Trial	Date recorded	Total scores *C. eremius* present	
		In open under illumination	Under cover in darkness
1a	1.V.70	29	91
1b	1.V.70	49	71
2a	2.V.70	32	88
2b	2.V.70	18	102
3a	2.V.70	18	102
3b	2.V.70	34	86
4a	12.V.70	16	104
4b	12.V.70	32	88
5a	14.V.70	40	80
5b	14.V.70	25	95
6a	15.V.70	51	69
6b	15.V.70	38	82
Total		382	1058
%		26.5	73.5

Table 66

Background colour preference by <u>C. eremius</u>. Some ten subjects for both trials. Each trial of 2 hours duration. Scoring numbers present every five minutes. In second trial backgrounds reversed to opposite ends of tank.

Table 66

Trial	Date recorded	Total scores *C. eremius* present per trial		
		Over yellow	Over border	Over black
1	2.IV.70	102	7	131
2	2.IV.70	107	13	120
Total		209	20	251
%		43.5	4.2	52.3

Table 67

Background texture preference by C. eremius. Same five subjects all trials. Each trial of one hour duration. Scoring every five minutes. Position of the different textured beds (3ply wood) reversed after each trial.

Table 67

Trial	Date recorded	Total scores *C. eremius* present	
		Over course textured bed	Over smooth textured bed
1	30.VIII.71	5	60
2	30.VIII.71	2	63
3	30.VIII.71	26	39
4	31.VIII.71	12	53
5	31.VIII.71	0	65
Total		45	280
%		13.8	86.2

Table 68

Background medium preference by C. eremius, sand versus silt. Same ten subjects per trial. Each trial of one hour duration. Scoring numbers present every five minutes. In second trial backgrounds reversed to opposite ends of tank.

Table 68

Trial	Date recorded	Total scores *C. eremius* present per trial		
		Over course textured light coloured sand	Over border	Over fine textured dark coloured silt
1	27.II.70	42	2	86
2	27.II.70	51	2	77
Total		93	4	163
%		35.7	1.6	62.7

Trial	Date recorded	Total scores *C. eremius* present			
		In open	Amongst Algae		
			Total	Beneath	Atop
1a	26.II.70	30	100	43	57
1b	26.II.70	46	84	39	45
2a	4.III.70	7	123	72	51
Total		83	307	154	153
%		21.3	78.7	39.5	39.2

Table 69

Algae preference by *C. eremius*. Ten subjects per trial. Different subjects for each pair of trials. Each trial of one hour duration. Scoring every five minutes. In second trial of each pair, same subjects but vegetated section reversed to opposite end of tank.

Table 70

Times taken for C. eremius pigmentation to respond cryptically to changes in background colour. Employing same 14 subjects first two trials. Fewer subjects final two trials (due to deaths) but same batch.

Table 70

		Transferring from Black to White Background.		Transferring from White to Black Background.	
Trial	Date	Time taken for each subject to respond (seconds)	Mean response time	Time taken for each subject to respond (seconds)	Mean response time (seconds)
1	7.VII.71	21.0, 28.0, 15.0, 8.5, 8.5, 20.0, 9.0, 16.5, 10.5, 8.0, 4.3, 3.5, 6.5, 5.5	11.7		
2	8.VII.71			3.0, 4.5, 7.0, 7.0, 13.0, 3.0, 3.0, 3.0, 3.5, 32.0, 4.0, 6.0, 2.0, 29.0	8.6
3	9.VII.71	7.0, 5.0, 4.0, 3.5, 5.0, 4.0, 2.5, 3.0, 3.5, 7.0, 3.5, 3.5.	4.3		
4	10.VII.71			5.0, 3.0, 4.5, 2.5, 3.5, 7.5, 9.0, 6.0, 6.0, 6.0, 8.5.	5.6
		Range of response time	3.0-28.0 secs		2.0-29.0 secs
		Mean response time	8.3 secs		7.3 secs

Table 71

Times taken for pigmentation in blind and vision-intact C. eremius to respond cryptically to change in background colour. Employing five blind subjects and five vision intact subjects.

Table 71

Trial	Date	Transferring from Black to White background.		Transferring from White to Black background.	
		Time taken to respond by vision-intact subjects (seconds)	Time taken to respond by blind subjects (seconds)	Time taken to respond by vision-intact subjects (seconds)	Time taken to respond by blind subjects (seconds)
1	13.VII.71	9.0, 5.0, 4.5, 4.0, 7.0.	11.0, 22.0, 4.0, 7.5, 6.5		
2	14.VII.71			6.0, 8.0, 6.0, 8.0, 5.5.	16.5, 21.0, 27.0, 22.0, 8.0.
Mean time	Response (secs)	5.9	10.2	6.7	18.9

Figure 25

Setting traps in pool at Johnson's No. 3 Bore (locality 24).

Table 72

Results of Trappings conducted at Johnsons No. 3 Bore (locality 24) large pool, Series 1A - 4A.

Series	Date	Day or night settings	Setting hours	No. of hrs. set	Phase of Moon.	Numbers Trapped Total Count	 % of first trappings in each series
1A	20-21.XII.68	Night	2000 hrs. to 0400 hrs.	8	New	473	100
	21.XII.68	Day	0900 hrs. to 1700 hrs.	8		67	14.1
	21-22.XII.68	Night	2000 hrs. to 0400 hrs.	8	New	315	66.1
2A	31.III.69 - 1.IV.69	Night	1900 hrs. to 0300 hrs.	8	First ¼	334	100
	1.IV.69	Day	0700 hrs. to 1500 hrs.	8		96	28.7
	1-2.IV.69	Night	1900 hrs. to 0300 hrs.	8	First ¼	119	55.6
3A	4.V.69	Day	0800 hrs. to 1600 hrs.	8		417	100
	4-5.V.69	Night	2000 hrs. to 0400 hrs.	8	Full	190	45.6
	5.V.69	Day	0800 hrs. to 1600 hrs.	8		139	33.3
	5-6.V.69	Night	2000 hrs. to 0400 hrs.	8	First ¼	90	21.7
4A	23-24.XI.69	Night	2000 hrs. to 0400 hrs.	8	Full	82	
	26.XI.69	Day	0800 hrs. to 1200 hrs.	4		158	100
	27.XI.69	Night	2000 hrs. to 2400 hrs.	4	First ¼	158	100

Table 72

Table 73

Results of Trappings conducted at Johnsons No. 3 Bore (locality 27) large pool, Series 5A and 6A.

Series	Date	Day or night settings	Setting hours	No. of hrs. set	Phase of Moon and Cloud Conditions				Numbers Trapped					
									Combined Totals			Day/Night %		
						♂♂	♀♀	Total	♂♂	♀♀	Both Sexes	♂♂	♀♀	Both Sexes
5A	13.VI.70	Day	0800 hrs. to 1600 hrs.	8		10	36	46	85	154	239	100	100	100
	14.VI.70	"				24	45	69						
	15.VI.70	"				32	41	73						
	16.VI.70	"				19	32	51						
	17-18.VI.70	Night	2000 hrs. to 0400 hrs.	8	Full (no cloud cover)	23	37	60	82	105	187	96.6	68.2	79.5
	18-19.VI.70	"			Full (90-100% cloud cover until 2400 hrs.)	24	32	56						
	19-20.VI.70	"			Full (100% cloud cover throughout most of setting period)	11	15	26						
	20-21.VI.70	"			Full (no cloud cover)	24	21	45						
6A	25-26.VIII.70	Night	2000 hrs. to 0400 hrs.	8	Last ¼ rising 0300 hrs. (no cloud cover)	47	66	113	183	281	464	77.2	61.6	66.9
	26-27.VIII.70	"			Last ¼ rising 0330 hrs. (no cloud cover)	45	86	131						
	27-28.VIII.70	"			Last ¼ rising 0400 hrs.	47	77	124						
	28-29.VIII.70	"			New	44	52	96						
	30.VIII.70	Day	0800 hrs. to 1600	8		70	125	195	237	456	693	100	100	100
	31.VIII.70	"				31	77	108						
	1.IX.70	"				47	107	154						
	2.IX.70	"				89	147	236						

Table 73

Table 74

Results of trappings conducted at Johnson's No. 3 Bore (locality 24), in small pool, series 1B - 3B.

Table 74

Series	Date	Day or night settings	Setting hours
1B	29-30.X.68	night	1930 hrs to 0530 hrs
	30.X.68	day	0830 hrs to 1830 hrs
	30-31.X.68	night	1930 hrs to 0530 hrs
2B	20-21.XII.68	night	2000 hrs to 0400 hrs
	21.XII.68	day	0900 hrs to 1700 hrs
	21-22.XII.68	night	2000 hrs to 0400 hrs
3B	23-24.XI.69	night	2030 hrs to 0430 hrs
	24.XI.69	day	0830 hrs to 1630 hrs

Table 75

Results of trappings conducted at Johnson's No. 3 Bore (locality 27) small pool, Series 4B.

Table 75

Series	Date	Day or night setting	Setting hours	No. of hrs. set	Phase of moon and cloud cover	No. of traps per setting	Numbers trapped			Combined totals			Day/Night %		
							♂♂	♀♀	Total	♂♂	♀♀	Total	♂♂	♀♀	Total
4B	14.VI.70	Day	0800hrs to 1600hrs	8		4	58	89	147	127	171	298	100	100	100
	15.VI.70		"	"		"	37	52	89						
	16.VI.70		"	"		"	32	30	62						
	17-18.VI.70	Night	2000hrs to 0400hrs	8	Full (no cloud cover)	4	40	31	71	123	87	210	96.8	50.8	70.5
	18-19.VI.70		"	"	Full (90-100% cloud cover until 2400 hrs		25	27	52						
	19-20.VI.70		"	"	Full (100% cloud cover)		58	29	87						

Table 76

Total night trapping counts at Johnson's No. 3 Bore (locality 24) according to lunar phases.

Data from table

Table 76

Trapping Date	Lunar Phase			
	New Moon	1st Qtr.	Last Qtr.	Full
20-21.XII.68	473			
21-22.XII.68	315			
31.III.69-1.IV.69		334		
1-2.IV.69		119		
4-5.V.69				190
5-6.V.69				90
23-24.XI.69		82		
17-18.VI.70		60		
18-19.VI.70		56		
19-20.VI.70				26
20-21.VI.70				45
25-26.VIII.70			113	
26-27.VIII.70			131	
27-28.VIII.70			124	
28-29.VIII.70			96	
Mean Count	394.0	130.2	116.0	87.7
		Mean trapping count combined quarter phases 123.9		
	Mean trapping count New Moon and quarter phases combined 173.0			

Table 77

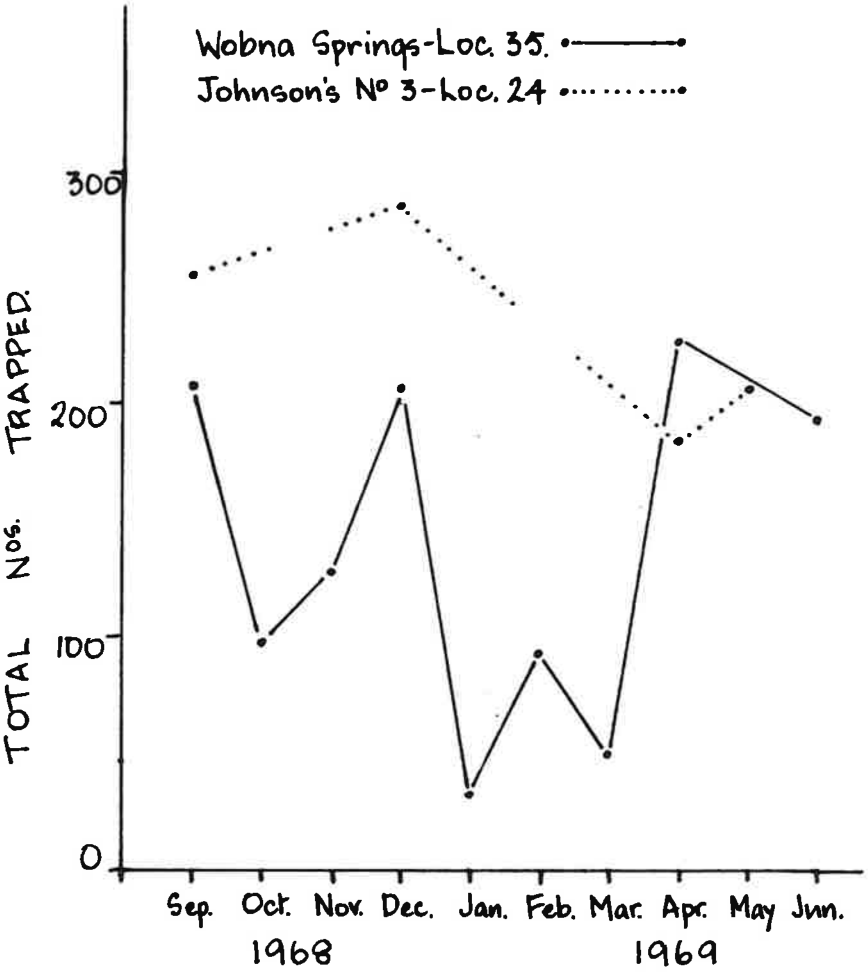
Total overnight trapping counts at Wobna Spring (locality 35) according to lunar phases. Data from Appendix.

Table 77

Trapping Date	New Moon	1st Qtr.	Last Qtr.	Full Moon
1.IX.68		209		
15.XI.68			129	
19.XII.68			208	
24.I.69	32			
24.II.69		93		
30.III.69		50		
30.IV.69		228		
25.VI.69		194		
13.XI.69	425			
22.II.70				89
11.IV.70	151			
11.VI.70	113			
22.VI.70				118
30.VII.70			145	
23.VIII.70				102
27.IX.70			64	
31.X.70	34			
25.XI.70			80	
Mean trapping Count	151.0	154.8	125.2	103.0
		Mean trapping count combined quarter phases 140.0		
	Mean trapping count New Moon and Quarter phases combined 143.7			

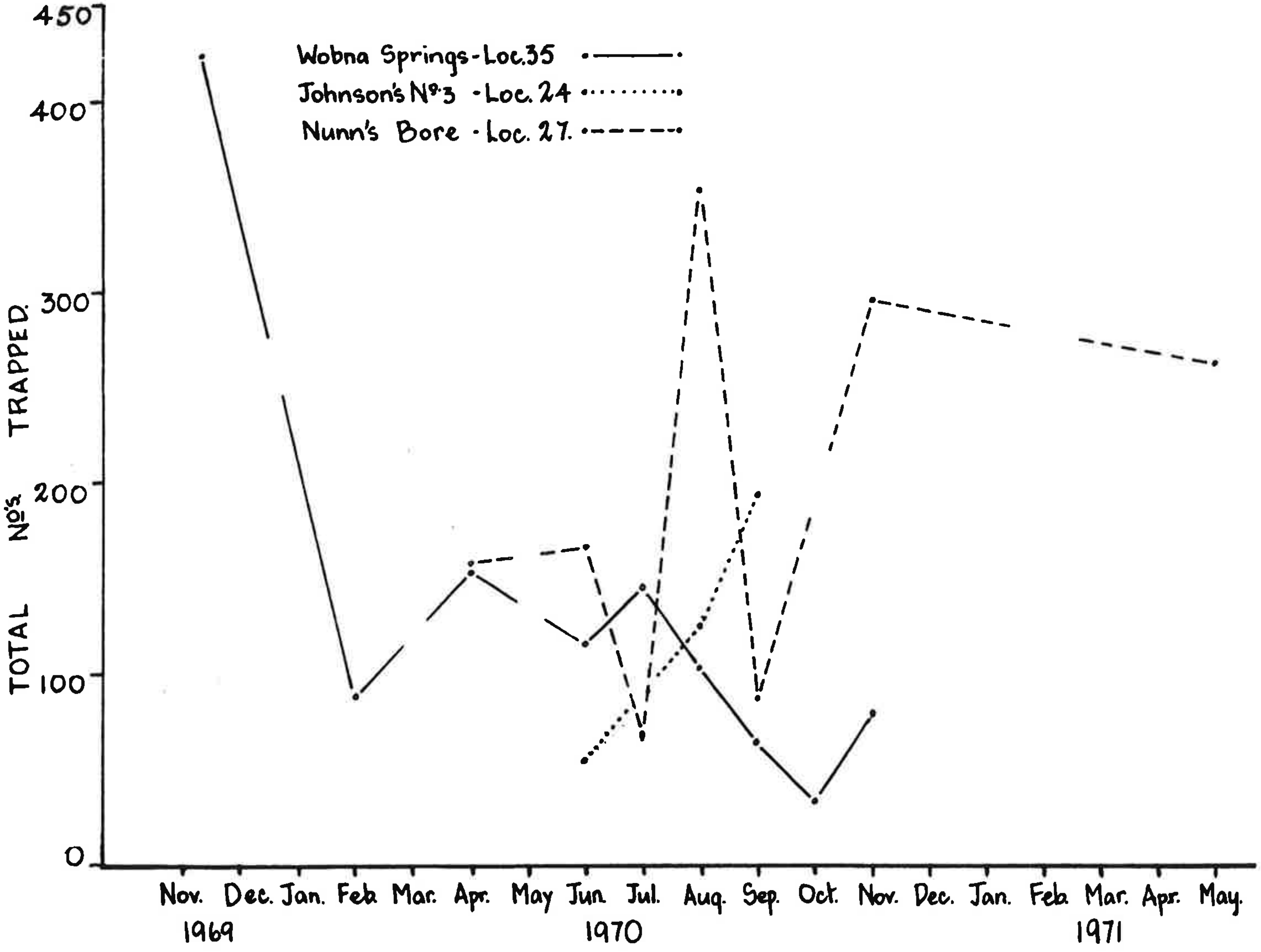
Graph 27

Total numbers of _C_. _eremius_ trapped at Johnson's No. 3 Bore (locality 24) and Wobna Spring (locality 35) on different occasions between September 1968 and June 1969.


Wobna Springs-Loc. 35.
Johnson's Nº 3-Loc. 24
TOTAL Nos. TRAPPED
0
100
200
300
Sep.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
Jun.
1968
1969

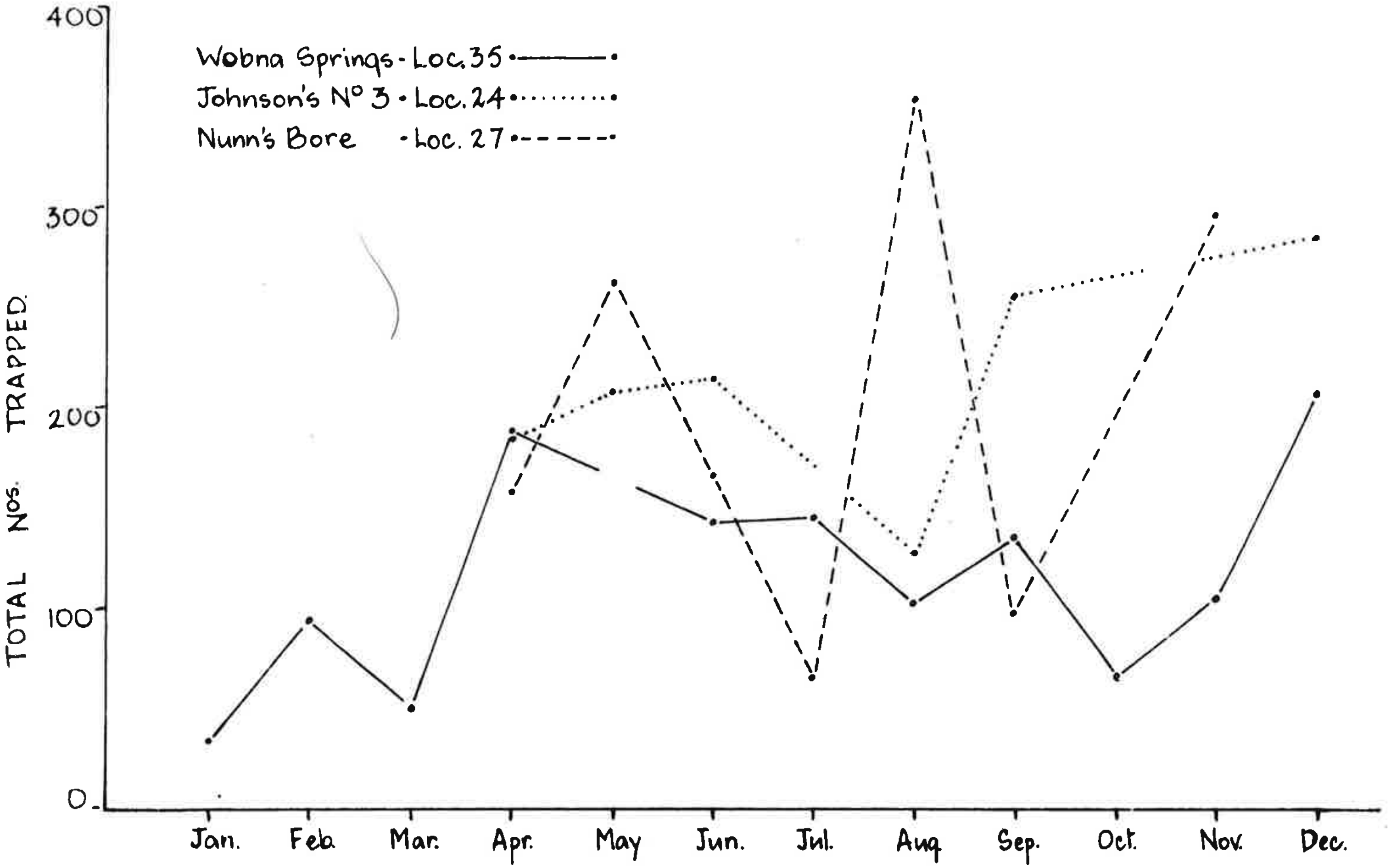
Graph 28

Total numbers of _C. eremius_ trapped at Johnson's No. 3 Bore (locality 35), Nunn's Bore (locality 27) and Wobna Spring (locality 35) on different occasions between November 1969 and May 1971.


450
400
300
200
100
0
TOTAL Nos. TRAPPED.
Wobna Springs - Loc. 35
Johnson's No. 3 - Loc. 24
Nunn's Bore - Loc. 27.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May.
1969
1970
1971

Graph 29

Estimated trapping rates of _C_. _eremius_ at Johnson's No. 3 Bore (locality 24), Nunn's Bore (locality 27) and Wobna Spring (locality 35) on different occasions throughout a hypothetical year.


Wobna Springs - Loc. 35
Johnson's N° 3 - Loc. 24
Nunn's Bore - Loc. 27
TOTAL N^os. TRAPPED
400
300
200
100
0
Jan.
Feb.
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.

IX DISCUSSION

On the available data the fish appears to be one species, C. *eremius*, throughout its known range, because an examination of specimens from all known populations has failed to establish any consistent morphological differences between them. Further, the species, as indicated in section III, is extremely widespread in central Australia within the Lake Eyre drainage system.

How has the fish managed to maintain itself, apparently as a single species, particularly as the aquatic environment of the central Australian region is fragmented, with populations restricted to scattered artesian springs and bores and occasional meteoric water masses? Furthermore, what mechanisms enable the fish to occur, either permanently or transiently, within practically every type of water mass within its range of distribution?; including pools and streams associated with either artesian springs or bores of widely ranging salinity and ionic composition, water holes and man-made reservoirs containing meteoric water of relatively low salinity (though prone to increasing salinity during periods of low rainfall and high evaporation) and the ephemeral waters of normally dry rivers and creeks; all of which are subject to frequent and sometimes extreme changes of salinity, temperature and probably dissolved oxygen levels.

The morphology of the species is typical of fish adapted to a demersal habitat in a flowing stream (such as is found associated with artesian springs and bores) with a partly dorso-ventrally compressed and streamlined body and ventral fins united to form a well developed and, as demonstrated (see p. 108), functional suction disc which could assist in preventing it being swept down stream. Even if not normally used in this way by those fish inhabiting some of the more slowly flowing artesian waters or stationary water masses (for example, water holes) the suction disc will be useful in a fluctuating environment in which changes in flow rates can be extreme, over long or short periods of time. For example, the outflow at Wobna Spring (locality 35) periodically increases dramatically so that the normally gently flowing stream becomes a **virtual** torrent for a short time. Without the benefit of the ventral suction disc it is probable that under such stress much of the population would be swept away. Clearly similar mechanical stresses can also arise in flood waters.

The ability of C. eremius to inhabit widely varying and fluctuating environments may be explained, in part, by its extreme physiological lability as evident by the wide range of physical environmental conditions (water temperature, pH, salinity, dissolved oxygen levels) under which it is known to occur and in which it can survive under experimental conditions (see section VI). Thus, in the field the fish has been taken in waters whose salinities vary from 205 to 12,500 p.p.m. and in the laboratory it has tolerated for a period of up to 27 days direct immersion in distilled water and prolonged periods in salinities as low as 147 p.p.m. and as high as 37,580 p.p.m. respectively. Although not necessarily true indicators of the degree of tolerance in the field these experiments demonstrate the potential capacity of the species to survive, at least temporarily, extreme salinity levels well beyond those from which it has been recorded in the field.

Similarly the species has been found in waters with a wide range of temperature, having been taken in the field during winter from water at 9.0°C and in summer in water up to 40°C (see p. 48). In addition it can tolerate temperatures down to at least 7.5°C for some time and for short periods it has been observed to enter water in excess of 40°C without apparent harmful effect.

In respect of dissolved oxygen levels the data are limited. Nevertheless fish have been observed inhabiting waters with recorded oxygen levels as low as 0.8 p.p.m.

However the influence of these levels and fluctuations of the environment may not be as real as my field measurements might suggest as the fish appear to be able to take compensating actions under conditions of particular stress. The fish have been found to take advantage of natural thermal refuges present in their environment, particularly in summer months when sections of some water masses heat to lethal levels (see p. 61); it has also been established that the species acclimates to seasonal changes in temperature and to environmental thermal gradients and in the laboratory it acclimates rapidly to large and sudden increases in water temperature (see pp. 68-70). Under conditions of presumed low dissolved oxygen tension the fish has been observed to lie out of water apparently surviving by aerial respiration (see p. 143).

However, such behavioural compensating responses as seeking thermal refuges or resorting to aerial respiration are likely to be of value only in times of particular stress because of the wide range of water temperatures, salinities and oxygen levels within which it has been observed or experimentally established the fish can survive.

It appears, on the basis of trapping data, that the overriding factor determining the sections of an artesian waterway preferred by _C. eremius_ is the amount of aquatic vegetation present. Certainly I have been unable to establish any correlation, other than exclusion, between the abundance of *C. eremius* and any of the physical parameters measured.

Further, the species is omnivorous and utalizes as food that flora and fauna, namely filamentous algae (various species, but commonly *Spirogyra* sp.) which is present in virtually every artesian waterway in the Lake Eyre drainage basin, a range of small animals which typically inhabit such waters (insects, ostracods, copepods) and detritus. Thus there is no apparent specialization in diet or feeding habit to restrict the fish's occurrence within the inhabited range.

It has been argued that floodwaters constitute the major way in which the fish is dispersed (see p. 17). If this be so, as seems likely, then the frequent and extensive flooding of the central Australian region would probably assist movement and exchanges of fish between populations and thus presumably ensure gene interchange.

In the light of these observations it appears that there is no obvious factor (apart from possibly topographical barriers restricting the flow of floodwaters) to restrict the occurrence of *C. eremius* to any of the scattered waters of the central Australian region and that there is probably frequent movements between populations. The occurrence of only one species over such a wide area is therefore understandable.

Any species occurring within such a wide range of physical environmental conditions, which are subject to violent fluctuations on occasions, would be expected to have special breeding features to ensure a maximum chance of survival. Although, as pointed out in section IV, nothing has been observed of actual breeding behaviour, the anal papilla present in both sexes does suggest that some form of pre-hatching parental care at least may possibly operate. Usually the young of fish with relatively low egg production, as in this case, have a relatively high survival rate and it has been shown that in spite of the low number of eggs produced C. eremius is able to build up population numbers very rapidly as at the Blanche Cup Spring (locality 36), (see p. 30).

The other fish most typically found in association with C. eremius or inhabiting similar waters in the central Australian region are the equally small Craterocephalids which do not appear to pose a significant predatory threat. The primary predatory force seems likely to be aquatic birds, but this influence appears to be reduced to a minimum as a result of the fish's strong negative phototactism (see p. 124) and a preference to inhabit vegetation cover rather than open water (see p. 129). In addition the fish's demonstrated ability to rapidly change colour to conform cryptically with its background (see p. 130) undoubtedly enhances its ability to avoid the attention of potential predators.

Because, as has been shown, olfactory/gustatory senses are the primary means by which the species locates food (see p. 121) the fish is readily able to feed at night as well as in the day, thus reducing its dependence on daylight feeding and possibly its chances of exposing itself unnecessarily to predators. This ability to locate food by means of non-visual senses is also a suitable adaptation to a fish which spends a considerable amount of time under the cover of vegetation, in particular the filamentous algae which constitute part of and harbours some of the animal components of its diet.

Thus C. eremius inhabits an environment in which salinity, ionic composition, temperature and possibly dissolved oxygen may grade and fluctuate rapidly over a wide range. It is clear that the fish is well adapted, both physiologically and behaviourily to acclimate to or survive, at least temporarily, such stresses.

The species is adaptive and opportunistic, features which have ensured its survival in waters subject to extreme change and have probably ensured its integrity as a single species.

X APPENDICES

Appendix

A. Inland water localities inspected and fishes taken therefrom, 1967 - 70.

B. Central Australian fishes collected and registered in the South Australian Museum, 1968 - 70.

C. Some major flooding events in the Lake Eyre basin region of central Australia.

D. Description of wire mesh trap.

E. Physical and non-physical data recorded at Coward Springs Railway Bore (locality 34), December 1967 - January 1969.

F. Physical and non-physical data recorded at Wobna Spring (locality 35), May 1968 - November 1970.

G. Bottom water temperatures and differences from sub-bed temperatures, Coward Springs Railway Bore (locality 34).

H. Bottom water temperatures and differences from sub-bed temperatures, Wobna Spring (locality 35).

Appendix	
I.	Length-frequencies of trapped collections from Johnson's No. 3 Bore (locality 24) - pool A.
J.	Length-frequencies of trapped collections from Johnson's No. 3 Bore (locality 24) - pool B.
K.	Length-frequencies of trapped collections from Johnson's No. 3 Bore (locality 24) - pool C.
L.	Length-frequencies of trapped collections from Nunn's Bore (locality 27).
M.	Length-frequencies of trapped collections from Wobna Spring (locality 35).
N.	Length-frequencies of trapped collections from Blanche Cup Spring (locality 36).
O.	Trap counts at Nunn's Bore (locality 27).
P.	Trap counts at Wobna Spring (locality 35).
Q.	Australian Mineral Development Laboratories reference numbers to water analyses.

Appendix

R. Analyses of test mediums employed in salinity tolerance trials.

S. Salinity tolerance trials data.

T. Gonad, Anal Papilla and Standard Length measurements recorded from male and female *C. eremius* sampled from Nunn's Bore (locality 27), April 1970 - May 1971.

U. Meristic data recorded from a collection made at Blythe Bore (locality 17).

V. Statistical reports .

Appendix A

Inland water localities inspected and Fishes taken therefrom during the period 1967-70.

* The Geographical Co-ordinates and Grid References are taken from the 1:250,000 Topographic Maps Series R502, prepared by the Division of National Mapping and printed by the Commonwealth Government Printer, Canberra.

\+ The term meteoric refers to surface waters originating from rainfall.

Locality No.	Locality	Geographical Co-ordinates		Map Sheet	Grid Reference	Date Inspected	Fish species collected (if any)	Type of Aquatic Site
1/1	Dalhousie Springs, Main Spring	26° 26'S (approx)	135° 30'E (approx)	Dalhousie SG 53-11	345718 (approx)	3-6.VIII.68 18-19.XI.69	*Neosilurus* sp. *Craterocephalus stercusmuscarum* *Chlamydogobius eremius* *Mogurnda mogurnda*	Artesian
1/2	Spring 2 (approx 1.6Km east of locality 1/1)	26° 26'S (approx)	135° 30'E (approx)	Dalhousie SG 53-11	345718 (approx)	5.VIII.68	*Neosilurus* sp. *Craterocephalus stercusmuscarum*	Artesian
1/3	Spring 3 (approx 0.8 Km west of spring 1)	26° 26'S (approx)	135° 30'E (approx)	Dalhousie SG 53-11	345718 (approx)	5.VIII.68	*Madigania unicolor* *Craterocephalus stercusmuscarum* *Craterocephalus fluviatilis*	Artesian
1/4	Spring 4 (approx 1.6Km west of spring 1)	26° 26'S (approx)	135° 30'E (approx)	Dalhousie SG 53-11	345718 (approx)	5.VIII.68	*Neosilurus* sp. *Craterocephalus stercusmuscarum* *Chlamydogobius eremius* *Mogurnda mogurnda*	Artesian
1/5	Spring 5 (approx 1.2Km south of spring 1)	26° 26'S (approx)	135° 30'E (approx)	Dalhousie SG 53-11	345718 (approx)	19.XI.69	*Neosilurus* sp. *Chlamydogobius eremius* *Craterocephalus stercusmuscarum* *Mogurnda mogurnda*	Artesian
1/6	Spring 6 (approx 4.8Km south of spring 1)	26° 26'S (approx)	135° 30'E (approx)	Dalhousie SG 53-11	345718 (approx)	19.XI.69	*Chlamydogobius eremius*	Artesian
1/7	Spring 7 (approx 1.2Km north-west of spring 1)	26° 26'S (approx)	135° 30'E (approx)	Dalhousie SG 53-11	345718 (approx)	19.XI.69	*Neosilurus* sp.	Artesian
2	Belts Creek	26° 40'S	135° 12'E	Dalhousie SG 53-11	311689	2.VIII.68		Meteoric ephemeral
3	Junction of Stevenson and Hamilton Rivers	26° 40'S	135° 18'E	Dalhousie SG 53-11	323689	2.VIII.68	*Madigania unicolor*	Meteoric ephemeral
4	Hamilton River Crossing	26° 43'S	135° 06'E	Dalhousie SG 53-11	301684	2.VIII.68		Meteoric ephemeral
5	Alberga River Crossing	27° 8'S (approx)	135° 22'E (approx)	Oodnadatta SG 53-15	332633 (approx)	1.VIII.68	*Craterocephalus eyresii* *Madigania unicolor*	Meteoric ephemeral
6	Mount Sarah Dam	27° 17'S (approx)	135° 23'E (approx)	Oodnadatta SG 53-15	335615 (approx)	20.XI.69	*Madigania unicolor*	Meteoric permanent
7	Forrest's Waterhole	27° 30'S	135° 24'E	Oodnadatta SG 53-15	335588	15.XI.69	*Madigania unicolor* *Chlamydogobius eremius*	Meteoric semi-permanent
8	Hookey's Waterhole	27° 36'S	135° 26'E	Oodnadatta SG 53-15	338577	9.VIII.68		Meteoric semi-permanent
9	Cramp's Camp Waterhole	27° 39'S	135° 24'E	Oodnadatta SG 53-15	336569	2.V.69	*Madigania unicolor*	Meteoric semi-permanent

10	North Creek	27° 44'S	135° 36'E	Oodnadatta SG 53-15	357559	31.VII.68		Meteoric semi-permanent
11	Ockenden Spring	27° 51'S	135° 44'E	Oodnadatta SG 53-15	372546	31.VII.68		Artesian spring (very minor flow)
12	Algebuckina Waterhole	27° 54'S	135° 49'E	Oodnadatta SG 53-15	380546	31.VII.68	Craterocephalus eyresii Madigania unicolor Chlamydogobius eremius	Meteoric permanent
13	Wood Duck Bore	28° 00'S	136° 13'E	Oodnadatta SG 53-15	423528	21.XI.69	Chlamydogobius eremius	Artesian
14	Peake Creek	28° 02'S	135° 48'E	Warrina SH 53-3	380523	30.VII.68	Chlamydogobius eremius	Ephemeral
15	Old Peake Homestead Bore	28° 05'S	135° 54'E	Warrina SH 53-3	390518	22.XI.69	Chlamydogobius eremius	Artesian
16	Freeling Spring	28° 04'S	135° 54'E	Warrina SH 53-3	390519	23.XI.69	Craterocephalus eyresii Craterocephalus stercusmuscarum Chlamydogobius eremius	Artesian
17	Blythe Bore	28° 12'S	136° 00'E	Warrina SH 53-3	400504	23.XI.69	Chlamydogobius eremius	Artesian
18	Birribirriana Spring	28° 12'S	135° 43'E	Warrina SH 53-3	369503	21.XI.69	Chlamydogobius eremius	Artesian
19	Nilpinna Spring	28° 13'S	135° 42'E	Warrina SH 53-3	367502	21.XI.69	Neosilurus sp. Cratercephalus fluviatilis Chlamydogobius eremius	Artesian
20	Cardajalburrana Spring	28° 11'S	135° 33'E	Warrina SH 53-3	352505	21.XI.69		Artesian
21	Salt Waterhole	28° 24'S (approx)	136° 25'E (approx)	Warrina SH 53-3	444479 (approx)	11.VIII.68		Meteoric ephemeral
22	Mussel Waterhole	28° 13'S	136° 23'E	Warrina SH 53-3	441471	10.VIII.68		Meteoric ephemeral
23	Honeymoon Bore	28° 58'S	136° 28'E	Warrina SH 53-3	442411	Sept. 1970		Artesian
24	Johnson's No. 3 Bore	28° 19'S	136° 31'E	Lake Eyre SH 53-4	456489	Aug. 1968	Craterocephalus eyresii Chlamydogobius eremius	Artesian
25	Anna Creek	29° 02'S	136° 17'E	Billa Kalina SH 53-7	4240	12.VIII.68		Meteoric ephemeral
26	Ellow Waterhole	29° 00'S (approx)	136° 00'E (approx)	Billa Kalina SH 53-7	4539	12.VIII.68		Meteoric ephemeral
27	Nunn's Bore	29° 00'S (approx)	136° 00'E (approx)	Billa Kalina SH 53-7	4539	Aug. 1968	Chlamydogobius eremius Craterocephalus eyresii	Artesian

28	Warriner's Creek	29° 09'S 136° 32'E	Curdimurka SH 53-8	456388	28.VII.68	Chlamydogobius eremius	Meteoric ephemeral
29	Strangways Springs Railway Bore	29° 09'S 136° 34'E	Curdimurka SH 53-8	461387	25.XI.70	Chlamydogobius eremius	Artesian
30	Strangways Springs Mound Spring	29° 11'S 136° 32'E	Curdimurka SH 53-8	456384	27.VIII.68		Artesian
31	Beresford Reservoir	29° 14'S 136° 39'E	Curdimurka SH 53-8	470377	1.XI.70	Chlamydogobius eremius	Meteoric permanent
32	Warburton Springs	29° 17'S 136° 49'E	Curdimurka SH 53-8	471373	27.VII.68		Artesian (minor flows and seepages).
33	Coward Springs proper	29° 24'S 136° 47'E	Curdimurka SH 53-8	484357	25.VI.69	Chlamydogobius eremius	Artesian
34	Coward Springs Railway Bore	29° 24'S 136° 49'E	Curdimurka SH 53-8	486357	5.XII.67	Chlamydogobius eremius	Artesian
35	Wobna Spring	29° 27'S 136° 51'E	Curdimurka SH 53-8	491352	23.III.68	Craterocephalus eyresii Chlamydogobius eremius	Artesian
36	Blanche Cup Spring	29° 27'S 136° 52'E	Curdimurka SH 53-8	491351	1.XI.68		Artesian
37	Artesian spring (1.2Km south-east of Wobna Spring)	29° 27'S 136° 03'E	Curdimurka SH 53-8	493351	23.VIII.70	Chlamydogobius eremius	Artesian
38	Margaret Creek Crossing	29° 29'S 137° 03'E	Curdimurka SH 53-8	511347	31.VII.68	Chlamydogobius eremius	Meteoric ephemeral
39	Chambers Creek Crossing	29° 29'S 137° 04'E	Curdimurka SH 53-8	514346	31.VIII.68	Chlamydogobius eremius	Meteoric ephemeral
40	Gregory Creek Crossing	29° 34'S 137° 30'E	Curdimurka SH 53-8	541337	May 1968	Craterocephalus eyresii Chlamydogobius eremius	Meteoric ephemeral
41	Alberrie Creek Crossing	29° 39'S 137° 38'E	Curdimurka SH 53-8	574327	4.IX.68	Chlamydogobius eremius	Meteoric ephemeral
42	Callana Reservoir	29° 36'S 137° 56'E	Curdimurka SH 53-8	602327	1.II.71		Meteoric semi-permanent
43	Lake Harry Bore	29° 26'S 138° 15'E	Marree SH 54-5	639351	22.XI.70		Artesian
44	Clayton Bore	29° 17'S 138° 23'E	Marree SH 54-5	653370	22.XI.70	Chlamydogobius eremius	Artesian
45	Dalkaninna Bore	29° 01'S 138° 28'E	Marree SH 54-5	662401	22.XI.70		Artesian
46	Cannawaukininna Bore	28° 47'S 138° 34'E	Kopperamanna SH 54-1	138429	22.XI.70		Artesian

47	Etadunna Bore	28° 43'S 138° 38'E	Kopperamanna SH 54-1	146437	22.XI.70		Artesian
48	Kopperamanna No. 1 Bore	28° 39'S 138° 42'E	Kopperamanna SH 54-1	154448	22.XI.70		Artesian
49	Mungeranie Bore	28° 01'S 138° 41'E	Kopperamanna SH 54-1	150522	22.XI.70		Artesian
50	Mirra Mitta Bore	27° 43'S 138° 44'E	Gason SG 54-13	156559	22.XI.70		Artesian
51	Gason Bore	27° 19'S 138° 45'E	Gason SG 54-13	157608	22.XI.70		Artesian
52	Lyndhurst Dam	30° 17'S 138° 21'E	Copley SH 54-9	647248	Dec. 1969		Meteoric permanent
53	Lyndhurst Railway Reservoir	30° 17'S 138° 21'E	Copley SH 54-9	647248	Dec. 1969		Meteoric permanent
54	Paralana Hot Springs	30° 11'S 139° 27'E	Copley SH 54-9	236262	21.X.69		Artesian
55	Balcanoona Creek	30° 29'S 139° 18'E	Copley SH 54-9	214225	30.X.69	Mogurnda striata	Artesian meteoric
56	Barraranna Waterhole	30° 17'S 139° 22'E	Copley SH 54-9	231249	19.X.69		Meteoric permanent
57	Nooldoonooldoona Waterhole	30° 16'S 139° 17'E	Copley SH 54-9	219251	18.X.69		Meteoric permanent
58	Bolla Bollana Spring	30° 17'S 139° 17'E	Copley SH 54-9	219249	18.X.69		Artesian
59	Arkaroola Waterhole	30° 17'S 139° 20'E	Copley SH 54-9	225249	18.X.69		Meteoric permanent
60	Montecolina Bore	29° 24'S 139° 59'E	Callabonna SH 54-6	292357	29.X.69		Artesian
61	Lake Callabonna Springs	29° 49'S 140° 10'E	Callabonna SH 54-6	312308	22.X.69		Artesian
62	Mulligan Springs	29° 44'S 139° 58'E	Callabonna SH 54-6	291318	23.X.69	Craterocephalus eyresii	Artesian
63	Twelve Springs	29° 51'S 139° 40'E	Callabonna SH 54-6	259303	24.X.69		Artesian
64	Woolatchi Bore	29° 51'S 139° 40'E	Callabonna SH 54-6	280300	29.X.69		Artesian
65	Mulkonbar Waterhole	27° 44'S 140° 46'E	Innamincka SG 54-14	373560	28.X.69		Meteoric permanent

66	Queerbidie Waterhole	27° 45'S	140° 43'E	Innamincka SG 54-14	369557	28.X.69	*Terapon welchi*	Meteoric permanent
67	Creek crossing 14.5 Km east of Parachilna	31° 08'S	138° 22'E	Parachilna SH 54-13	142145	21.II.70		Meteoric ephemeral
68	Spring, 11.3Km south of Blinman	31° 12'S	138° 40'E	Parachilna SH 54-13	157138	21.III.70		Meteoric seepage
69	Waterhole, north-west of Moralana Homestead	31° 22'S	138° 07'E	Parachilna SH 54-13	624117	4.VII.70	*Craterocephalus fluviatilis*	Meteoric ephemeral
70	Waterhole, 6.4Km south-east of Hawker (adjacent main road)	31° 55'S	138° 28'E	Parachilna SH 54-13	659051	21.II.70		Meteoric ephemeral
71	Walloway Creek	32° 39'S	138° 36'E	Orroroo SI 54-1	152936	25.II.70		Meteoric ephemeral
72	Broughton River	33° 31'S	138° 37'E	Burra SI 54-5	158857	26.XI.70		Meteoric permanent
73	Light River	34° 21'S	138° 46'E	Adelaide SI 54-9	176755	26.XI.70		Meteoric permanent
74	Glen Helen Gorge	23° 40'S	132° 40'E	Hermannsburg SF 53-13	587048	Jan. 1959		Meteoric permanent
75	Finke River, Hermannsburg Homestead	23° 58'S	132° 46'E	Hermannsburg	597015	12.III.70		Meteoric permanent

Appendix B

Registered fish collections in the South Australian Museum taken in the central Australian region between 1968 and 1970.

Loc. No.	Locality	Collection Date	Species	No. of specs.	S.A.M. Reg.No.
1/1	Dalhousie Springs (Main Spring)	3.VIII.68	Neosilurus sp.	139	F3454
		4.VIII.68	" "	4	F3455
		5.VIII.68	" "	1	F3456
		19.XI.69	" "	4	F3470
		19.XI.69	" "	12	F3535
		3.VIII.68	Craterocephalus stercusmuscarum	535	F3453
		4.VIII.68	" "	8	F3542
		3.VIII.68	Chlamydogobius eremius	2	F3507
		26.VI.69	" "	18	F3490
		4.VIII.68	Mogurnda mogurnda	1	F3541
		19.XI. 69	" "	9	F3468
1/2	Dalhousie Springs	5.VIII.68	Neosilurus sp.		F3551
1/3	Dalhousie Springs	5.VIII.68	Neosilurus sp.	14	F3461
		5.VIII.68	Craterocephalus stercusmuscarum	38	F3462
		5.VIII.68	Chlamydogobius eremius	14	F3463
		5.VIII.68	Mogurnda mogurnda	1	F3460
1/4	Dalhousie Springs	5.VIII.68	Craterocephalus fluviatilis	5	F3459
		4.VIII.68	Madigania unicolor	13	F3458
1/5	Dalhousie Springs	19.XI.69	Neosilurus sp.	4	F3465
		19.XI.69	Craterocephalus stercusmuscarum	34	F3466
		19.XI.69	Chlamydogobius eremius	9	F3467
1/6	Dalhousie Springs	19.XI.69	Neosilurus sp.	4	F3465
3	Junction of Stevenson and Hamilton Rivers	2.VIII.68	Madigania unicolor	1	F3471
5	Alberga River Crossing	1.VIII.68	Craterocephalus eyresii	2	F3482
		1.VIII.68	Madigania unicolor	9	F3483
6	Mount Sarah Dam	20.XI.69	Madigania unicolor	8	F3474
7	Forrest's Waterhole	15.XI.69	Madigania unicolor	4	F3475
		15.XI.69	Chlamydogobius eremius	1	F3543
9	Cramp's Camp Waterhole	2.V.69	Madigania unicolor	4	F3472
12	Algebuckina Waterhole	31.VII.68	Craterocephalus eyresii	2	F3479
		31.VII.68	Madigania unicolor	1	F3480
		31.VII.68	Chlamydogobius eremius	5	F3481
13	Wood Duck Bore	21.XI.69	Chlamydogobius eremius	11	F3499
14	Peake Creek	30.VII.68	Chlamydogobius eremius	36	F3487
15	Old Peake Homestead Bore	22.XI.69	Chlamydogobius eremius	15	F3498

Loc. No.	Locality	Collection Date	Species	No. of specs.	S.A.M. Reg.No
16	Freeling Springs	23.XI.69	Craterocephalus stercusmuscarum	29	F3514
		23.XI.69	Chlamydogobius eremius	98	F3510
17	Blyth Bore	24.XI.69	Craterocephalus eyresii	5	F3547
		24.XI.69	Chlamydogbius eremius	22	F3497
		24.XI.69	" "	97	F3511
18	Birribirriana Spring	21.XI.69	Chlamydogobius eremius	12	F3493
19	Nilpinna Spring	21.XI.69	Neosilurus sp.	1	F3494
		21.XI.69	Craterocephalus fluviatilis	1	F3495
		21.XI.69	Chlamydogobius eremius	46	F3496
24	Johnson's No. 3 Bore	11.VIII.68	Craterocephalus eyresii	14	F3545
		27.VIII.70	" "	31	F3539
		11.VIII.68	Chlamydogobius eremius	41	F3544
		2.IX.68	" "	21	F3538
		30.X.68	" "	5	F3537
		1.IV.69	" "	56	F3546
		4.V.69	" "	71	F3548
		29.VI.69	" "	40	F3515
		21.VI.70	" "	55	F3513
27	Nunn's Bore	1.V.69	Craterocephalus eyresii	13	F3504
		29.VII.68	Chlamydogobius eremius	1	F3502
		1.V.69	" "	56	F3536
28	Warriner's Creek	28.VII.68	Chlamydogobius eremius	1	F3484
29	Strangways Springs Railway Bore	25.XI.70	Chlamydogobius eremius	23	F3551
31	Beresford Reservoir	1.XI.70	Chlamydogobius eremius	4	F3512
33	Coward Springs proper	26.VI.69	Chlamydogobius eremius	18	F3490
34	Coward Springs Railway Bore	5.XII.67	Chlamydogobius eremius	1	F3527
		14.XII.67	" "	7	F3524
		22.III.68	" "	16	F3518
		26.IV.68	" "	2	F3519
		29.V.68	" "	7	F3521
		22.VI.68	" "	4	F3528
		2.VII.68	" "	10	F3509
		4.VII.68	" "	1	F3520
		26.VII.68	" "	5	F3517
		27.VII.68	" "	23	F3529
		31.VIII.68	" "	7	F3523
		29.X.68	" "	9	F3530
		20.XII.68	" "	6	F3522
		25.I.69	" "	12	F3526
		31.III.69	" "	9	F3525

Loc. No.	Locality	Collection Date	Species	No. of specs.	S.A.M. Reg.No.
35	Wobna Spring	23.III.68	Craterocephalus eyresii	2	F3506
		23.III.68	Chlamydogobius eremius	12	F3505
		29.V.68	" "	6	F3531
		30.VI.68	" "	24	F3532
		26.VII.68	" "	9	F3533
		20.XII.68	" "	3	F3534
38	Margaret Creek Crossing	31.VIII.68	Chlamydogobius eremius	4	F3486
39	Chambers Creek Crossing	31.VIII.68	Chlamydogobius eremius	1	F3485
41	Alberrie Creek Crossing	4.IX.68	Chlamydogobius eremius	3	F3492
44	Clayton Bore	23.XI.70	Chlamydogobius eremius	12	F3549
55	Balcanoona Creek	30.X.69	Mogurnda striata	11	F3478
62	Mulligan Springs	24.X.69	Craterocephalus eyresii	53	F3500
66	Queerbidie Waterhole	28.X.69	Terapon welchi	6	F3477
69	Waterhole, North-West of Moralana Station	4.VII.70	Craterocephalus fluviatilis	15	F3488
75	Finke River, near Hermansburg Homestead	12.III.70	Chlamydogobius eremius	5	F3550

Appendix C

Some Major Flooding Events in the Lake Eyre basin region of central Australia.

This data has been obtained primarily from newspaper reports ("The Advertiser" and "The News", published in Adelaide). Other data have been obtained from the records of the South Australian Railways Department.

It is not a complete record of floodings but it does indicate the frequent and extensive nature of floodwaters characteristic of the region concerned.

Although rainfall gaugings are available for many places within the central Australian region it is difficult to establish flood conditions on these alone. It was therefore decided that general descriptive reports offered the best indication of flood conditions.

Year	Month	District Affected	Remarks
1893-94	?	Flooding alongside railway line between Coward Springs and Oodnadatta.	
1894-95	?	Flooding in all districts alongside railway line between Port Augusta and Oodnadatta.	
1897-98	?	Flooding in all districts alongside railway line between Port Augusta and Oodnadatta.	
1898-99	?	Flooding in all districts alongside railway line between Port Augusta and Oodnadatta.	
1939	January	Heavy rain in central Australia between region of Marree and north-west to Alice Springs. Floods in vicinity of railway line immediately south of Marree and between Strangways Springs and Oodnadatta.	Southbound train from Alice Sprin delayed by floods. In places water 18 feet above bridges. Extensive damage to railway line between Marree and Farina. Washaways at Edwards Creek between Oodnadatta and Marree. Three trains marooned at Strangways Springs.
"	February	Further heavy rain in north and central Australia. Floods north of Oodnadatta disrupt train service to Alice Springs. Many places including Oodnadatta and Alice Springs isolated. Heavy rain in south west Queensland.	Most aerodromes along the Adelaid Darwin air route, including Oodnadatta and Alice Springs, waterlogged.
1940	January	Heavy rains in central Australia.	Serious dislocations of transport services in the far north of Sout Australia

Year	Month	District Affected	Remarks
1940	February	Alice Springs aerodrome waterlogged	Aeroplanes unable to land at Alice Springs.
1946	February	Alberga River in flood, covering the railway line in the vicinity of Oodnadatta to a depth of some feet.	
1948	March	Heavy rainfall and floodwaters in central Australia. Floodwaters of Finke River cover railway line south of Alice Springs to a depth of 9 feet. Floods at Peake Creek hold up north-bound train to Alice Springs. Diamantina River flooded. Heavy rains in region of Birdsville, Cooper Creek rising.	
1949	February	Heavy rains cause Finke River to rise and Todd River to flow.	Trains from Port Augusta to Alice Springs delayed.
"	March	Torrential rains in north west New South Wales and south west Queensland. Cooper Creek in flood. Areas around Tibooburra and Nappa Merrie flooded. Creeks flooded and traffic halted between Hawker and Copley in South Australia. Cooper Creek rising.	Royal Flying Doctor Service reports that country around Tibooburra like an inland sea. Reported heaviest rain since 1889. Some stations in flooded area abandoned.
"	May	Cooper Creek floodwaters running fast across Birdsville Track at Kopperamanna on approximately a 2 mile front; flowing towards Lake Killalpaninna.	

Year	Month	District Affected	Remarks
1949	June	Cooper Creek flowing towards Lake Eyre west of Kopperamanna.	Estimated main channel of Cooper Creek 25 feet deep and current flowing at 6 - 8 miles per hour.
1960	May	Parts of far north-west of South Australia flooded following heavy rains.	
1962	January	Heavy rains throughout central Australia. Vast areas in central Australia flooded including Alice Springs and north west and south west of Alice Springs, between Oodnadatta and Alice Springs and between Marree and Birdsville. Todd and Finke Rivers in flood.	Extensive washaways along the Port Augusta-Alice Springs railway line, including Telford, Brachina and Copley areas. Line covered for 350 yards by 3 feet of water at 923 mile mark between Port Augusta and Leigh Creek
1963	March	Far north generally flooded. Heavy rains around Lake Eyre. Bopechee Creek flooded. The Neales River in flood. Creeks flooding across the Birdsville Track near Mulka.	Washaways on railway line north of the Finke River crossing.

Year	Month	District Affected	Remarks
1963	April	Heavy rains and flooding between Oodnadatta and Alice Springs and Marree and Birdsville. Extensive areas of north east South Australia flooded including Innamincka area. Cooper Creek in flood; front up to 60 miles wide.	Innamincka Homestead evacuated. Very heavy rainfall gaugings in some areas reported on 8.IV.63; some stations in the southern part of the Northern Territory in excess of 600 points; some in the area north of Oodnadatta up to 300 points, Macumba Station 316 points, Mount Sarah Station 279 points.
"	May	Much of north east South Australia flooded. Cooper Creek in flood and approaching Kopperamanna. Floods between Leigh Creek and Marree, Marree and Muloorina Homestead and Marree and Oodnadatta. Bopechee, Lyndhurst, Beltana and Balcanoona areas flooded. Road between Coober Pedy and Alice Springs and area north west of William Creek flooded.	Floodwaters of Diamantina River about three days from Lake Eyre. Train marooned at William Creek 14.V.63. Extensive floodwater damage to railway line between Marree and Oodnadatta. At Bopechee floodwater up to 10 feet above the line. Some high rainfall gaugings reported 14.V.63; William Creek 500 points, Stuart Creek 380 points, Curdimurka 100 points, Farina 537 points, Balcanoona 346 points.

Year	Month	District Affected	Remarks
1963	July	Region around Lake Eyre flooded. Serious flooding generally in the far north and far north east.	Train held up north of Bloods Creek (north of Oodnadatta) 22.XII.65 due to floodwaters.
1965	August	Oodnadatta-Maree road and Leigh Creek area flooded. Hamilton River near Ilbunga in flood. Railway line flooded between Oodnadatta and Alice Springs.	
"	December	Birdsville Track flooded.	
1966	January	Heavy rains and flooding in areas of far north west South Australia and at Alice Springs.	Railway line cut in more than 12 places between Oodnadatta and Alice Springs due to floodwaters.
1967	March	The Finke, Alberga and Neales River in flood. Heaviest flooding in the Ernabella-Finke area.	
"	July	Heavy rains and general flooding between Port Augusta and Alice Springs.	Railway line cut in 30 places between Port Augusta and Alice Springs. Alice Springs rain gauging reported 24.VII.67, 600 points.
1968	April	Railway line flooded between Marree and Alice Springs. Isolated sheet flooding within 100 mile radius of Alice Springs.	

Year	Month	District Affected	Remarks
1969	January	Heavy rainfalls and isolated flooding in the central Australian region in the far north and north west of South Australia and around Alice Springs. Railway line flooded 25 miles south of Alice Springs.	
"	February	Heavy rainfalls in the central Australian region.	24 hour rainfall gaugings of more than 200 points reported at some places in the central Australian region on 26.II.69.
"	March	Heavy rainfall in the Marree area.	24 hour rainfall gaugings of 120 points reported at Marree on 11.III.69.
1971	March	Heavy flooding in the far north east of South Australia. Birdsville, Innamincka and Pandie Pandie areas flooded. Cooper Creek flooding near Etadunna. Strzlecki Creek causes flooding between Leigh Creek and Lake Gregory.	

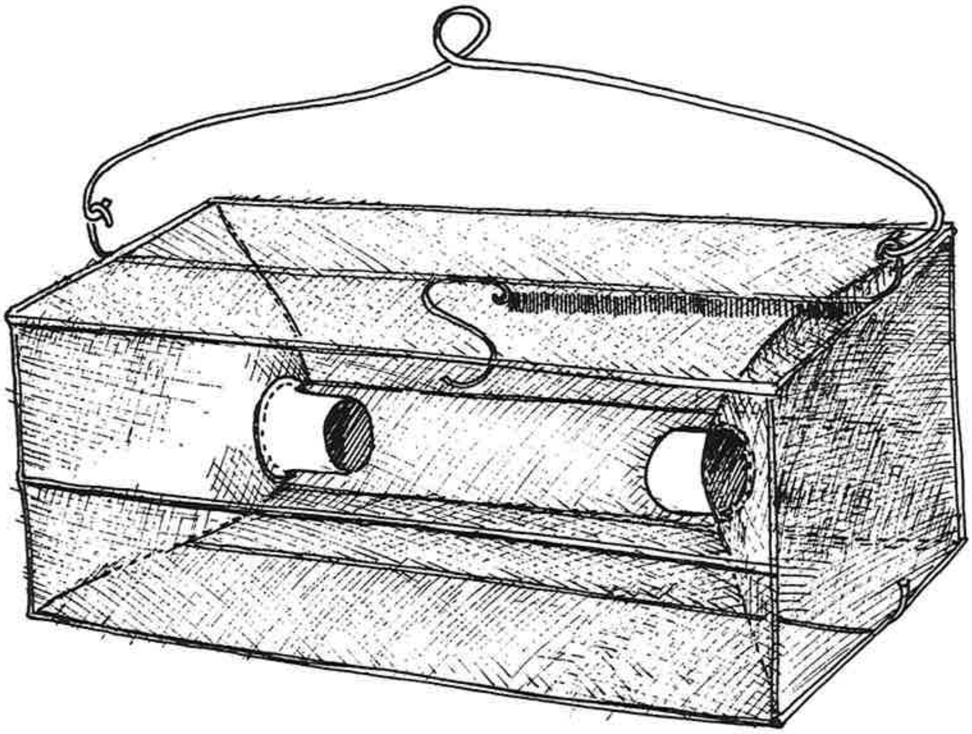
Appendix D

Description of wire mesh traps employed in trapping.

The form of trap is as illustrated on the next page. Dimensions as follows: frames 31.0 x 15.0 x 15.0 cm; end apertures 3.5 cm diameter; 26 gauge wire; 2 mm mesh.

When employed at Wobna Spring (locality 35) each trap was always baited with 30gm of canned beef and 30gm of 'Rye-Vita' crisp bread, items which C. eremius was observed to eat in the laboratory and which were convenient for field use. Shortly after commencing these trappings at Wobna Spring (locality 35) it was found, in comparative trappings made at Johnson's No. 3 Bore (locality 24), that approximately the same number of fish were trapped when bait was used as when it was not. Nevertheless it was decided to continue using bait when trapping at Wobna Spring (locality 35) in order to ensure that the data obtained from all the series of trappings were comparative.

Bait was not employed in the other trappings conducted at Johnson's No. 3 Bore (locality 24) and Nunn's Bore (locality 27).



Appendix E

Physical and non-physical data and trapping rates recorded at 8 stations along the stream at Coward Springs Railway Bore (locality 34) on different occasions between December 1967 and January 1969.

The stations were located in midstream at the following distances from the bore head: st. 1, bore head pool; st. 2, 35m; st. 3, 55m; st. 4, 155m; st. 5, 220m; st. 6, 290m; st. 7, 400m; st. 8, 455m.

Where only a single time (hours) is indicated for a recording session this indicates the time readings commenced. In some instances, two or three sets of times are indicated and these refer to different recording sessions conducted on the same date.

1. Absolute dens./m^2: Estimated by quadrant measurements (see p. 42).
2. Relative density: Total number of fish trapped in a single trap (see Appendix) set at each station for 15 hours overnight (approx. 1700 hours - 0800 hours).

Date Recorded 14.XII.67

Stn.	Time rec.	Temperature °C						Diff. sub-bed/ bott. temp.		Water depth cms.	Water pH	Absolute dens./m^2
		Amb.	Surf	Mid.	Bott.	2.5cm sub-bed	9.0cm sub-bed	2.5cm sub-bed	9.0cm sub-bed			
1	0900	27.5	Not re-corded	30.3	31.0	31.1	30.8	+0.1	-0.2	Not re-corded	Not re-corded	Not re-corded
	1400	33.8		30.7	31.6	31.9	32.0	+0.3	+0.4			
2	0910			28.5	29.0	27.6	24.0	-1.4	-5.0			
	1415			34.2	35.0	34.5	30.7	-0.5	-4.3			
3	0920			24.2	24.7	22.9	34.0	-1.8	-0.7			
	1425			33.3	34.5	32.5	27.5	-2.0	-7.0			
4	0935			26.0	25.8	22.3	21.0	-3.5	-4.8			
	1435			32.5	33.0	31.5	28.5	-1.5	-4.5			

21.II.68												
		Temperature °C						Diff. sub-bed/ bott. temp.		Water depth cm.	Water pH	^{1}Absolute dens/m^2
Stn.	Time rec.	Amb.	Surf	Mid.	Bott.	25cm sub-bed	9.0cm sub-bed	2.5cm sub-bed	9.0cm sub-bed			
1	0725	29.9	30.4	30.0	30.0	30.0	30.0	0	0	9	7.6	2
	1200	36.0	31.0	31.5	31.5	32.4	31.6	+0.9	+0.1			
	1800	38.0	31.0	30.9	30.9	31.2	31.5	+0.3	+0.6			
2	0740	29.0	26.3	26.3	26.4	25.6	25.8	-0.8	-0.6		7.6	0
	1210	36.5	39.3	39.0	38.2	33.1	29.9	-5.1	-8.3			
	1810	38.0	33.1	33.6	33.6	34.8	34.2	+1.2	+0.6			
3	0755	29.5	24.9	24.9	25.2	25.5	26.1	+0.3	+0.9	18	7.6	-
	1225	34.7	37.8	37.8	37.8	30.9	28.0	-6.9	-9.8			
	1820	38.0	35.0	35.0	35.0	34.8	33.5	-0.2	-1.5			
4	0940	32.1	27.2	27.1	25.8	26.0	26.0	+0.2	+0.2	8	7.6	-
	1345	36.6	35.6	33.6	31.5	27.4	27.0	-4.1	-4.5			
	1830	38.0	32.1	32.1	32.2	32.3	31.3	+0.1	-0.9			
5	0830	31.0	25.8	25.5	25.5	25.6	25.7	+0.1	+0.2	23	7.6	25
	1350	36.2	34.0	31.5	30.0	27.4	27.2	-2.6	-2.8	23	7.6	25
	1835	38.0	32.0	32.0	32.0	29.2	28.0	-2.8	-4.0			
6	0845	30.1	25.2	25.1	25.0	25.2	25.2	+0.2	+0.2	10	9.2	37
	1300	36.1	37.5	34.8	33.0	28.0	28.0	-0.5	-0.5			
	1840	37.9	34.5	34.5	34.4	31.0	30.5	-3.4	-3.9			
7	0905	30.1	26.0	25.8	25.9	25.6	25.6	-0.3	-0.3	15	9.4	-
	1315	37.0	36.1	36.1	36.1	32.6	30.0	-3.5	-6.1			
	1900	37.5	34.9	34.8	34.5	34.2	33.8	-0.3	-0.7			
8	0915	31.5	27.1	27.0	27.0	25.8	26.0	-1.2	-1.0	10	9.6	2
	1330	36.4	38.1	37.8	37.8	30.0	29.0	-7,8	-8.8			
	1850	37.8	33.9	33.9	33.9	33.54	32.7	-0.4	-12.			

22.III.68												
Stn.	Time rec.	Temperature °C						Diff. sub-bed/bott. temp.		Water depth cms.	Water pH	^{1}Absolute dens./m^2
		Amb.	Surf.	Mid.	Bott.	2.5cm sub-bed	9.0cm sub-bed	2.5cm sub-bed	9.0cm sub-bed			
1	0745	25.1	29.7	30.0	30.0	30.0	30.0	0	0	20	7.5	Not recorded
	1600	37.0	31.0	31.0	31.0	31.5	31.5	+0.5	+0.5			
2	0800	25.9	22.1	22.4	22.4	23.0	23.0	+0.6	+1.4	8	7.6	
	1610	35.0	33.1	33.1	33.1	33.1	31.8	0	-1.3			
3	0810	27.0	21.0	21.0	21.0	22.2	24.0	+1.2	+3.0	10	7.6	
	1620	35.1	34.3	34.2	34.0	33.3	30.5	-0.7	-3.5			
4	0815	26.9	21.4	21.1	21.1	22.0	22.9	+0.9	+1.8	3	7.7	
	1630	34.8	30.0	30.0	29.9	29.5	27.9	-0.4	-2.0			
5	0830	27.8	22.5	22.5	22.5	23.0	23.5	+0.5	+1.0	7	7.7	
	1640	36.1	30.0	30.0	30.0	28.0	27.0	-2.0	-3.0			
6	0840	28.9	22.0	22.0	22.0	22.0	22.5	0	-0.5	3	8.9	
	1650	36.6	31.8	31.5	31.5	30.5	28.0	-1.0	-3.5			
7	0840	30.2	33.0	22.7	22.7	23.5	24.1	+0.8	+1.4	8	9.2	
	1700	36.0	32.0	32.0	32.0	31.3	30.5	-0.7	-0.3			
8	0900	30.3	24.0	24.0	24.0	22.9	22.5	+1.1	+1.5			
	1705	35.9	29.6	29.6	29.6	30.4	29.8	+0.8	+0.2			

		26.IV.68										
Stn.	Time rec.	Temperature °C						Diff. sub-bed/ Bott. temp.		Water depth cm.	Water pH	[1]Absolute dens./m^2
		Amb.	Surf.	Mid.	Bott.	2.5cm sub-bed	9.0cm sub-bed	2.5cm sub-bed	9.0cm sub-bed			
1	1000	25.2	29.8	29.9	29.7	30.0	30.5	+0.3	+0.8	21	7	Not Recorded
	1610	31.7	29.9	29.9	29.9	30.0	31.0	+0.1	+0.2			
2	1015	27.0	24.4	24.4	24.4	23.0	21.5	-1.4	-2.9	2	7.8	
	1615	32.6	25.5	25.5	25.5	26.5	26.0	+1.0	+0.5			
3	1020	27.0	21.5	21.5	21.0	20.5	20.0	-0.5	-1.0	10	7.8	
	1620	32.5	25.8	25.8	25.8	24.5	24.0	-1.3	-1.8			
4	1030	27.0	19.5	19.4	19.4	19.0	18.5	-0.4	-0.9	2	7.8	
	1630	32.5	22.0	22.0	22.0	22.0	21.0	0	-1.0			
5	1040	27.0	18.8	18.7	18.5	18.0	18.0	-0.5	-0.5	8	8.0	
	1635	32.4	22.0	21.8	21.5	20.6	20.2	-0.9	-1.3			
6	1055	28.5	20.5	20.5	20.5	19.0	19.0	-1.5	-1.5	14	8.8	
	1640	31.5	23.5	23.7	23.7	21.9	21.6	-1.8	-2.1			
7	1105	28.3	21.0	21.0	20.9	20.7	19.6	-0.2	-1.3	3	9.0	
	1650	32.0	23.5	23.5	23.5	23.5	23.3	0	-0.2			
8	1110	28.5	22.0	22.0	22.0	21.0	19.9	-1.0	-2.1	1	9.0	
	1655	31.5	23.6	23.6	23.6	23.5	23.5	-0.1	-0.1			

28.V.68												
		Temperature °C						Diff. sub-bed bott. temp.		Water depth cm.	Water pH	[2]Relative Density
Stn.	Time rec.	Amb.	Surf.	Mid.	Bott.	2.5cm sub-bed	9.0cm sub-bed	2.5cm sub-bed	9.0cm sub-bed			
1	1500	18.5	29.5	29.6	29.6	30.0	30.0	+0.4	+0.4	22	7.0	0
2			22.0	22.0	22.0	22.3	21.5	+0.3	-0.5	12	7.4	0
3			21.8	21.8	21.5	20.5	19.5	-1.0	-2.0	21	7.4	-
4		18.4	17.1	17.1	17.0	16.1	15.5	-0.9	-1.5	22	7.5	7
5			16.5	16.4	16.1	15.0	15.0	-1.1	-1.1	17	7.6	14
6			19.0	18.5	16.0	15.5	15.0	-0.5	-0.1	30	8.0	25
7			18.9	18.9	18.9	18.5	17.5	-0.4	-1.4	19	9.2	0
8			18.7	18.7	18.7	18.4	18.0	-0.3	-0.7	9	9.5	3

29.V.68

Stn.	Time rec.	Temperature °C						Diff. sub-bed/ bott. temp.		Water depth cm	Water pH	[2]Relative Density
		Amb.	Surf.	Mid.	Bott.	2.5cm sub-bed	9.0cm sub bed	2.5cm sub-bed	9.0cm sub-bed			
1	0715	13.9	29.5	29.5	29.5	29.8	30.0	+0.3	+0.5	22	7.0	Not Recorded
2			19.9	19.5	19.3	19.0	19.2	-0.3	-0.1	12	7.4	
3			18.1	18.2	18.2	18.0	18.0	-0.2	-0.2	21	7.4	
4		13.5	15.0	15.0	15.0	15.0	15.0	0	0	22	7.5	
5			14.0	14.0	14.0	14.2	14.2	+0.2	+0.2	17	7.6	
6			12.9	13.0	13.0	13.4	13.7	+0.4	+0.7	30	8.0	
7		13.9	13.5	13.5	13.5	13.0	14.00	+0.3	+0.5	19	9.2	
8			13.3	13.3	13.3	13.5	14.0	+0.2	+0.7	9	9.5	

30.VI.68

Stn.	Time rec.	Temperature °C						Diff. sub-bed / bott. temp.		Water depth cms.	Water pH	^{2}Relative Density
		Amb.	Surf.	Mid.	Bott.	2.5cm sub-bed	9.0cm sub-bed	2.5cm sub-bed	9.0cm sub-bed			
1	0700 1615	9.7 29.3	29.5 29.0	29.4 29.0	29.0 29.3	29.4 29.3	29.4 29.3	+0.4 +0.3	+0.4 +0.3	22	7.0	0
2			17.0 18.0	17.0 18.0	17.0 18.0	17.8 18.5	17.5 18.8	+0.8 +0.5	+0.5 +0.8	8	7.2	0
3			15.3	15.4	15.4	16.0	16.0	+0.6	+0.6	13	7.2	2
4			12.0 13.5	13.4 13.5	13.4 13.8	13.8 13.9	14.0 14.1	+0.4 +0.1	+0.6 +0.3	23	7.0	0
5			12.9 12.9	12.8 12.9	12.7 13.0	13.1 13.1	13.2 13.2	+0.4 +0.1	+0.5 +0.2	17	7.0	1
6			11.6 12.8	11.6 12.8	11.7 12.8	12.0 13.3	13.0 13.5	+0.3 +0.5	+1.3 +0.7	19	7.8	4
7			11.6 12.7	11.6 12.8	11.7 12.9	12.5 13.3	13.2 13.5	+0.8 +0.4	+1.5 +0.6	19	9.4	3
8			10.5 12.71	10.5 12.9	10.5 13.4	12.0 13.8	13.0 14.0	+1.5 +0.4	+2.5 +0.6	21	10.0	5

26.VII.68												
		Temperature °C						Diff. sub-bed/ bott. temp.				
Stn.	Time rec.	Amb.	Surf.	Bott.		2.5cm sub-bed	9.0cm sub-bed	2.5cm sub-bed	9.0cm sub-bed	Water depth cm.	Water pH	[2]Relative Density
1	1530	21.0	29.5	29.5	29.3	30.0	30.1	+0.7	+0.8	22	7.0	0
2			20.0	20.0	20.0	20.0	19.8	0	-0.2	6	7.0	0
3			18.6	18.7	17.5	16.0	16.0	-1.5	-1.5	13	7.0	1
4			12.5	12.4	11.0	11.0	11.0	0	0	20	7.0	0
5			12.0	11.0	10.5	10.5	10.2	0	-0.3	17	7.0	0
6			16.8	16.8	16.5	14.0	13.5	-2.5	-3.0	22	7.0	5
7			17.6	17.4	15.5	13.5	13.0	-2.0	-2.5	21	10.0	1
8			18.0	18.0	17.2	14.9	14.0	-2.3	-3.2	8	11.0	0

31.VIII.68												
		Temperature °C						Diff. sub-bed/ bott. temp.				[2]Relative density
Stn.	Time rec.	Amb.	Surf.	Mid.	Bott.	2.5cm. sub-bed	9.0cm. sub-bed	2.5cm. sub-bed	9.0cm. sub-bed	Water depth cm.	Water pH	
1	1540	18.9	30.0	29.9	29.9	30.0	30.2	+0.1	+0.3	27	7.0	0
2			22.5	-	22.7	22.5	21.0	-0.2	-1.7	5	7.4	23
3			21.0	21.0	19.0	17.5	16.5	-1.5	-2.5	13	7.9	10
4			15.6	14.5	20.0	12.0	12.0	-8.0	-8.0	14	7.9	1
5			16.9	14.5	13.5	13.0	12.0	-0.5	-1.5	12	8.1	9
6			22.0	21.9	21.9	17.5	16.0	-4.4	-5.9	17	9.8	4
7			22.5	22.2	19.7	1755	15.5	-2.2	-4.2	7	10.0	0
8				No water present - stream receded 19 metres towards bore head.								

28.X.68												
Stn.	Time rec.	Temperature °C						Diff. sub-bed bott. temp.		Water depth cm.	Water pH	[2]Relative Density
		Amb.	Surf.	Mid.	Bott.	2.5cm. sub-bed	9.0cm. sub-bed	2.5cm. sub-bed	9.0cm. sub-bed			
1	1508	37.0	30.4	30.4	30.4	30.6	30.6	+0.2	+0.2	26	7.0	0
2			31.0	31.0	31.1	31.4	30.0	+0.3	-0.1	6	7.9	20
3			31.8	30.5	29.0	25.0	22.0	-4.0	-7.0	10	8.1	32
4			27.0	34.4	24.0	21.5	20.5	-2.5	-3.5	18	8.8	30
5			27.5	26.5	26.2	24.0	23.0	-2.2	-3.2	7	7.9	12
6												
7				No water present - stream receded.								
8												

15.XI.68

Stn.	Time rec.	Temperature °C						Diff. sub-bed/ bott. temp.		Water depth cm.	Water pH	[2]Relative density
		Amb.	Surf.	Mid.	Bott.	2.5cm. Sub-bed	9.0cm. Sub-bed	2.5cm. Sub-bed	9.0cm. Sub-bed			
1	1445	28.9	30.5	30.5	30.5	31.0	31.0	+0.5	+0.5	25	7.0	0
2			31.5	31.9	32.0	29.5	26.5	-2.5	-5.5	5	7.6	8
3			29.6	29.0	28.0	22.3	22.0	-5.7	-6.0	14	7.9	10
4			22.0	21.0	22.3	21.0	19.5	-1.3	-2.8	13	7.8	2
5												
6												
7			No water present - stream receded 23 metres towards bore head.									
8												

19.XII.68.

Stn.	Time rec.	Temperature °C						Diff. sub-bed/ bott. temp.		Water depth cm.	Water pH	^{2}Relative Density
		Amb.	Surf.	Mid.	Bott.	2.5cm. Sub-Bed	9.0cm. sub-bed	2.5cm. sub-bed	9.0cm. sub-bed			
1	1615	36.5	30.1	30.2	30.3	30.5	30.5	+0.2	+0.2	27	7.0	0
2			30.4	30.5	30.8	31.5	30.0	+0.7	-0.8	5	7.9	8
3			31.5	31.5	31.5	30.5	28.5	-1.0	-3.0	8	8.0	20
4												
5												
6			No water present - stream receded 27 metres towards bore head, from station 4.									
7												
8												

24.I.69.												
		Temperature °C						Diff. sub-bed/ bott. temp.				
Stn.	Time rec.	Amb.	Surf.	Mid.	Bott.	2.5cm. Sub-bed	9.0cm. Sub-bed	2.5cm. sub-bed	9.0cm. sub-bed	Water depth cm.	Water pH.	[2]Relative density
1	1500	30.7	30.7	30.6	30.6	31.0	31.0	+0.4	+0.4	28	7.0	0 (but fish sighted in vicinity)
2		No water present - stream receded to bore head pool.										
3												
4												
5												
6												
7												
8												

Appendix F

Physical and non-physical data and trapping rates recorded at 13 stations along and in a pool adjacent the stream at Wobna Spring (locality 35) on different occasions between May 1968 and November 1970.

The stations were located in midstream at the following distances from the spring head: st. 1, spring head pool (5m diam.); st. 2, 10m; st. 3, 25m; st. 4, 50m; st. 5, 65m; st. 6, 90m; st. 7, 125m; st. 8, 185m; st. 9, 200m; st. 10, 260m; st. 11, 330m; st's. 12 and 13, in ephemeral side pool adjacent main stream and connecting via vegetated shallows.

The single time (hours) indicated for each recording session indicates the time readings commenced; these usually took approximately 50 minutes to complete.

No sub-bed temperatures recorded at st. 3 due to rock bed.

1. Vegetation (rel. abund.): Estimate, on an arbitrary scale of 0 - 5 of approximate area each plant form covered within an overall area of approximately 0.5 square metre within the stream at each station.
2. Relative Density: Total number of fish trapped in a single trap (see Appendix D) set at each station for 12 hours overnight (approx. 1800 hours - 0600 hours).
3. Standard Length (mm.): Indicating ranges (R) and means (M) of standard lengths for each sex at each station.

27.IV.68

		Temperature °C							[1]Vegetation (Rel.abund)		[2]Relative Density			[3]Standard length(mm)			
Stn.	Time rec. comm.	Amb.	Bott. H_2O	2.5cm sub-bed	Diff. Sub-bed bott.temp.	H_2O pH	HH_2O depth (cm)	Strm width (cm)	Cyp.	Algae	Total	♂	♀	♂		♀	
														R	M	R	M
1	1100		29.6	30.0	+0.4	7.0					species present						
2	No data recorded at this station																
3			30.5	-													
4			30.3	30.0	-0.3												
5	No data recorded at this station																
6			30.3	29.7	-0.6												
7			30.0	29.7	-0.3	7.2											
8			23.8	20.0	-0.8	8.0											

29.V.68

Stn.	Time rec. comm.	Temperature °C							[1]Vegetation (Rel. abund)		[2]Relative Density			[3]Standard length (mm)			
		Amb.	Bott. H_2O	2.5cm sub-bed	Diff. sub-bed bott. temp.	H_2O pH	H_2O depth (cm)	Strm. width (cm)	Cyp.	Algae	Tot.	♂	♀	♂		♀	
														R	M	R	M
1	1015	17.0	28.9	30.5	+1.6	7.0					species abundant amongst veg.						
2			30.2			7.0											
3			30.1			7.1											
4			30.0	29.5	-0.5	7.1											
5			29.8	29.6	-0.2	7.1	8										
6			29.3	28.9	-0.4	7.2	4				species present amongst veg.						
7			28.9	28.7	-0.2	7.2	8				species present						
8			25.5	24.5	-1.0	8.0											
9			24.5	24.1	-0.4	8.0	3				species present						
10			17.6	16.5	-1.1	8.2	9				species not present						
11			19.8	18.9	-0.9	8.1	3				species						

30.VI.68

Stn.	Time rec. comm.	Temperature °C				H_2O pH	H_2O dpth (cm)	Strm width (cm)	[1]Vegetation (Rel.abund)		[2]Relative Density			[3]Standard length (mm)			
		Amb.	Bott. H_2O	2.5cm sub-bed	Diff. sub-bed bott. temp.				Cyp.	Algae	Total	♂	♀	♂		♀	
														R	M	R	M
1	1400	13.5	29.0	29.6	+0.6	7.0	8										
22			30.0	30.0	0	7.0	14										
3			29.2			7.0	4										
4			29.0	29.0	0	7.2	5										
5			29.0	28.8	-0.2	7.2	7										
6			27.3	27.0	-0.3	7.4	4										
7			27.3	27.0	-0.3	7.4	6										
8			26.8	26.8	0	8.2	2										
9			15.2	15.5	+0.3	8.4	1										
10			12.5	12.9	+0.4	8.6	1										
11			13.5	13.6	+0.1	8.4	2										
12			13.5	14.0	+0.5	9.0											

26.VII.68

Stn.	Time rec. comm.	Temperature °C				H_2O pH	H_2O dpth (cm)	Strm. width (cm)	[1] Vegetation (Rel.abund)		[2] Relative Density			[3] Standard length (mm)			
		Amb.	Bott. H_2O	2.5cm sub-bed	Diff. sub-bed bott. temp.				Cyp.	Algae	Tot	♂	♀	♂ R	♂ M	♀ R	♀ M
1	1200	19.9	29.9	30.9	+1.0	7.0	7				species present						
2			30.5	29.9	-0.6	7.0	14										
3			30.0			7.1	20										
4			29.8	29.6	-0.2	7.2	4										
5			29.5	29.3	-0.2	7.2	9										
6			28.8	28.5	-0.3	7.4	5										
7			28.9	28.7	-0.2	7.4	8				species present						
8			22.3	21.5	-0.8	8.4	2										
9			22.5	21.8	-1.3	8.5	2										
10			19.0	18.5	-0.5	9.0	1										
11			18.7	18.1	-0.6	9.0	5										
12			19.0	17.0	-2.0	8.8	3				species present						

1.IX.68

Stn.	Time rec. comm.	Temperature °C				H_2O pH	H_2O dpth (cm)	Strm wdth (cm)	[1]Vegetation (Rel.abund)		[2]Relative Density			[3]Standard length (mm)			
		Amb.	Bott. H_2O	2.5cm sub-bed	Diff. sub-bed bott. temp.				Cyp.	Algae	Tot.	♂	♀	♂		♀	
														R	M	R	M
1	1115	20.1	30	30.4	+0.3	7.2	10				2						
2			30.5	30.4	-0.1	7.0	14				2						
3			30.2			7.1	9										
4			30.0	30.0	0	7.0	5				47						
5			30.0	29.5	-0.5	7.0	6										
6			30.0	29.9	-0.1	7.2	3				101						
7			29.9	29.7	-0.2	7.1	4				48						
8			25.5	24.9	+0.4	8.4	1				8						
9			25.4	25.5	+0.1	8.4	1										
10			22.8	22.0	-0.8	8.5	4										
11			21.2	19.5	-1.7	8.4	3										
12			22.3	20.0	-2.3	8.5	4				1						
13			20.5	17.3	-3.2	9.0	12				0						

28.X.68

Stn.	Time rec. comm.	Temperature °C				H_2O pH	H_2O dpth (cm)	Strm wdth (cm)	[1]Vegetatn. (Rel.abund)		[2]Relative Density			[3]Standard length (mm)			
		Amb.	Bott. H_2O	2.5cm sub-bed	Diff. sub-bed bott. temp.				Cyp.	Algae	Total	♂	♀	♂		♀	
														R	M	R	M
1	1635	34.1	30.0	30.4	+0.4	7.0					1						
2			30.5	30.5	0	6.8	12										
3			30.5			?	10										
4			30.5	30.5	0	7.1	9										
5			30.4	30.4	0	7.1	8										
6			30.3	30.3	0	7.2	10				51						
7			30.0	30.2	+0.2	7.2	9				47						
8			29.4	30.0	_0.6	8.0	2										
9			28.8	29.1	_0.3	8.1	2										
10			27.5	28.0	+0.5	8.4	2										
11			26.0	26.5	_0.5	8.4	3										
12			29.8	29.5	-0.3	8.0	9										
13			29.6	27.5	-2.1	8.9	9										

15.XI.68

		Temperature °C							[1]Vegetation (Rel.abund)		[2]Relative Density			[3]Standard lgth (mm)			
														♂		♀	
Stn.	Time rec. comm.	Amb.	Bott. H_2O	2.5cm sub-bed	Diff. sub-bd bott. temp.	H_2O pH	H_2O dpth (cm)	Strm. wdth (cm)	Cyp.	Algae	Tot.	♂	♀	R	M	R	M
1	1030	25.5	30.5	31.0	+0.5	7.4	5				0						
2			30.9	30.4	-0.5	7.2	14				2						
3			30.9				9										
4			30.9	30.5	-0.4	7.1	8				6						
5			31.0	30.5	-0.5	7.2	18				13						
6			31.0	30.5	-0.5	7.2	15				36						
7			31.0	39.0	-2.0	7.3	11				53						
8			29.5	28.0	-1.5	9.4	2				species not present						
9			29.5	29.8	+0.3	9.1	1				species not present						
10			30.1	28.0	-2.1	9.1	1				species not present						
11			31.0	25.8	-5.2	9.0	3				species not present						
12			30.5	27.7	-2.8	8.8	9				4						
13			29.5	26.7	-2.8	8.8	14				15						

19.XII.68

Stn.	Time rec. comm.	Temperature °C				H_2O pH	H_2O dpth (cm)	Strm wdth (cm)	[1]Vegetatn. (Rel.abund)		[1]Relative Density			[3]Standard length (mm)			
		Amb.	Bott. H_2O	2.5cm sub-bed	Diff. sub-bed bott.				Cyp.	Algae	Total	♂	♀	♂		♀	
														R	M	R	M
1	1100	35.0	32.7	31.4	-1.3	7.0	9				0						
2			31.4	31.4	0	7.0	7				4						
3			31.7			7.0	3										
4			32.0	31.8	-0.2	7.1	8				36						
5			32.3	32.4	+0.1	7.3	7				71						
6			32.8	32.0	-0.8	7.3	11				59						
7			33.5	33.4	-0.1	7.3	6				31						
8			34.5	34.0	-0.5	7.4	3				7						
9			34.8	34.6	-0.2	7.6	3				-						
10			35.6	34.9	-0.7	7.9	3				-						
11			38.0	37.0	-1.0	8.3	4				-						
12			37.0	32.0	-5.0	9.0	11										
13			36.0	30.5	-5.5	9.0	19				0						

24.I.69

Stn.	Time rec. comm.	Temperature °C				H_2O pH	H_2O dpth (cm)	Strm wdth (cm)	[1]Vgtatn (Rel. abund)		[2]Relative Density			[3]Standard length (mm)			
		Amb.	Bott. H_2O	2.5cm sub-bed	Diff. sub-bed bott. temp.				Cyp.	Algae	Total	♂	♀	♂		♀	
														R	M	R	M
1	1200	41.3	31.8	31.5	-0.3	7.0	3.5				0						
2			31.3	31.0	-4.3	7.0	9	65			0						
3			31.2				8	30									
4			31.0	30.6	-0.4	7.2	6	66			1						
5			30.9	30.9	0	7.2	8	73			5						
6			31.0	31.0	0	7.2	5	109			6						
7			31.1	31.0	-0.1	7.2	5	130			11						
8			32.5	30.5	-2.0	7.8	8	480			6						
9			31.4	31.4	0	7.6	6	135			3						
10			33.5	32.9	+0.6	8.3	2	23			species sighted between stns. 10 and 11						
11			32.6			7.9	5	76			11						
12	No data recorded - no water																
13			33.4	28.6	-4.8	9.6	5	pool 10x50									

Date Recorded 24.II.69

Stn.	Time rec. comm.	Temperature °C				H_2O pH	H_2O dpth (cm)	Strm wdth (cm)	[1]Vegetation (Rel.abund)		[2]Relative Density			[3]Standard length (mm)			
		Amb.	Bott. H_2O	2.5cm sub-bed	Diff. sub-bed bott. temp.				Cyp.	Algae	Total	♂	♀	♂		♀	
														R	M	R	M
1	1245	30.6	33.0	32.4	-0.6	7.0	3		2	1	0						
2			31.3	31.5	+0.2	7.0	6	115	2	2	0						
3			31.5			7.0	10	60	4	0							
4			31.5	31.6	+0.1	7.0	4	100	2	3	11						
5			32.0	31.7	-0.3	7.1	6	130	0	3	14						
6			32.1	31.7	-0.4	7.2	7	100	1	4	21						
7			32.5	32.1	-0.4	7.2		110	3	4	60						
8			34.8	30.9	-3.9	7.9	5	180	5	0	0						
9			30.5	31.0	+0.5	7.8	6	100	2	3	10						
10			30.5	33.0	+2.5	7.4	5	70	1	1	17						
11			33.6	32.5	-1.1	7.8	6	50	3	3	0						
12			No data recorded - no water present														
13			No data recorded - no water present														

30.III.69

Stn.	Time rec. comm.	Temperature ^{o}C				H_2O pH	H_2O dpth (cm)	Strm wdth (cm)	[1] Vegetatn. (Rel.abund)		[2] Relative Density			[3] Standard length (mm)			
		Amb.	Bott. H_2O	2.5cm sub-bed	Diff. sub-bed bott. temp.				Cyp.	Algae	Total	♂	♀	♂		♀	
														R	M	R	M
1	1145	25.7	29.8	30.6	+0.8	7.0	4	pool diam 7m	1	1	0						
2			30.8	30.5	+0.3	7.0	7	100	1	1	0						
3			30.6				9	90	3	2	4						
4			30.5	30.4	-0.1	7.1	6	128	3	2	4						
5			30.6	30.1	-0.5	7.1	7	124	1	3	6						
6			30.7	30.3	-0.4	7.3	13	116	0	4	20						
7			30.5	30.0	-0.5	7.3	10	122	1	5	4						
8			30.4	30.0	-0.4	7.4	7	160	1	3	5						
9			29.9	28.8	-1.1	7.6	3	400	2	2	11						
10			28.5	27.0	-1.5	7.9	4	230	1	0	0 but present						
11			27.9	26.5	-1.4	8.2	7	100	4	3	0 but present						
12			25.5	23.5	-2.0	9.0	9		0	0	0						
13			25.0	22.5	-2.5	9.0	20	pool 25X113 m.	0	0	0						

30.IV.69

Stn.	Time rec. comm.	Temperature °C				H_2O pH	H_2O dpth (cm)	Strm wdth (cm)	[1]Vegetn. (Rel.abund)		[2]Relative Density			[3]Standard length (mm)			
		Amb.	Bott. H_2O	2.5cm sub-bed	Diff. sub-bed bott. temp.				Cyp.	Algae	Total	♂	♀	♂		♀	
														R	M	R	M
1	1145	26.4	29.0	30.2	+1.2	7.1	3		2	1	0						
2			30.5	30.5	0	7.3	8	146	2	2	5						
3			30.5			7.3	12		4	1							
4			30.4	30.0	-0.4	7.4	5	143	4	2	58						
5			30.5	30.0	-0.5	7.5	10	172	3	4	43						
6			30.5	30.1	-0.4	7.5	13	238	0	3	27						
7			30.7	30.0	-0.7	7.6	11	125	1	1	39						
8			30.5	30.3	-0.2	7.8	12	75	1	2	28						
9			29.8	29.9	-0.1	7.9	7	250	2	3	18						
10			28.4	28.8	+0.4	7.9	1	240	½	½	5						
11			28.4	28.5	+0.1	8.0	1	230	2	2	5						
12			No data recorded - no water														
			No data recorded - no water														

25.VI.69

Stn.	Time rec. comm.	Temperature °C				H_2O pH	H_2O depth (cm)	Strm wdth (cm)	[1]Vegetation (Rel.abund)		[2]Relative Density			[3]Standard length (mm)			
		Amb.	Bott. H_2O	2.5cm sub-bed	Diff. sub-bed bott. temp.				Cyp.	Algae	Tot.	♂	♀	♂		♀	
														R	M	R	M
1	1155	15.9	29.7	30.2	+0.5	7.3	7				15						
2			30.0	30.0	0	7.2	6				2						
3			29.8			8.5											
4			29.5			7.2	8				1						
5			29.5			7.3	24				41						
6			29.3	29.3	0	7.3	13.5				23						
7			29.0	28.7	-0.3	7.3	7				31						
8			28.1	28.2	+0.1	7.5	8				39						
9			27.9	27.7	-0.2	7.6	10				14						
10			24.0	24.0	0	8.2	2				15						
11			22.3	21.8	-0.5	8.8	8				1						
12			16.8	15.4	-1.4	8.9	13				0						
13			18.0	16.0	-2.0	8.9	14				0						

13.XI.69

Stn.	Time rec. comm.	Temperature °C				H_2O pH	H_2O dpth (cm)	Strm width (cm)	[1]Vegetation (Rel.abund)		[2]Relative Density			[3]Standard length (mm)			
		Amb.	Bott. H_2O	2.5cm sub-bed	Diff. sub-bed bott. temp.				Cyp.	Algae	Tot.	♂	♀	♂		♀	
														R	M	R	M
1	1500	31.8	31.0	29.0	-2.0	7.2	13	10	5	0	0 species in abundance						
2			31.0	31.0	0	7.2	14	210	5	1	0						
3			31.0			7.2	14	80	4	1							
4			31.0	31.0	0	7.3	12	122	5	1	64						
5			31.0	31.0	0	7.3	8	134	0	3	99						
6			31.0	31.0	0	7.4	7	120	0	3	43						
7			31.0	31.0	0	7.5	8	118	1	2	48						
8			31.7	31.5	-0.2	8.1	2	150	2	2	35						
9			29.1	29.5	+0.4	8.4	2	52	0	½	0						
10			28.9	29.0	+0.1	8.8	3	750	1	0	0						
11			31.7	31.6	-0.1	7.9	4	76	2	0	13						
12			31.0	29.9	-0.1	9.0	10	110x26 m	0	0	35						
13			30.7	29.9	-0.8	9.1	16		0	0	88						

22.II.70

Stn.	Time rec. comm.	Temperature °C				H_2O pH	H_2O depth (cm)	Strm width (cm)	[1]Vegetation (Rel.abund)		[2]Relative Density			[3]Standard length (mm)			
		Amb.	Bott. H_2O	2.5cm sub-bed	Diff. sub-bed bott. temp.				Cyp.	Algae	Tot.	♂	♀	♂		♀	
														R	M	R	M
1	1615	30.9	30.9	0	7.0	3			1	1	0						
2			30.5	30.9	+0.4	7.2	5	117	1	2	0						
3			30.4			7.2	6	90	3	1							
4			30.1	30.3	+0.2	7.2	5	75	1	1	13						
5			30.2	30.4	+0.2	7.3	6	160	0	4	10						
6			30.1	30.4	+0.3	7.4	6	180	0	4	20						
7			30.0	30.1	+0.1	7.5	6	90	0	2	19						
8			29.5	30.0	+0.5	7.7	8	43	0	1	3						
9			29.5	30.0	+0.5	7.7	9	50	1	3	6						
10			29.2	30.0	+0.8	7.8	6	100	½	3	14						
11			29.0	29.1	+0.1	7.9	6	73	1	2	4						
12			No data recorded - no water														
13			No data recorded, no water														

11.IV.70

		Temperature °C							[1]Vegetation (Rel.abund)		[2]Relative Density			[3]Standard lgth (mm)			
Stn.	Time rec. comm.	Amb.	Bott. H_2O	2.5cm sub-bed	Diff. sub-bed bott. temp.	H_2O pH	H_2O depth (cm)	Strm width (cm)	Cyp.	Algae	Tot.	♂	♀	♂		♀	
														R	M	R	M
1	1630	28.7	30.0	30.8	+0.8	7.2	4		0	½	0						
2			30.0	30.8	+0.8	7.2	6	100	½	2	0						
3			29.5			7.3	9	86	3	½							
4			29.0	29.0	0	7.3	5	128	0	1	15 incl.one unsexed juv.	7	7				
5			28.9	29.0	+0.1	7.4	8	190	0	3	12 three unsexed juv.	6	3				
6			28.5	28.5	0	7.4	6	190	0	4	24	6	14	(four unsx.juv.)			
7			27.8	27.8	0	7.4	10	88	0	1	48	18	25	(five " ")			
8			27.0	27.0	0	7.6	5	75	0	2	10	7	3				
9			26.5	27.0	+0.5	7.6	5	80	0	2	9	5	4				
10			26.0	26.5	+0.5	7.8	11	75	2	3	23	13	10				
11			25.0	25.5	+0.5	7.8	7	100	2	2	10	4	4	(two unxd.juv.)			
12			No data recorded, no water														
13			" "	"	"	"											

10.VI.70

Stn.	Time rec. comm.	Temperature °C				H_2O pH	H_2O dpth (cm)	Strm wdth (cm)	[1]Vegetation (Rel.abund)		[2]Relative Density			[3]Standard length (mm)			
		Amb.	Bott. H_2O	2.5cm sub-bed	Diff. sub-bed bott. temp.				Cyp.	Algae	Tot.	♂	♀	♂		♀	
														R	M	R	M
1	1250	20.5	29.0	30.0	+1.0	7.2	1		4	4	0						
2			30.5	30.5	0	7.2	6	107	½	½	0						
3			30.4			7.2	8	80	3	½							
4			30.0	30.0	0	7.3	5	73	0	1	5	3	2	27-33	30.7	30-31	30.5
5			29.9	29.4	-0.5	7.3	7	90	0	3	34	15	19	24-40	33.9	22-40	33.9
6			29.9	29.4	-0.5	7.3	7	90	0	3	15	7	8	21-40	32.4	27-36	33.0
7			29.5	29.5	0	7.3	8		½	3	15	5	10	28-40	32.8	26-37	32.5
8			29.0	29.0	0	7.6	8	61	0	1	7 (one juv)	3	3	33-41	38.3	27-33	31.0
9			29.0	29.0	0	7.6	14	53	1	2	25	15	10	26-42	34.3	27-37	32.6
10			28.5	28.5	0	7.7	13	110	2	2	9	3	6	33-38	35.0	26-41	33.5
11			28.0	28.1	+0.1	7.7	9	225	2	2	3	2	1	26-29	27.5	33	33.0
12			No data recorded, no water														
13			No data recorded, no water														

23.VI.70

Stn.	Time rec. comm.	Temperature °C				H_2O pH	H_2O dpth (cm)	Strm wdth (cm)	[1]Vegetatn.		[2]Relative Density			[3]Standard length (mm)			
		Amb.	Bott. H_2O	2.5cm sub-bed	Diff. sub-bed bott. temp.				Cyp.	Algae	Tot.	♂	♀	♂		♀	
														R	M	R	M
1											0						
2											0						
3																	
4											16 (one un-sxd.juv.)	9	6	23-38	29.3	21-36	27.5
5											17	9	8	22-35	22.7	18-37	28.2
6											37	15	22	19-42	27.2	19-37	29.0
7											10	2	8	35-37	36.0	26-38	33.7
8											14	7	7	29-38	35.4	21-38	33.4
9											8	5	3	31-44	36.4	34-39	36.0
10											8	3	5	21-39	31.7	23-37	32.0
11											8	3	5	21-35	27.7	20-33	24.2
12		No data recorded - no water															
13		No data recorded - no water															

30.VII.70

Stn.	Time rec. comm.	Temperature °C				H_2O pH	H_2O dpth (cm)	Strm wdth (cm)	[1]Vegetatn. (Rel. abund)		[2]Relative Density			[3]Standard length (mm)			
		Amb.	Bott. H_2O	2.5cm sub-bed	Diff. sub-bed bott. temp.				Cyp.	Algae	Tot.	♂	♀	♂		♀	
														R	M	R	M
1	1400	17.7	25.5	29.3	+0.9	7.2		6	0	0	0						
2			30.3	30.0	-0.3	7.1	6	110	6	2	0						
3			29.7			7.2	10	80	3	1							
4			29.0	29.0	0	7.3	4	120	1	1	7	3	4	20-24	22.3	20-26	22.5
5			29.0	29.0	0	7.3	3	80	0	5	14	3	11	23-28	25.6	20-32	25.2
6			28.5	28.5	0	7.3	4	96	0	5	11	6	5	19-36	24.0	22-41	26.8
7			28.0	28.0	0	7.3	5	80	2	5	19	10	9	19-36	26.9	17-33	26.7
8			27.0	27.0	0	7.6	5	84	5	1	22	10	12	22-31	25.6	20-28	23.4
9			27.0	27.0	0	7.6	9	61	1½	2½	24	17	7	20-33	27.1	22-35	27.1
10			26.3	26.4	+0.1	7.7	3	190	5	1	35	18	17	22-43	27.4	20-31	24.8
11			25.4	25.5	+0.1	7.8	4	200	2	1	13	8	5	17-28	24.8	21-36	26.8
12			No data recorded.			No water.											
13			No data recorded.			No water.											

22.VIII.70

Stn.	Time rec. comm.	Temperature °C				H_2O pH	H_2O dpth (cm)	Strm wdth (cm)	[1]Vegetatn. (Rel.abund)		[2]Relative Density			[3]Standard length (mm)			
		Amb.	Bott. H_2O	2.5cm sub-bed	Diff. sub-bed bott. temp.				Cyp.	Algae	Tot.	♂	♀	♂		♀	
														R	M	R	M
1	1400	19.7	31.0	31.0	0	7.1	7		0	0	0						
2			30.4	30.5	+0.1	7.1	1	120	3	2	0						
3			30.0			7.2	10	91	½	3							
4			29.6	29.8	+0.2	7.3	4	120	¼	¼	30	19	11	24-41	30.6	25-37	31.8
5			29.5	29.5	0	7.3	5	81	0	¼	17	9	8	19-34	27.9	20-41	33.2
6			29.1	29.1	0	7.4	5	88	0	¼	23	11	12	17-37	28.1	20.42	29.6
7			28.7	29.0	+0.3	7.6	4	235	¼	¼	4	3	1	30-31	30.3	27	27
8			28.2	28.4	±0.2	7.7	4	275	¼	½	18	11	7	19-40	25.9	23-33	25.8
9			28.0	27.1	-0.9	7.7	4	800	0	0	0						
10			26.9	26.5	-0.4	7.8	2	64	¼	0	7 (one unsxd. juv.)	3	3	21-34	29.0	18-27	23.7
11			26.1	25.7	-0.4	7.9	4	157	1	¼	3	3	0	24-29	26.3		
12			No data recorded - no water														
13			No data recorded - no water														

27.IX.70

Stn.	Time rec. comm.	Temperature °C				H_2O pH	H_2O dpth (cm)	Strm wdth (cm)	[1]Vegetatn (Rel.abund)		[2]Relative Density			[3]Standard length (mm)			
														♂		♀	
		Amb.	Bott. H_2O	2-5cm sub-bed	Diff. sub-bed bott. temp.				Cyp.	Algae	Total	♂	♀	R	M	R	M
1	1520	18.5	28.9	30.4	+1.5	7.1			0	0	0						
2			28.8	28.2	-0.6	7.1	9	115	3	3	0						
3			28.5			7.1	8	100	3	1							
4			28.0	27.9	-0.1	7.2	8	107	1	3	18	7	11	23-24	27.6	25-34	28.0
5			28.4	27.5	-0.9	7.2	3	122	0	2	19	13	6	23-43	32.1	22-40	29.0
6			27.6	27.4	-0.2	7.3	8	62	0	2	16 (one un-sxd juv.)	6	9	25-35	27.8	24-41	29.2
7			27.0	26.5	-0.5	7.3	6	110	½	½	8	3	5	28-31	29.7	24-34	30.2
8			25.9	25.0	-0.9	7.5	4	500	¼	1	0						
9			24.5	24.0	-0.5	7.6	5	600	0	3	1	1	0		32		
10			21.9	21.6	-0.3	7.9	5	80	2	¼	1 (unsxd juv)						
11			20.6	20.5	-0.1	8.1	5	120	½	¼	1	1	0		27		
12			18.7	18.4	-0.3	9.3	8		0	0	0						
13			17.5	17.6	_0.1	9.3	12		0	0	0						

31.X.70

Stn.	Time rec. comm.	Temperature °C				H_2O pH	H_2O dpth (cm)	Strm width (cm)	1Vegetatn. (Rel.abund)		2Relative Density			2Standard length (mm)			
		Amb.	Bott. H_2O	2.5cm sub-bed	Diff. sub-bed bott. temp.				Cyp.	Algae	Tot.	♂	♀	♂		♀	
														R	M	R	M
1	1010	26.9	31.5	31.5	0	7.0	4		3	2	0						
2			31.4	31.1	-0.3	7.0	5	130	4	4	0						
3			31.0			7.0	8	90	2	3							
4			31.0	31.3	+0.3	7.1	6	118	1	2	2	0	2			35-41	38.0
5			31.3	31.3	0	7.3	5	218	0	4	9	3	6	28-35	32.3	27-36	30.0
6			31.7	31.5	-0.2	7.3	8	147	0	1	13 (one unsxd. juv.)	6	6	27-40	33.3	27-37	31.0
7			32.0	31.7	-0.3	7.3	6	180	¼	1	4	2	2	19-31	25.0	29.33	31.0
8			32.1	31.9	-0.2	7.4	5	171	0	0	3	2	1	25-33	29.0		36.0
9			32.0	31.9	-0.1	7.5	3	117	¼	¼	3	1	2		33.0	29-31	30.0
10			29.5	27.6	-1.9	8.6	4	20	1	0							
11			33.0	32.2	-0.8	8.3	5	81	1	0	0						
12			31.0	30.5	-0.5	9.5	3	11m	0	0	0						
13																	

25.XI.70

Stn.	Time rec. comm.	Temperature °C				H_2O pH	H_2O dpth (cm)	Strm width (cm)	[1]Vegetatn. (Rel.abund)		[2]Relative Density			[3]Standard length (mm)			
		Amb.	Bott. H_2O	2.5cm sub-bed	Diff. sub-bed bott. temp.				Cyp.	Algae	Tot.	♂	♀	♂		♀	
														R	M	R	M
1	1335	30.0	31.0	31.3	+0.3	7.0			3	2	species present in abundance						
2			31.0	31.0	0	7.0			3	3	5	2	3	28-32	30.0	25-28	26.3
3			31.0			7.1			3	3							
4			30.9	31.0	+0.1	7.2			3	2	18	10	8	23-40	33.8	30-41	35.4
5			30.9	31.0	+0.1	7.2			0	2½	23	15	8	25-45	32.7	26-43	32.1
6			30.8	31.0	+0.2	7.3			0	3	13	7	6	25-37	31.1	28-41	32.8
7			30.5	30.9	+0.4	7.3			½	2	17	10	7	27-41	33.4	24-37	32.1
8			30.5	30.5	0	7.4			¼	1	4	2	2	30-37	33.5	31-37	34.0
9																	
10																	
11			No data recorded														
12																	
13																	

Appendix 9

Bottom water temperatures and differences between them, and sub-bed temperatures (at 2.5 and 9.0 cm depth) recorded at the respective stations at Coward Springs Railway Bore (locality 34) 1968.

Date recorded 14.XII.67			
Station	Bottom-water temp °C	Difference sub-bed/bott. water temp °C	
		2.5 cm depth	9.0 cm depth
1	31.6	+0.3	+0.4
2	35.0	-0.5	-4.3
3	34.5	-2.0	-7.0
4	33.0	-1.5	-4.5
5			
6			
7			
8			
Range	31.6 to 35.0	-0.5 to -2.0	-4.3 to -7.0
Mean	33.5	-0.9	-3.8

Date recorded 21.II.68			
Station	Bottom-water temp °C	Difference sub-bed/bott. water temp °C	
		2.5 cm depth	9.0 cm depth
1	31.5	+0.9	+0.1
2	38.2	+5.1	-8.3
3	37.8	-6.9	-9.8
4	31.5	-4.1	-4.5
5	30.0	-2.6	-2.8
6	33.0	-0.5	-0.5
7	36.1	-3.5	-6.1
8		-7.8	-8.8
Range	30.0 to 38.2	-0.5 to -6.9	+0.5 to -9.8
Mean	34.5	-3.7	-5.1

Date recorded 22.III.68			
Station	Bottom-water temp °C	Difference sub-bed/bott. water temp °C	
		2.5 cm depth	9.0 cm depth
1	31.0	+0.5	+0.5
2	33.1	0	-1.3
3	34.0	-0.7	-3.5
4	29.9	-0.4	-2.0
5	30.0	-2.0	-3.0
6	31.5	-1.0	-3.5
7	32.0	-0.7	-0.3
8	29.6	+0.8	+0.2
Range	29.6 to 34.0	+0.8 to -2.0	+0.2 to -3.5
Mean	31.4	-0.6	-1.6

Date recorded 26.IV.68			
Station	Bottom-water temp °C	Difference sub-bed/bott. water temp °C	
		2.5 cm depth	9.0 cm depth
1	29.9	+0.1	+0.2
2	25.5	+1.0	+0.5
3	24.5	-1.3	-1.8
4	22.0	0	-1.0
5	21.5	-0.9	-1.3
6	23.7	-1.8	-2.1
7	23.5	0	-0.2
8	23.6	-0.1	-0.1
Range	21.5 to 29.9	+1.0 to -1.8	+0.5 to -2.1
Mean	24.3	-0.4	-0.7

Date recorded 28.V.68				Date recorded 30.VI.68			
Station	Bottom-water temp °C	Difference sub-bed/bott. water temp °C		Station	Bottom-water temp °C	Difference sub-bed/bott. water temp °C	
		2.5 cm depth	9.0 cm depth			2.5 cm depth	9.0 cm depth
1	29.6	+0.4	+0.4	1	29.0	+0.3	+0.3
2	22.0	+0.3	-0.5	2	18.0	+0.5	+0.8
3	21.5	-1.0	-2.0	3	16.9	+0.1	+0.1
4	17.0	-0.9	-1.5	4	13.8	+0.1	+0.3
5	16.1	-1.1	-1.1	5	13.0	+0.1	+0.2
6	16.0	-0.5	-0.1	6	12.8	+0.5	+0.7
7	18.9	-0.4	-1.4	7	12.9	+0.4	+0.6
8	18.7	-0.3	-0.7	8	13.4	+0.4	+0.6
Range	16.1 to 29.6	+0.4 to -1.9	+0.4 to -2.0	Range	12.9 to 29.0	+0.1 to +0.5	+0.1 to +0.8
Mean	19.9	-0.4	-0.8	Mean	16.2	+0.3	+0.4

Date recorded 26.VII.68				Date recorded 31.VIII.68			
Station	Bottom-water temp °C	Difference sub-bed/bott. water temp °C		Station	Bottom-water temp °C	Difference sub-bed/bott. water temp °C	
		2.5 cm depth	9.0 cm depth			2.5 cm depth	9.0 cm depth
1	29.3	+0.7	+0.8	1	29.9	+0.1	+0.3
2	20.0	0	-0.2	2	22.7	-0.2	-1.7
3	17.5	-1.5	-1.5	3	19.0	-1.5	-2.5
4	11.0	0	0	4	20.0	-8.0	-8.0
5	10.5	0	-0.3	5	13.5	-0.5	-1.5
6	16.5	-2.5	-2.5	6	21.9	-4.4	-5.9
7	15.5	-2.0	-2.5	7	19.7	-2.2	-4.2
8	17.2	-2.3	-3.2	8			
Range	10.5 to 29.3	-2.5 to +0.7	-3.2 to +0.8	Range	13.5 to 29.9	-4.4 to +0.1	-8.0 to +0.3
Mean	17.2	-0.9	-1.2	Mean	20.9	-2.4	-3.4

Date recorded 28.X.68				Date recorded 15.XI.68			
Station	Bottom-water temp °C	Difference sub-bed bott. water temp °C		Station	Bottom-water temp °C	Difference sub-bed bott. water temp °C	
		2.5 cm depth	9.0 cm depth			2.5 cm depth	9.0 cm depth
1	30.4	+0.2	+0.2	1	30.5	+0.5	+0.5
2	31.1	+0.3	-0.1	2	32.0	-2.5	-5.5
3	29.0	-4.0	-7.0	3	28.0	-5.7	-6.0
4	24.0	-2.5	-3.5	4	22.3	-1.3	-2.8
5	26.2	-2.2	-3.2	5			
6				6			
7				7			
8				8			
Range	24.0 to 31.1	-4.0 to +0.3	-7.0 to +0.2	Range	22.3 to 32.0	-5.7 to +0.5	-6.0 to +0.5
Mean	28.1	-1.6	-2.7	Mean	28.2	-2.2	-3.4

Date recorded 19.XII.68			
Station	Bottom-water temp °C	Difference sub-bed bott. water temp °C	
		2.5 cm depth	9.0 cm depth
1	30.3	+0.2	+0.2
2	30.8	+0.7	-0.8
3	31.5	-1.0	-3.0
4			
5			
6			
7			
8			
Range	30.8 to 31.5	-1.0 to +0.7	-3.0 to +0.2
Mean	30.8	0	-1.2

Appendix H

Bottom water temperatures and differences between them and sub-bed temperatures (at 2.5 cm depth) recorded at the respective stations at Wobna Spring (locality 35), 1968-70.

Date recorded 27.IV.68			Date recorded 29.V.68		
Station	Bottom-water temp °C	Difference sub-bed bott. water temp °C	Station	Bottom-water temp °C	Difference sub-bed bott water temp °C
1	29.6	+0.4	1	28.9	+1.6
2	-	-	2	30.2	-
3	30.5	-	3	30.1	-
4	30.3	-0.3	4	30.0	-0.5
5	-	-	5	29.8	-0.2
6	30.3	-0.6	6	29.3	-0.4
7	30.0	-0.3	7	28.9	-0.2
8	23.8	-0.8	8	25.5	-1.0
9	-	-	9	24.5	-0.4
10	-	-	10	17.6	-1.1
11	-	-	11	19.8	-0.9
12	-	-	12	-	-
13	-	-	13	-	-
Range	23.8 to 30.5	-0.8 to +0.4	Range	17.6 to 30.2	-1.1 to +1.6
Mean	29.1	-0.3	Mean	24.0	-0.3

Date recorded 30.VI.68			Date recorded 26.VII.68		
Station	Bottom-water temp °C	Difference sub-bed bott. water temp °C	Station	Bottom-water temp °C	Difference sub-bed bott water temp °C
1	29.0	+0.6	1	29.9	+1.0
2	30.0	0	2	30.5	-0.6
3	29.2	-	3	30.0	-
4	29.0	0	4	29.8	-0.2
5	29.0	-0.2	5	29.5	-0.2
6	27.3	-0.3	6	28.8	-0.3
7	27.3	-0.3	7	28.9	-0.2
8	26.8	0	8	22.3	-0.8
9	15.2	+0.3	9	22.5	-1.3
10	12.5	+0.4	10	19.0	-0.5
11	13.5	+0.1	11	18.7	-0.6
12	13.5	+0.5	12	19.0	-2.0
13	-	-	13	-	-
Range	12.5 to 30.0	-0.3 to +0.6	Range	18.7 to 30.5	-2.0 to +1.0
Mean	23.5	+0.1	Mean	25.7	-0.5

Date recorded 1.IX.68			Date recorded 28.X.68		
Station	Bottom-water temp °C	Difference sub-bed bott. water temp °C	Station	Bottom-water temp °C	Difference sub-bed bott. water temp °C
1	30.1	+0.4	1	30.0	+0.4
2	30.5	-0.1	2	30.5	0
3	30.2	-	3	30.5	-
4	30.0	0	4	30.5	0
5	30.0	-0.5	5	30.4	0
6	30.0	-0.1	6	30.3	0
7	29.9	-0.2	7	30.0	+0.2
8	25.5	+0.4	8	29.4	+0.6
9	25.4	+0.1	9	28.8	+0.3
10	22.8	-0.8	10	27.5	+0.5
11	21.2	-1.7	11	26.0	+0.5
12	22.3	-2.3	12	29.8	-0.3
13	17.3	-3.2	13	29.6	-2.1
Range	17.3 to 30.5	-3.2 to +0.4	Range	26.0 to 30.5	-2.1 to +0.6
Mean	26.5	-0.7	Mean	29.5	0

Date recorded 15.XI.68			Date recorded 24.I.69		
Station	Bottom-water temp °C	Difference sub-bed bott. water temp °C	Station	Bottom-water temp °C	Difference sub-bed bott. water temp °C
1	30.5	+0.5	1	31.8	-0.3
2	30.9	-0.5	2	31.3	-0.3
3	30.9	-	3	31.2	-
4	30.9	-0.4	4	31.0	-0.4
5	31.0	-0.5	5	30.9	0
6	31.0	-0.5	6	31.0	0
7	31.0	-2.0	7	31.1	-0.1
8	29.5	-1.5	8	32.5	-2.0
9	29.5	+0.3	9	31.4	0
10	30.1	-2.1	10	33.5	-0.6
11	31.0	-5.2	11	32.6	-
12	30.5	-2.8	12	-	-
13	29.5	-2.8	13	33.4	-4.8
Range	29.5 to 31.0	-5.2 to +0.5	Range	31.0 to 33.5	-4.8 to 0
Mean	30.5	-1.5	Mean	31.8	-0.8

Date recorded 24.II.69			Date recorded 30.III.69		
Station	Bottom-water temp °C	Difference sub-bed bott. water temp °C	Station	Bottom-water temp °C	Difference sub-bed bott. water temp °C
1	33.0	-0.6	1	29.8	+0.8
2	31.3	+0.2	2	30.8	-0.3
3	31.5	-	3	30.6	-
4	31.5	+0.1	4	30.5	-0.1
5	32.8	-0.3	5	30.6	-0.5
6	32.1	-0.4	6	30.7	-0.4
7	32.5	-0.4	7	30.5	-0.5
8	34.8	-3.9	8	30.4	-0.4
9	30.5	+0.5	9	29.9	-1.1
10	30.5	+2.5	10	28.5	-1.5
11	33.6	-1.1	11	27.9	-1.4
12	-	-	12	25.5	-2.0
13	-	-	13	25.0	-2.5
Range	30.5 to 34.8	-3.9 to +2.5	Range	25.0 to 30.8	-2.5 to +0.8
Mean	32.2	-0.3	Mean	29.3	-0.8

Date recorded 30.IV.69			Date recorded 25.VI.69		
Station	Bottom-water temp °C	Difference sub-bed bott. water temp °C	Station	Bottom-water temp °C	Difference sub-bed bott. water temp °C
1	29.0	+1.2	1	29.7	+0.5
2	30.5	0	2	30.0	0
3	30.5	-	3	29.8	-
4	30.4	-0.4	4	29.5	-
5	30.5	-0.5	5	29.5	-
6	30.5	-0.4	6	29.3	0
7	30.7	-0.7	7	29.0	-0.3
8	30.5	-0.2	8	28.1	+0.1
9	29.8	-0.1	9	27.9	-0.2
10	28.4	+0.4	10	24.0	0
11	28.4	+0.1	11	22.3	-0.5
12	-	-	12	16.8	-1.4
13	-	-	13	18.0	-2.0
Range	28.4 to 30.7	-0.7 to +1.2	Range	16.8 to 30.0	-2.0 to +0.5
Mean	29.9	-0.1	Mean	26.4	-0.3

Date recorded 13.XI.69			Date recorded 22.II.70		
Station	Bottom-water temp °C	Difference sub-bed bott. water temp °C	Station	Bottom-water temp °C	Difference sub-bed bott. water temp °C
1	31.0	-2.0	1	30.9	0
2	31.0	0	2	30.5	+0.4
3	31.0	-	3	30.4	-
4	31.0	0	4	30.1	+0.2
5	31.0	0	5	30.2	+0.2
6	31.0	0	6	30.1	+0.3
7	31.0	0	7	30.0	+0.1
8	31.7	-0.2	8	29.5	+0.5
9	29.1	+0.4	9	29.5	+0.5
10	28.9	+0.1	10	29.2	+0.8
11	31.7	-0.1	11	29.0	+0.1
12	31.0	-0.1	12	-	-
13	30.0	-0.8	13	-	-
Range	29.1 to 31.7	-2.0 to +0.4	Range	29.0 to 30.9	0 to +0.8
Mean	30.7	-0.1	Mean	29.9	+0.3

Date recorded 11.IV.70			Date recorded 10.VI.70		
Station	Bottom water temp °C	Difference sub-bed bott. water temp °C	Station	Bottom-water temp °C	Difference sub-bed bott. water temp °C
1	30.0	+0.8	1	29.0	+1.0
2	30.0	+0.8	2	30.5	0
3	29.5	-	3	30.4	-
4	29.0	0	4	30.0	0
5	28.9	+0.1	5	30.0	0
6	28.5	0	6	29.9	-0.5
7	27.8	0	7	29.5	0
8	27.0	0	8	29.0	0
9	26.5	+0.5	9	29.0	0
10	26.0	+0.5	10	28.5	0
11	25.0	+0.5	11	28.0	+0.1
12	-	-	12	-	-
13	-	-	13	-	-
Range	25.0 to 30.0	0 to +0.8	Range	28.0 to 30.5	-0.5 to +1.0
Mean	28.0	+0.3	Mean	29.4	+0.1

Date recorded 29.VII.70			Date recorded 22.VIII.70		
Station	Bottom-water temp °C	Difference sub-bed bott. water temp °C	Station	Bottom-water temp °C	Difference sub-bed bott. water temp °C
1	25.5	+0.9	1	31.0	0
2	30.3	-0.3	2	30.4	+0.1
3	29.7	-	3	30.0	-
4	29.0	0	4	29.6	+0.2
5	29.0	0	5	29.5	0
6	28.5	0	6	29.1	0
7	28.0	0	7	28.7	+0.3
8	27.0	0	8	28.2	+0.2
9	27.0	0	9	28.0	-0.9
10	26.3	+0.1	10	26.9	-0.4
11	25.4	+0.1	11	26.1	-0.4
12	-	-	12	-	-
13	-	-	13	-	-
Range	25.4 to 30.3	-0.3 to +0.9	Range	26.1 to 31.0	-0.9 to +0.3
Mean	28.2	+0.1	Mean	28.8	-0.1

Date recorded 27.IX.70			Date recorded 31.X.70		
Station	Bottom-water temp °C	Difference sub-bed bott. water temp °C	Station	Bottom-water temp °C	Difference sub-bed bott. water temp °C
1	28.9	+1.5	1	31.5	0
2	28.8	-0.6	2	31.4	-0.3
3	28.5	-	3	31.0	-
4	28.0	-0.1	4	31.0	+0.3
5	28.4	-0.9	5	31.3	0
6	27.6	-0.2	6	31.7	-0.2
7	27.0	-0.5	7	32.0	-0.3
8	25.9	-0.9	8	32.1	-0.2
9	24.5	-0.5	9	32.0	-0.1
10	21.9	-0.3	10	29.5	-1.9
11	20.6	-0.1	11	33.0	-0.8
12	18.7	-0.3	12	31.0	-0.5
13	17.5	+0.1	13	-	-
Range	17.5 to 28.9	-0.9 to +1.5	Range	29.5 to 33.0	-1.9 to +0.3
Mean	25.1	-0.2	Mean	31.5	-0.4

Date recorded 25.XI.70		
Station	Bottom-water temp °C	Difference sub-bed bott. water temp °C
1	31.0	+0.3
2	31.0	0
3	31.0	-
4	30.9	+0.1
5	30.9	+0.1
6	30.8	+0.2
7	30.5	10.4
8	30.5	0
9	-	-
10	-	-
11	-	-
12	-	-
13	-	-
Range	30.5 to 31.0	0 to +0.4
Mean	30.8	+0.2

Appendix I

Length - Frequencies of trapped _C_. _eremius_ collections from Johnson's No. 3 Bore (locality 24) - pool A.

SL mm.	Sampled 3.IX.68		Sampled 3.VI.70		Sampled 14.IV.70		Sampled 15.VI.70	
	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀
17								
18								
19						1		
20	1			2				
21	1	1			1	2		2
22	1	5		3		3	2	2
23	2	6	1	4	1	4	3	2
24		10	1	2	4	4	2	3
25	2	5	1	1	2	8	1	5
26	3	9	1	2	1	5	2	5
27	8	14	1	3	4	2	6	5
28	7	19		5		1	2	4
29	5	19	2	4	1	3	2	4
30	5	13	1	4	2	4	2	
31	8	7		4		1	1	2
32	8	8			1	2		1
33	10	6	1	1		3	1	1
34	10	1		1	1		1	1
35	10	2					1	2
36	1	4						1
37	5	6				1		1
38	4	3				1		
39	5	2			1		3	
40	2	3					1	
41	1		1		3		1	
42	2						1	
43	3							
44	3							
45	1				1			
46	4				1			
47								
48								
Total Nos	112	143	10	36	24	45	32	41

SL mm.	Sampled 16.VI.70		Sampled 18.VI.70		Sampled 19.VI.70		Sampled 20.VI.70	
	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀
17								
18								
19		1		1				
20			1				1	
21	1	1			1	1		2
22		1	1	1				
23	3	2	2		1	3		1
24		1	1	1	1	5		
25		2	1	5	1	1	1	2
26		1	1	6	3	3	2	3
27		2		4		3	1	2
28	3	4		3	3	4	1	1
29	2	1	1	4			1	1
30	1	3	6	6	2	1		2
31	1	3		4	1	3		
32		3	1	1		2		
33	1	1	2		2	2		
34		2	2			2		
35	3	2	1		2			
36					2	2		
37	2			1			1	
38								1
39		2	2		1			
40								
41	1		1		2			
42	1						1	
43								
44					1			
45								
46							1	
47								
48					1		1	
Total Nos	19	32	23	37	24	32	11	15

SL mm.	Sampled 21.VI.70		Sampled 26.VIII.70		Sampled 27.VIII.70		Sampled 28.VIII.70	
	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀
17						1		
18								
19								
20								
21	1	1						
22	2	1	1	1		1		2
23	2	2	2				2	1
24	1		3	6	4	7		4
25	3		3	4	2	5	2	11
26	1	2	2	9		6	6	7
27	1	1	3	11	6	14	3	6
28	1	1	1	3	5	9	1	12
29	3	3	3	7	8	10	2	12
30	2	4	3	9	2	6	3	4
31	1		3	2	5	7	5	10
32	1	2	4	2	2	3	7	2
33		2	3	3	4	3	4	1
34			5	2	3	5	3	1
35			2	3		3	1	1
36			2	3		2	1	2
37		1	3		1	1		1
38	1	1				2	1	
39				2	1		1	
40			2			1	2	
41	1		2				1	
42							1	
43	2							
44					1			
45	1							
46					1		1	
47								
48								
Total Nos	24	21	47	66	45	86	47	77

SL mm.	Sampled 29.VIII.70		Sampled 30.VIII.70		Sampled 31.VIII.70		Sampled 1.IX.70		Sampled 2.IX.70	
	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀
17										
18			1							1
19			1							
20	1									
21	1			1			1		1	
22	2			1		4		1		1
23	2	3	2	1			2	1		1
24		4	7	3		6	1	3	1	2
25		5	5	5		4	2	6	2	8
26	2	6	8	5	4	9	2	11	1	12
27	1	4	16	2	1	9	4	19	6	12
28	5	7	17	5	5	11	5	17	8	18
29	7	8	16	7	4	8	6	8	8	18
30	2	3	18	8	7	9	7	10	6	22
31	2	4	13	4	3	8	7	12	13	22
32	4	2	5	9	3	4	6	3	8	6
33	3	2	4	6	1	3	2	2	13	10
34	3	2	6	6	3		1	5	9	9
35	3		2	2				5	5	1
36	2	1	1	3		1		2	5	2
37	1	1	1	1			1			1
38	1		1			1		1	1	1
39									2	
40	1		1	1				1		
41	1									
42				1						
43										
44										
45										
46										
47										
48										
Total Nos	44	52	125	71	31	77	47	107	89	147

Appendix J

Length frequencies of trapped collections made at Johnson's No. 3 Bore (locality 24) - Pool B.

SL. mm.	Frequency													
	Sampled 14.VI.70		Sampled 15.VI.70		Sampled 16.VI.70		Sampled 18.VI.70		Sampled 19.VI.70		Sampled 20.VI.70		Sampled 27.VIII.70	
	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀
19													1	
20													3	1
21										1			5	
22	1		1		1	1				1			7	6
23						1				1			11	10
24	1	2				1	1			1			14	17
25	1	1	1		3					1	1	1	18	30
26		2	1	1		1						2	19	45
27	1	3	1	2		1		2	2	1	1	1	12	54
28	2	4	1	4		3	1	3	1	1	4	1	19	60
29	3	2		4		3	1	3	3	4	4	3	17	53
30	5	6		3	1	4	1	2		2	1	2	29	54
31		11		1		4	3	2	1	2	1	2	24	34
32	2	9	1	3	1			3		1		1	17	24
33	3	10	4	4	1	1	1	4	1	2	2	1	12	17
34	1	8		4		1	2		1	3	2	3	11	26
35	4	11	1	4		3		3	2	1	1	3	7	13
36	4	8		4	1	3	2	4	1	2	3	3	7	8
37	1	5		5	4	2		1		2	1	1	3	10
38	3	3	1	6	1		1	2	1		2	3	1	6
39	3	2	2	3	4	1		2	1		2	1	2	2
40	5	1	5	3	2		3		2	1	2	1	4	2
41	4		3		1		2		2				1	1
42	1	1	2		1		5						1	
43	3		2		3		4		2		5		4	
44	5		2		5		3		1		5			
45			3		1		5		2		1		3	
46			2				3		2		5			
47	2		1				1				5			
48	1										4			
49	2		1								3		1	
50	2		2		2						2			
51				1										
52														
53							1				1			
Total Nos.	58	89	37	52	32	30	40	31	25	27	58	29	253	472

Appendix K

Length frequencies of trapped collections made at Johnson's No. 3 Bore (locality 24) - Pool C.

SL. mm.	Frequency			
	Sampled 14.VI.70		Sampled 17.VI.70	
	♂♂	♀♀	♂♂	♀♀
20				
21		2		1
22	1		1	3
23	4		2	2
24	4		3	4
25	3	4	3	1
26	5	10	2	3
27	6	2	2	1
28	4	7	1	2
29	6	13	3	1
30	8	12	3	1
31	8	18		1
32	6	9	3	1
33	5	13	2	1
34	5	10	1	4
35	5	10	3	1
36	5	12	4	
37	7	6	1	
38	10	9	1	3
39	4	6	1	
40	7	2	3	1
41	15	6	1	1
42	5	1	2	
43	16	1		
44	9			
45	6	1	1	
46	8		3	
47	8			
48	5		1	
49	2			
50	2			
51	1			
52	2			
Total Nos.	182	154	47	32

Appendix L

Length frequencies of _C. eremius_ trapped collections from locality 27, Nunn's Bore.

Appendix

SL. mm.	Sampled 13.IV.70		Sampled 22.VI.70		Sampled 31.VII.70		Sampled 24.VIII.70		Sampled 4.IX.70		Sampled 1.XI.70		Sampled 31.V.71	
	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀
18												1		
19						1								
20						2								
21										1	1	3		
22												4		
23										1	5	2		
24				1				1				3		
25			1			1		1	1		5	2		1
26				2						1	5	5		1
27	1		1						1	2	3	6		
28	1	1			1			1			7	6		
29	1		1		2		2		2	2	3	11		
30	2	5	1	1	1	2	4	1		2	3	11		1
31	2	2	1		1	4	3	3	2	4	6	8		
32				1		1	3	4	1		3	9		
33	3	8	1	3		4	2	11		2	6	6		1
34	1	11	1	2		1	1	12		2	6	13		
35	3	12	1	3		2	3	7	1		7	15	1	
36	5	2		3	1	2	2	11		5	7	15		1
37	5	2		2	3	2	3	7		4	4	9		6
38	3	1	1	1	1	3	1	5	2	2	2	20	3	5
39	3	6		1	1	4	2	9			5	15		3
40	8	5	2	2		2	5	4	2	2	3	12		9
41	5	2	1	4			5	10		1	5	4	4	9
42	1	1		1	1	2	2	8		3	2	5	2	9
43	8	1	2	4		2	5	4	2	1	1	3	6	9
44	2		6	1			4	4			1	3	9	7
45	6		3	5			12	9	1		3	1	4	12
46	6		2	2	1	2	11	7	4	2	1	2	12	6
47	6		5	1	2		12	6	3	3	2		17	5
48	7		10				16	9			1		15	5
49	8		4	3	2		16	3	1		2	1	24	3
50	4		17	1	1		25	4	6		1	1	20	3
51			11		5		17	3	5				17	1
52	4		10		1		15	1	5				11	
53	1		9	1	3		9	1	5				3	
54	1		9				10	4	1		1	1	5	
55	2		12		2		5	1	3				5	
56			4				2						3	
57			2				2	1					2	
58			3				1							
59							2							
60													1	
61														
62														
63					1									
Total Nos.	99	59	121	45	30	36	202	152	48	40	101	196	164	97

Appendix M

Length Frequencies of Trapped Collections from Wobna Mound Spring (locality 35).

SL. mm.	Sampled 2.VI.70		Sampled 23.IV.70		Sampled 30.VII.70		Sampled 23.VIII.70	
	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀
15								
16		1			1			
17		1			1	1	1	
18			1	1			1	1
19			1	1	2		3	
20			1	2	3	4	2	2
21	1		3	5	1	6	1	2
22		1	2	1	6	5	1	
23			5	3	7	16	1	2
24	1		1	2	7	8	5	2
25	1	1	2	2	7	2	4	3
26	3	2	2	3	9	8	5	4
27	2	3	5		5	6	2	4
28	2	1	2	2	9	1	1	3
29	3	2	2	3	5	2	3	1
30	3	3		3	3	2	5	3
31	1	3	2	3	5	3	4	
32	3	7	4	7		3	3	2
33	4	9	1	5	1	1	5	
34	2	8		4			5	2
35	5	2	5	6		1	2	
36	2	5	1	4	3	1		4
37	7	8	4	3			3	4
38	4		5	2				
39	2	2	1	1				
40	5	1	1				1	
41	1	1		1		1	1	1
42	1		1					2
43					1			
44			1					
Total	53	60	53	64	75	71	59	42

APPENDIX N

Length frequencies of trapped collections from Blanche Cup Spring (locality 36).

SL. mm.	Frequency															
	Sampled 2.IX.70		Sampled 31.X.70		Sampled 24.XI.70		Sampled 1.II.71		Sampled 1.III.71		Sampled 31.III.71		Sampled 25.IV.71		Sampled 31.V.71	
	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀
25							1		1							
26							2									
27																1
28												2		1	1	
29					1				1							1
30							1		2						1	1
31		1					2	1	2	2			1		1	2
32	2	4						1	3					2	2	3
33	2	3					2		3	1	1	1			2	3
34	2	12					2		2	2	2	1	1		2	4
35	3	3	1					2	3	1	2	2	3	1	2	11
36	4	5							2		5	1	3	2	6	6
37		6					3		5	1	10	1	4	3	4	8
38		7						1	1	1	8	2	10	3	10	6
39	7	4	1	1			2	2	5	5	9	9	10	5	16	12
40	7	2					5	1	6	2	15	11	8	8	13	11
41	4	1					2	6	3	4	20	14	14	8	12	15
42	2	1					8	2	2	4	13	22	21	12	12	6
43	3	1		1			3	4	7	9	25	29	11	21	20	13
44	4			1			3	1	2	6	23	14	21	15	11	14
45	1		2			1	4		9	1	37	22	23	15	20	21
46	2						7	1	13		28	14	22	20	20	8
47	2		2	1		2	8	1	3		31	8	39	6	18	7
48					1		9		8		32	3	26	2	15	5
49			1	1	1	1	3		11	1	32	3	32	2	25	3
50	1		1		1	1	7	1	10	1	41	1	28	2	18	
51	1		1	1	2	1	1	1	10		30	1	27		27	1
52			3	1		2	1	1	8	3	24	3	20	2	23	4
53					1	2	1	3	6	2	21	7	16	2	27	1
54			3	2	2	4		4	5	1	9	8	14	4	6	5
55			4	1	3	4	1	8		6	7	6	7	6	7	7
56			1		2	3		2	1	4	4	3	2	2	6	4
57			1		1	1	1	3	2	1	3	2		1	1	6
58					2		2			3	4					1
59			1		3	2	2				2					
60					1	1			3		1					
Total Nos.	50	50	24	9	21	25	83	46	139	63	439	188	363	145	329	179

Appendix O

Trapping data, Nunn's Bore (locality 27) for the period 13.IV.70 to 31.V.71.

At each setting ten standard wire mesh traps (not baited) were placed at random for a 15 hour period overnight (1700 to 0800 hours).

Appendix

Trapping Date	Numbers Trapped
13.IV.70	158
22.VI.70	166
31.VII.70	66
24.VIII.70	354
4.IX.70	88
1.XI.70	297
31.V.71	262

Appendix P

Trapping date, Wobna Spring (locality 35) for the period 1.IX.68 to 25.XI.70.

At each setting single standard wire mesh trap, see Appendix for description (baited), placed at each station indicated for a 12 hour period overnight (1800 to 0600 hours). Where traps not set this was due to either no water or insufficient depth.

A trap was not set at Station 1 if it was obvious no fish were in the vicinity.

No trap was set at Station 3 due to a rock bed and insufficinet depth of water to set a trap.

Where traps were not set at Stations 12 and 13 (a side pool) this was due to the pool having dried up.

Where traps were not set at other stations, this was due to insufficient depth of water.

A = Although no fish were trapped, (apparently due to the trap sinking into the sand bed) many were sighted in the vicinity of Station 1 on these occasions.

B = Although no fish were trapped, several were sighted in the vicinity of the Station.

? = Fish unable to be sexed (juveniles).

																																											SIDE POOL										
	Station 1				Station 2				Station 3	Station 4				Station 5				Station 6				Station 7				Station 8				Station 9				Station 10				Station 11				Station 12				Station 13				Total numbers trapped			
Distance from Station 1 (Springhead) in metres					10				25	50				65				90				125				185				200				260				330				24m from St. 8				30m from St. 8							
Date of trapping	♂♂	♀♀	?	Total	♂♂	♀♀	?	Total		♂♂	♀♀	?	Total	♂♂	♀♀	?	Total	♂♂	♀♀	?	Total	♂♂	♀♀	?	Total	♂♂	♀♀	?	Total	♂♂	♀♀	?	Total	♂♂	♀♀	?	Total	♂♂	♀♀	?	Total	♂♂	♀♀	?	Total	♂♂	♀♀	?	Total	♂♂	♀♀	?	Total
1.IX.68				2				2					47	No	trap	set					101				48				8	No	trap	set		No	trap	set		No	trap	set					0				1				209
28.X.68				1	No	trap	set		No	No	trap	set					51				47																																99
15.XI.68				0				2	trap				6				13				36				53	No	trap	set		No	trap	set		No	trap	set		No	trap	set					4				15				129
19.XII.68				0				4	set				36				71				59				31				7																0				0				208
24.I.69				0				0	at				1				5				6				11				6				3				0				11	No	trap	set					0				43
24.II.69				0				0	any				11				14				21				60				0				10				17				0	No	trap	set		No	trap	set					133
30.III.69				0				0	time				4				6				20				4				5				11				0B				0B				0				0				50
30.IV.69				0				5					58				43				27				39				28				18				5				5				0				0				228
25.VI.69				15				2					13				41				23				31				39				14				15				1				0				0				194
13.XI.69				0A				0					64				99				43				48				35				0				0				13				35				88				425
22.II.70				0				0					13				10				20				19				3				6				14				4	No	trap	set		No	trap	set					89
11.IV.70				0				0		7	7	1	15	6	3	3	12	6	14	4	24	18	25	5	48	7	3	0	10	5	4	0	9	13	10	0	23	4	4	2	10	No	trap	set		No	trap	set		66	70	15	151
10.VI.70				0				0		3	2	0	5	15	19	0	34	7	8	0	15	5	10	0	15	3	3	1	7	15	10	0	25	3	6	0	9	2	1	0	3	No	trap	set		No	trap	set		53	59	1	113
23.VI.70				0				0		9	6	1	16	9	8	0	17	15	22	0	37	2	8	0	10	7	7	0	14	5	3	0	8	3	5	0	8	3	5	0	8	No	trap	set		No	trap	set		53	64	1	118
30.VII.70				0				0		3	4	0	7	3	11	0	14	6	5	0	11	10	9	0	19	10	12	0	22	17	7	0	24	18	17	0	35	8	5	0	13	No	trap	set		No	trap	set		75	70	0	145
22.VIII.70				0				0		19	11	0	30	9	8	0	17	11	12	0	23	3	1	0	4	11	7	0	18	0	0	0	0	3	3	1	7	3	0	0	3	No	trap	set		No	trap	set		59	42	1	102
27.IX.70				0				0		7	11	0	18	13	6	0	19	6	9	1	16	3	5	0	8				0	1	0	0	1	0	0	1	1	1	0	0	1				0				0	31	31	2	64
31.X.70				0				0		0	2	0	2	3	6	0	9	6	6	1	13	2	2	0	4	2	1	0	3	1	2	0	3	No	trap	set					0				0				0	14	19	1	34
25.XI.70				0A				5		10	8	0	18	15	8	0	23	7	6	0	13	10	7	0	17	2	2	0	4	No	trap	set		No	trap	set		No	trap	set		No	trap	set		No	trap	set		46	34	0	80

APPENDIX Q

Australian Mineral Development Laboratories reference numbers to water analyses.

Locality No.	Locality Name	Date Sampled	AMDL. Ref. No.
1/1	Dalhousie Main Spring	6.VIII.68	ANI/36/0 - 677/69
1/3	Dalhousie Spring 3	6.VIII.68	ANI/36/9 - 677/69
7	Forrest's Waterhole	20.XI.69	ANI/36/1 - 2263/70
9	Cramps Camp Waterhole	29.V.69	ANI/36/0 - 4361/69
12	Algebuckina Waterhole	31.VII.68	ANI/36/0 - 677/69
14	Peake Creek	30.VII.68	ANI/36/0 - 677/69
18	Birribirrina Spring	21.XI.69	ANI/36/1 - 2263/70
22	Mussel Waterhole	June 1969	ANI/36/0 - 82/70
23	Honeymoon Bore	1.II.71	ANI/36/0 - 3550/71
24	Johnsons No. 3 Bore	3.IX.68	ANI/36/0 - 1271/69
27	Nunn's Bore	(28.XI.69 (22.VI.70	ANI/36/1 - 2263/70 ANI/36/0 - 210/71
29	Strangways Springs Railway Bore	(31.X.71 (31.I.71	ANI/36/0 - 2357/71 ANI/36/0 - 3550/71
30	Strangways Springs Mound Spring	28.XI.69	ANI!36/1 - 2263/70
31	Beresford Reservoir	31.I.71	ANI/36/0 - 3550/71
32	Warburton Springs	(1959 (5.V.71	W1315/59 ANI/36/0 - 3550/71
33	Coward Springs proper	3.XI.61	W1827/61
34	Coward Springs Railway Bore	(26.IV.68 (April 1969	ANI/36/0 - 3370/68 ANI/36/0 - 3707/69
35	Wobna Spring	(27.IV.68 (3.X.70	ANI/36/0 - 3370/68 ANI/36/0 - 2357/71
36	Blanche Cup Spring	(2.XI.61 (1.II.71	W1833/61 ANI 36/0 - 3550/71
42	Callana Reservoir	1.II.71	ANI/36/0 - 3550/71
43	Lake Harry Bore	23.XI.70	ANI/36/0 - 2960/71
44	Clayton Bore	23.XI.70	ANI/36/0 - 2960/71
45	Dalkannina Bore	23.XI.70	ANI/36/0 - 2960/71
46	Cannawaukininna Bore	23.XI.70	ANI/36/0 - 2960/71
48	Kopperamanna No. 1 Bore	23.XI.70	ANI/36/0 - 2960/71
50	Mirra Mitta Bore	23.XI.70	ANI/36/0 - 2960/71
51	Gason Bore	23.XI.70	ANI/36/0 - 2960/71
54	Paralana Hot Springs	30.X.69	ANI/36/0 - 1816/70
55	Balcanoona Creek	30.X.69	ANI/36/0 - 1816/70
60	Montecolina Bore	29.X.69	ANI/36/0 - 1816/70
62	Mulligan Springs	24.X.69	ANI/36/0 - 1816/70
63	Twelve Springs	24.X.69	ANI/36/0 - 1816/70
64	Woolatchi Bore	29.X.69	ANI/36/0 - 1816/70
72	Broughton River	29.I.71	ANI/36/0 - 2960/71
73	Light River	26.XI.70	ANI/36/0 - 2960/71
76	Kroehns Landing, River Murray	12.VI.68	ANI/36/0 - 3897/68

Appendix R

Chemical analyses of test mediums employed in salinity tolerance tests upon C. *eremius*. All chemical values expressed in parts per million.

Medium	Origin	Amdel Ref. No.	Anions					Cations					Assumed Composition of Salts												Total Dissolved Salts (salinity)	Hardness (as $CaCO_3$)						Total alkalinity as $CaCO_3$	pH
			CL	SO_4	HCO_3	NO_3	F	Na	K	Ca	Mg	Fe	$CaHCO_3$	$CaSO_4$	$CaCl_2$	$MgHCO_3$	$MgSO_4$	$MgCl_2$	$NaHCO_3$	$NaSO_4$	NaCl	$NaNO_3$	KCL	$FeHCO_3$		Total	Temporary	Permanent	Due to Ca	Due to Mg	Due to Fe		
Distilled Water	S.A. Museum still	ANI/36/0 1881/71	1	< 2	< 5	-	-	<0.05	0.05	0.1	0.1														>1.25 <8.30								5.6
Control Artesian Water	Locality No. 26 (Nunn's Bore)	ANI/36/0 210/71	2720	600	310	-	-	1815	70	212	37		412	374			183			281	4380		134		5609	680	225	425	530	150		255	6.7
Diluted 1:19 Artesian Water	Locality No. 26 (Nunn's Bore)	ANI/36/0 1881/71	70	20	10	-	-	49	1	6	1		13	10			5			13	114		2		147	20	8	12	15	5		8	7.6
Saturated Artesian Water	Locality No. 26 (Nunn's Bore)	ANI/36/0 4791/70	4795	1260	95	-	-	3257	125	240	75		126	710			371			684	7718		238		9797	910	80	830	600	310		80	8.2
Sea Water	Off Grange S.A. St. Vincent's Gulf	ANI/36/0 1881/71	20800	2900	175	-	-	11545	450	360	1440		233	1026			2727	3481			29345		858		37580	6820	145	6675	900	5290		145	7.7

Appendix S

Data recorded during series of salinity tolerance trials upon *C. eremius*.

The control medium and diluted and saturated mediums were all prepared from artesian water sampled from the outflow point at Nunn's Bore (locality 26). The test subjects were stock from Nunn's Bore

\+ = mortality. The number following the mortality symbol indicates the standard length of the fish in mm.

Trial 1.

Test mediums:

(a) Distilled water, salinity = >1.25 <8.3ppm.

(b) Saturated artesian water salinity = 9,797ppm.

Control medium:

Artesian water sampled from locality 27, salinity = 5,609ppm.

Date commenced: 26.V.70

Duration of Trial: 13 days.

Remarks: Water temperatures and lengths not recorded.

Day from commencement	Control	Test medium (a)	Test medium (b)
1			
2			
3		I	
4			
5			
6		+	
7			
8			
9			
10			
11			
12			
13			

Trial 2.

Test mediums:

(a) Distilled water, salinity = >1.25 <8.3ppm.

(b) Saturated artesian water sampled from locality 27, salinity = 9,797ppm.

Control medium:

Artesian water sampled from locality 27, salinity = 5,609ppm.

Date commenced: 8.VI.1970.

Duration of Trial: 20 days.

Remarks:

Day from commencement	H_2O Temp. °C.	Control	Test medium (a)	Test medium (b)
1	16.0		+	
2	16.0			
3	16.0		+	
4	16.0			
5	16.0			
6	16.0			
7	16.0			
8	16.0			
9	16.0		+	
10	15.5			
11	16.0			
12	16.0			
13	16.0			
14	16.0		+	
15	16.0		+	
16	16.0			
17	16.0			
18	16.0			
19	16.0			
20	16.0		‡	

Trial 3.

Test mediums:

(a) Distilled water, salinity = >1.25 < 8.3ppm.

(b) Saturated artesian water sampled from locality 26, salinity = 9,797ppm.

Control Medium:

Artesian water sampled from locality 27, salinity = 5,609pp

Date commenced: 30.VI.1970.

Duration of trial: 34 days.

Remarks:

Day from commencement	H_2O Temp °C.	Control	Test Medium (a)	Test Medium (b)
1	15.0			
2	15.0			
3	14.5			
4	14.6			
5	14.7		+(34) +(30) +(38)	+(37)
6	14.5			
7	14.5		+(37)	
8	14.4			
9	13.0		+(36)	
10	12.0		+(49)	
11	13.5			
12	13.0			
13	13.5		+(49)	
14	13.3		+(33)	
15	12.5			
16	12.7		+(47)	
17	12.7		+(38)	
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
34				

Trial 4.

Test mediums:

(a) Distilled water salinity = >1.25 <8.3ppm.

(b) Saturated artesian water, salinity = 9,797ppm.

Control medium:

Artesian water sampled from Locality 27, salinity 5,609 ppm.

Date commenced: 4.VIII.70.

Duration of Trial: 35 days.

Day from commencement	H_2O Temp °C.	Control	Test Medium (a)	Test Medium (b)
1	13.5			
2	13.7			
3	13.0			
4	13.0			
5	13.0			
6	13.0	+(33) +(41)		
7	12.7			
8	13.5			
9	13.7			
10	13.0			
11	-			
12	13.0		+(34)	
13	13.0			
14	12.5			
15	13.5			
16	13.5			
17	13.7			
18	13.5			
19	13.1			
20	12.0		+(37) +(30) +(28)	
21	12.5			
22	12.5		+(29)	
23	13.0			
24	12.0		+(31) +(10)	
25	12.0			
26	12.2			
27	12.5		+(32) +(29) +(27)	
28	12.0			
29	12.5			
30	12.4			
31	12.5			
32	12.5			
33	13.5			
34	14.7			
35	15.9	+(32)		

Trial 5.

Test Mediums:

(a) Distilled water salinity = >1.25 <8.3ppm.

(b) Diluted 1:19 artesian water salinity = 147ppm.

(c) Saturated artesian water, salinity = 9,797ppm.

Control medium:

Artesian water sampled from locality no. 27 salinity 5609ppm.

Date commenced: 9.IX.70.

Duration of trial: 60 days.

Remarks: Water temperature readings not taken on days 43 to 57 inclusive.

Day from commencement	H_2O Temp °C.	Control	Test Medium (a)	Test Medium (b)	Test Medium (c)
1	14.2				
2	14.7				
3	15.6				
4	14.7				
5					
6	15.5				
7	15.2				
8	14.0		+		
9	14.0				
10	14.4				
11	14.5		+(23) +(24)		
12	14.0		+(15) +(16)		
13	15.5				
14	15.5		+		
15	16.0				
16	16.7				
17	17.5		+(31) +(31) +(33)		
18	17.5				
19	17.5		+(31)		
20	18.0				
21	18.4				
22	18.3				
23	18.1				
24	17.6				
25	17.3				

(cont.)

26	17.0				
27	17.0				
28	17.0				
29	16.7				
30	16.7				
31	16.8				
32	17.5	+39			
33	16.5				
34	16.5				
35	16.5				
36	16.5	+39			
37	16.2	+45			
38	16.0				
39	16.0				
40	16.0				
41	16.1				
42	16.1				
43					
44					
45					
46		+47			
47					
48					
49					
50					
51					
52					
53					
54					
55					
56					
57					
58	19.0				
59	18.2				
60	18.4				

Trial 6.

Test Medium:

Sea water sampled off Grange, St. Vincent Gulf, October 1970. Salinity = 37,58-ppm.

Control Medium:

Artesian water sampled from Locality No. 27. Salinity = 5,609ppm.

Date commenced: 21.X.70.

Duration of Trial: 60 days.

Remarks:

Day from commencement	H_2O Temp °C.	Control	Test Medium	Day from commencement	H_2O Temp °C.	Control	Test Medium
1	16.5		+(39)	31			
2	17.2			32			
3	17.0			33	19.5		+(30)
4	16.0			34	20.0	+(30)	
5	17.0			35	19.7		
6	18.0			36	19.5		
7				37	19.7		
8				38	20.0		
9				39	20.3		
10				40	20.0	+(32)	+(25)
11				41	21.0		
12				42	19.9		
13				43	20.0		
14				44	20.5		+(31)
15				45	19.0		
16	19.0			46	19.0		
17	18.2			47	19.0		
18	18.4			48	19.2		
19	19.8			49	21.3		
20	19.9			50	19.2		
21	19.6			51	19.5		
22	19.5			52			
23	18.9			53			
24				54	18.9		+(41) +(44) +(44)
25	17.2			55	18.8		
26	18.0			56	21.0		
27	17.0			57	19.5		
28	17.5		+(31)	58	20.5		
29	17.5	+(33)		59	20.0		
30	18.0			60	20.5		

Appendix T

Gonad, Anal Papilla and Standard Length measurements recorded from 20 male and 20 female *C. eremius* sampled from Nunn's Bore (locality 27) population on different occasions between April 1970 and May 1971, inclusive.

MALE MEASUREMENTS.

13/IV/70

SL	AP	$\frac{AP}{SL}$	LEFT TESTIS		RIGHT TESTIS		L_l+L_r	W_l+W_r	$\frac{(L_l+L_r)\ (W_l+W_r)}{SL}$
			Length L_l	Width W_l	Length L_r	Width W_r			
48	2.9	0.06	7.8	1.3	7.8	1.5	15.6	2.8	0.91
41	2.2	0.05	4.9	0.6	5.9	0.7	10.8	1.3	0.34
41	2.2	0.05	6.0	0.6	6.5	1.0	12.5	1.6	0.48
47	2.9	0.06	7.3	1.3	8.3	1.6	15.6	2.9	0.96
31	1.6	0.05	3.7	0.6	4.5	0.6	8.2	1.2	0.32
42	2.5	0.06	5.8	1.1	5.8	1.0	11.6	2.1	0.58
47	3.3	0.07	6.8	1.2	7.4	1.3	14.2	2.5	0.75
38	2.2	0.06	1.1	6.2	0.8	10.2	1.9	0.51	
45	2.9	0.06	5.2	1.0	6.4	1.1	11.6	2.1	0.54
50	3.1	0.06	8.0	1.3	9.6	1.4	17.6	2.7	0.95
47	2.7	0.06	7.0	1.4	7.0	1.8	14.0	3.2	0.95
49	3.2	0.06	8.0	1.5	8.7	1.6	16.7	3.1	1.06
39	2.2	0.06	5.1	1.0	7.1	0.8	12.2	1.8	0.56
40	2.5	0.06	4.9	1.4	6.6	1.4	11.5	2.8	0.80
45	2.6	0.06	7.4	0.7	6.2	0.9	13.6	1.6	0.48
41	2.7	0.06	4.9	1.0	6.2	1.5	11.1	2.5	0.67
41	2.4	0.06	5.7	0.6	5.7	0.9	11.4	1.5	0.42
43	2.4	0.06	5.1	0.8	7.7	0.8	12.8	1.6	0.47
38	2.4	0.06	4.5	0.8	5.1	0.6	9.6	1.4	0.35
30	1.4	0.05	4.0	0.7	4.0	0.6	8.0	1.3	0.35
		0.06 Mean							0.62 Mean

13/IV/70

SL	AP	$\frac{AP}{SL}$	LEFT TESTIS		RIGHT TESTIS		L_1+L_r	W_1+W_r	$\frac{(L_1+L_r)\quad(W_1+W_r)}{SL}$
			Length L_1	Width W_1	Length L_r	Width W_r			
50	3.1	0.06	7.4	1.4	9.0	1.6	16.4	3.0	0.98
45	3.0	0.06	4.6	1.1	5.8	1.2	10.4	2.3	0.53
42	2.9	0.07	4.9	1.0	6.3	1.5	11.2	2.5	0.67
48	3.5	0.07	6.3	1.3	7.0	1.3	13.3	2.6	0.72
39	2.8	0.07	4.1	1.4	6.3	1.3	10.4	2.7	0.72
45	2.8	0.06	7.2	0.7	6.0	0.9	13.2	1.6	0.47
41	2.2	0.05	6.1	0.7	6.6	0.9	12.7	1.6	0.49
43	2.7	0.06	5.6	1.1	5.6	1.0	11.2	2.1	0.55
50	3.2	0.06	7.8	1.5	8.6	1.4	16.4	2.9	0.95
42	2.4	0.06	4.6	0.9	7.3	0.8	11.9	1.7	0.48
41	a.4	0.06	5.8	0.6	5.8	0.7	11.6	1.3	0.37
47	2.8	0.06	7.0	1.4	7.0	2.0	14.0	3.4	1.01
39	2.4	0.06	3.7	1.1	5.8	0.8	9.5	1.9	0.46
39	2.1	0.05	4.5	1.1	6.8	0.9	11.3	2.0	0.58
47	3.1	0.06	6.2	1.4	7.4	1.5	13.6	2.9	0.84
48	3.0	0.06	7.1	1.0	7.1	1.4	14.2	2.4	0.71
41	2.4	0.06	5.1	0.7	6.0	0.7	11.1	1.4	0.38
38	2.4	0.06	4.7	0.7	5.4	0.7	10.1	1.4	0.37
31	1.6	0.05	4.1	0.7	4.9	0.6	9.0	1.3	0.37
30	1.7	0.06	3.7	0.5	4.1	0.6	7.8	1.1	0.28
		0.06 Mean							0.59 Mean

22/VI/70									
			LEFT TESTIS		RIGHT TESTIS				
SL	AP	$\frac{AP}{SL}$	Length L_l	Width W_l	Length L_r	Width W_r	L_l+L_r	W_l+W_r	$\frac{(L_l+L_r)\quad(W_l+W_r)}{SL}$
50	2.8	0.06	5.7	1.1	5.0	1.5	10.70	2.60	0.56
44	2.5	0.06	3.6	1.0	5.5	1.1	9.10	2.10	0.43
48	2.4	0.05	5.8	1.2	5.8	1.0	11.60	2.20	0.53
53	2.7	0.05	6.9	1.2	6.9	1.2	13.80	2.40	0.62
41	2.2	0.05	5.8	0.9	6.3	0.9	12.10	1.80	0.53
44	2.4	0.05	5.4	0.8	4.2	0.9	9.60	1.70	0.37
47	3.0	0.06	5.3	1.7	6.1	2.1	11.40	3.80	0.92
47	2.9	0.06	6.4	1.2	8.4	1.5	14.80	2.70	0.85
50	3.0	0.06	5.0	1.8	6.6	1.6	11.60	3.40	0.78
47	2.5	0.05	4.0	0.9	5.7	1.1	9.70	2.00	0.41
49	2.5	0.05	8.3	0.9	8.3	1.2	16.60	2.10	0.71
47	3.0	0.06	6.5	1.1	7.6	0.9	14.10	2.00	0.60
48	2.9	0.06	6.7	1.1	7.6	1.3	14.30	2.40	0.71
45	2.7	0.06	6.8	0.8	7.4	1.1	14.20	1.90	0.59
47	2.4	0.05	5.7	1.2	6.4	1.5	12.10	2.70	0.69
40	2.2	0.05	3.8	0.5	5.0	0.7	8.80	1.20	0.26
54	2.9	0.05	5.3	1.1	6.3	1.1	11.60	2.20	0.47
39	2.6	0.07	5.9	1.0	5.9	1.0	11.80	2.00	0.60
33	1.6	0.05	4.7	0.5	5.3	0.5	10.00	1.00	0.30
30	1.3	0.04 0.05 Mean	4.9	0.5	5.7	0.7	10.60	1.20	0.42 0.57 Mean

31/VII/70

SL	AP	$\frac{AP}{SL}$	LEFT TESTIS		RIGHT TESTIS		L_1+L_r	W_1+W_r	$\frac{(L_1+L_r)\quad(L_1+W_r)}{SL}$
			Length L_1	Width W_1	Length L_r	Width W_r			
49	3.0	0.06	7.2	1.2	6.1	1.4	13.3	2.6	0.70
37	1.9	0.05	4.5	0.7	4.5	0.7	9.0	1.4	0.34
44	2.8	0.06	4.8	1.1	5.5	1.3	10.3	2.4	0.56
31	1.4	0.04	4.1	0.5	4.6	0.5	8.7	1.0	0.28
35	1.7	0.04	5.5	0.4	6.3	0.6	11.8	1.0	0.33
29	1.2	0.04	3.6	0.4	4.4	0.4	8.0	0.8	0.22
47	2.2	0.04	7.2	0.9	7.2	1.0	14.4	1.9	0.58
49	3.0	0.06	8.4	0.9	8.4	1.4	16.8	2.3	0.78
45	2.7	0.06	6.7	1.2	7.4	1.4	14.1	2.6	0.81
41	1.9	0.04	4.4	1.2	5.8	1.2	10.2	2.4	0.59
37	1.8	0.04	4.6	0.5	4.6	0.5	9.2	1.0	0.24
28	1.3	0.04	2.7	0.4	4.3	0.5	7.0	0.9	0.22
50	2.9	0.05	8.9	1.2	8.9	1.2	17.8	2.4	0.85
34	3.8	0.07	10.4	1.9	9.4	1.7	19.8	3.6	1.32
50	3.2	0.06	6.7	1.1	8.6	1.0	15.3	2.1	0.64
52	2.9	0.05	6.9	1.6	6.9	1.8	13.8	3.4	0.90
51	3.3	0.06	7.5	1.3	10.2	1.3	17.7	2.6	0.90
36	1.9	0.05	6.1	0.5	5.3	0.7	11.4	1.2	0.38
36	2.0	0.05	5.6	1.1	6.6	1.0	12.2	2.1	0.71
29	1.2	0.04	4.2	1.2	5.4	1.1	9.6	2.3	0.76
		0.05 Mean							0.60 Mean

24/VIII/70									
			LEFT TESTIS		RIGHT TESTIS				
SL	AP	$\frac{AP}{SL}$	Length L_1	Width W_1	Length L_r	Width. W_r	L_1+L_r	W_1+W_f	$\frac{(L_1+L_f)\ (W_1+W_r)}{SL}$
54	3.2	0.06	8.2	0.9	8.2	1.0	16.4	1.9	0.57
47	3.1	0.06	8.8	2.2	8.8	2.3	17.6	4.5	1.68
47	2.7	0.06	7.8	2.1	7.8	2.0	15.6	4.1	1.36
49	3.3	0.07	7.8	1.5	7.8	1.5	15.6	3.0	0.95
50	3.0	0.06	8.1	1.9	11.7	2.3	19.8	4.2	1.66
56	3.7	0.06	11.9	2.1	13.9	2.4	25.8	4.5	2.07
52	3.2	0.06	9.6	1.9	9.6	2.0	19.2	3.9	1.44
46	3.3	0.07	9.0	2.6	9.0	2.6	18.0	5.2	2.03
50	3.4	0.07	7.8	2.4	9.2	2.2	17.0	4.6	1.56
56	3.3	0.06	9.7	1.8	9.7	2.0	19.4	3.8	1.32
47	2.8	0.06	8.6	1.6	8.6	1.4	17.2	3.0	1.09
46	2.8	0.06	8.1	1.3	7.3	2.1	15.4	3.4	1.14
29	1.5	0.05	6.0	1.2	7.5	1.3	13.5	2.5	1.16
32	1.7	0.05	6.2	1.0	6.2	1.2	12.4	2.2	0.85
44	2.5	0.06	6.2	0.8	7.0	1.1	13.2	1.9	0.57
42	2.4	0.06	5.1	0.9	5.8	0.9	10.9	1.8	0.45
39	2.1	0.05	4.5	0.4	4.5	0.4	9.0	0.8	0.18
42	2.3	0.05	4.6	1.2	6.5	1.0	11.1	2.2	0.58
40	2.6	0.06	7.8	1.8	7.8	2.3	15.6	4.1	1.59
36	1.6	0.04	8.0	1.3	7.0	1.5	15.0	2.8	1.16
		0.06 Mean							1.17 Mean

27/IX/70									
SL	AP	$\frac{AP}{SL}$	LEFT TESTIS		RIGHT TESTIS		L_l+L_r	W_l+W_r	$\frac{(L_l+L_r)\ (W_l+W_r)}{SL}$
			Length L_l	Width W_l	Length L_r	Width W_r			
37	2.7	0.07	6.7	1.5	7.2	1.3	13.9	2.8	1.05
52	3.7	0.07	9.7	3.1	12.1	2.5	21.8	5.6	2.35
45	3.2	0.07	9.3	2.1	9.3	2.6	18.6	4.7	1.94
31	2.4	0.07	8.4	3.1	8.4	2.6	16.8	5.7	3.09
29	2.0	0.07	7.7	2.2	7.7	2.3	15.4	4.5	2.39
27	2.2	0.08	6.7	2.3	7.1	2.1	13.8	4.4	2.25
52	3.6	0.07	9.8	3.6	13.1	3.4	22.9	7.0	3.08
34	2.5	0.07	8.2	2.7	8.2	3.3	16.4	6.0	2.89
40	2.6	0.06	8.7	1.6	8.7	13.9	17.4	3.2	1.39
45	3.1	0.07	9.2	3.3	10.7	3.0	19.9	6.3	2.78
33	2.3	0.07	5.2	0.5	5.2	0.6	10.4	1.1	0.35
30	2.4	0.08	8.5	3.3	8.1	3.3	16.6	6.6	3.65
27	2.2	0.08	7.7	2.5	7.7	2.5	15.4	5.0	2.85
45	3.2	0.07	9.7	2.4	11.0	3.3	20.7	5.7	2.62
45	3.2	0.07	8.7	2.6	8.7	3.2	17.4	5.8	2.24
33	2.4	0.07	8.6	2.6	8.6	3.2	17.2	5.8	3.02
26	1.8	0.07	6.8	2.2	7.6	1.6	14.4	3.8	2.10
49	3.6	0.07	9.3	2.7	10.5	2.9	19.8	5.6	2.26
48	3.2	0.07	9.6	2.1	9.6	2.7	19.2	4.8	1.92
24	1.8	0.07	7.0	2.0	7.0	2.3	14.0	4.3	2.51
		0.07 Mean							2.34 Mean

31/X/70									
			LEFT TESTIS		RIGHT TESTIS				
SL	AP	$\frac{AP}{SL}$	Length L_l	Width W_l	Length L_r	Width W_r	L_l+L_r	W_l+W_r	$\frac{(L_l+L_r)\ (W_l+W_r)}{SL}$
41	2,5	0,06	4,5	0,9	6,4	0,7	10,9	1,6	0,42
49	3,3	0,07	7,1	2,3	9,3	2,5	16,4	4,8	1,61
31	1,6	0,05	4,3	0,5	5,1	0,4	9,4	0,9	0,27
39	2,4	0,06	5,9	0,8	7,2	0,7	13,1	1,5	0,50
47	3,7	0,08	9,1	2,2	9,1	2,5	18,2	4,7	1,82
35	2,1	0,06	5,2	0,7	5,8	0,7	11,0	1,4	0,44
53	4,0	0,07	9,3	2,6	9,3	2,7	18,6	5,3	1,86
36	2,5	0,07	5,9	1,1	5,9	1,1	11,8	2,2	0,72
41	2,3	0,06	6,1	0,9	6,1	0,8	12,2	1,7	0,50
46	2,9	0,06	10,5	2,1	10,5	2,2	21,0	4,3	1,96
44	2,5	0,06	7,1	1,1	7,1	1,2	14,2	2,3	0,74
47	2,5	0,05	8,1	0,7	7,2	1,0	15,3	1,7	0,55
45	2,8	0,06	7,0	1,1	8,4	1,1	15,4	2,2	0,75
47	2,8	0,06	8,1	1,9	8,1	2,3	16,2	4,2	1,45
28	1,3	0,05	5,1	0,3	6,3	0,3	11,4	0,6	0,24
39	2,5	0,06	6,3	1,0	7,2	0,9	13,5	1,9	0,66
40	2,7	0,07	5,5	1,6	6,1	1,4	11,6	3,0	0,87
37	2,4	0,06	5,8	0,6	5,8	0,8	11,6	1,4	0,44
46	2,5	0,05	6,9	0,9	7,7	1,1	14,6	2,0	0,63
38	2,3	0,06	6,0	0,9	6,5	1,1	12,5	2,0	0,66
		0,06 Mean							0,85 Mean

25/XI/70									
SL	AP	$\frac{AP}{SL}$	LEFT TESTIS		RIGHT TESTIS		L_l+L_r	W_l+W_r	$\frac{(L_l+L_r)\ (W_l+W_r)}{SL}$
			Length L_l	Width W_l	Length L_r	Width W_r			
46	2.5	0.05	6.1	0.7	5.4	1.2	11.5	1.9	0.47
46	2.6	0.06	7.1	1.4	7.6	1.4	14.7	2.8	0.89
44	2.1	0.05	5.3	0.7	5.3	0.9	10.6	1.6	0.38
53	3.7	0.07	9.8	2.4	10.8	2.2	20.6	4.6	1.78
43	2.5	0.06	9.3	0.5	7.8	0.7	17.1	1.2	0.47
43	2.4	0.05	4.3	0.5	5.3	0.7	9.6	1.2	0.27
25	1.1	0.04	3.6	0.2	3.6	0.2	7.2	0.4	0.11
50	3.5	0.07	8.1	2.4	9.5	2.3	17.6	4.7	1.65
47	3.2	0.07	8.5	1.0	7.9	1.3	16.4	2.3	0.80
38	2.5	0.06	6.1	0.6	5.1	0.8	11.2	1.4	0.41
36	1.6	0.04	4.9	0.4	5.5	0.4	10.4	0.8	0.23
47	2.8	0.06	8.5	2.1	7.3	1.7	15.8	3.8	1.27
30	1.5	0.05	4.1	0.3	5.0	0.3	9.1	0.6	0.18
45	3.2	0.07	10.8	1.4	9.6	2.0	20.4	3.4	1.54
41	2.4	0.06	6.0	0.8	7.4	1.1	13.4	1.9	0.62
40	3.0	0.07	12.5	1.2	13.5	1.6	26.0	2.8	1.82
48	3.2	0.07	9.4	2.2	10.4	2.0	19.8	4.2	1.73
25	1.4	0.06	4.7	0.6	4.7	0.6	9.4	1.2	0.45
50	3.2	0.06	7.6	1.3	8.4	2.0	16.0	3.3	1.06
44	2.5	0.06	5.2	0.6	6.5	0.9	11.7	1.5	0.39
		0.06 Mean							0.83 Mean

31/I/71									
SL	AP	$\frac{AP}{SL}$	LEFT TESTIS		RIGHT TESTIS		L_l+L_r	W_l+W_r	$\frac{(L_l+L_r)\ (W_l+W_r)}{SL}$
			Length L_l	Width W_l	Length L_r	Width W_r			
25	1.1	0.04	3.0	0.2	4.1	0.2	7.1	0.4	0.11
27	1.2	0.04	4.0	0.4	5.3	0.3	9.3	0.7	0.24
30	2.0	0.07	8.1	1.2	8.1	1.5	16.2	2.7	1.46
31	1.5	0.05	5.1	0.2	5.1	0.2	10.2	0.4	0.13
33	1.9	0.06	4.7	1.0	6.3	0.8	11.0	1.8	0.60
37	2.5	0.07	7.2	1.5	8.1	1.7	15.3	3.2	1.32
37	1.8	0.05	6.4	0.3	6.4	0.3	12.8	0.6	0.21
38	2.5	0.06	7.1	1.8	7.9	2.0	15.0	3.8	1.50
41	2.4	0.06	2.9	0.6	7.2	1.1	10.1	1.7	0.42
41	2.9	0.07	9.0	1.2	10.8	1.3	19.8	2.5	1.21
45	3.1	0.07	8.1	2.3	8.1	2.5	16.2	4.8	1.73
45	3.1	0.07	10.4	2.2	10.4	2.1	20.8	4.3	1.98
45	3.3	0.07	9.0	1.5	9.0	2.2	18.0	3.7	1.48
46	3.2	0.07	8.0	1.2	8.0	1.8	16.0	3.0	1.04
47	3.5	0.07	9.2	2.0	11.3	1.8	20.5	3.8	1.66
47	3.1	0.06	8.8	1.9	8.8	1.8	17.6	3.7	1.38
47	2.9	0.06	10.1	1.7	10.1	1.7	20.2	3.4	1.46
47	3.1	0.06	9.6	2.1	9.6	2.5	19.2	4.6	1.88
49	3.0	0.06	8.5	0.9	8.5	1.0	17.0	1.9	0.66
50	2.8	0.06	5.4	0.7	5.4	1.2	10.8	1.9	0.41
		0.06 Mean							1.04 Mean

28/II/71

SL	AP	$\frac{AP}{SL}$	LEFT TESTIS Length L_l	Width W_l	RIGHT TESTIS Length L_r	Width W_r	L_l+L_r	R_l+R_r	$\frac{(L_l+L_r)\ (W_l+W_r)}{SL}$
28	1.8	0.06	7.9	1.6	7.9	2.5	15.8	4.1	2.31
29	1.5	0.05	5.5	0.7	5.5	0.9	11.0	1.6	0.61
33	1.8	0.05	5.8	0.4	5.8	0.4	11.6	0.8	0.28
36	2.3	0.06	4.1	0.4	5.8	0.5	9.9	0.9	0.25
37	2.4	0.06	8.1	0.9	8.1	1.1	16.2	2.0	0.87
38	2.3	0.06	7.2	0.4	9.2	0.4	16.4	0.8	0.34
41	3.2	0.08	9.3	1.6	9.3	2.2	18.6	3.8	1.72
41	2.7	0.06	5.4	0.9	7.2	1.1	12.6	2.0	0.61
42	2.4	0.06	5.0	0.5	6.4	0.6	11.4	1.1	0.29
43	3.0	0.07	7.2	1.2	7.2	1.2	14.4	2.4	0.80
43	2.6	0.06	9.8	2.0	11.1	2.3	20.9	4.3	2.09
45	3.4	0.07	9.9	2.1	9.9	2.3	19.8	4.4	1.94
45	3.2	0.07	7.4	1.5	7.4	1.6	14.8	3.1	1.02
46	3.4	0.07	8.1	1.9	8.1	2.0	16.2	3.9	1.37
46	3.4	0.07	10.0	2.1	10.0	2.3	20.0	4.4	1.91
46	3.2	0.07	9.2	1.4	9.2	1.5	18.4	2.9	1.16
47	2.8	0.06	6.9	0.8	8.1	0.7	15.0	1.5	0.48
48	2.6	0.05	6.6	0.8	6.6	1.0	12.1	1.8	0.49
48	3.4	0.07	9.8	1.9	9.8	2.0	19.6	3.9	1.59
49	3.0	0.06	7.3	1.2	6.5	1.6	13.8	2.8	0.78
		0.06 Mean							1.04 Mean

31/III/71									
			LEFT TESTIS		RIGHT TESTIS				
SL	AP	$\frac{AP}{SL}$	Length L_l	Width W_l	Length L_r	Width W_r	L_l+L_r	W_l+W_r	$\frac{(L_l+L_r)(W_l+W_r)}{SL}$
39	2.5	0.06	7.8	1.4	7.8	1.6	15.6	3.0	1.20
40	2.2	0.05	4.2	0.8	5.8	0.8	10.0	1.6	0.40
41	2.3	0.06	7.1	0.8	6.6	0.9	13.7	1.7	0.57
42	2.3	0.05	4.8	1.0	5.6	1.0	10.4	2.0	0.49
42	2.7	0.06	5.3	0.9	7.2	0.9	12.5	1.8	0.53
43	2.2	0.05	7.3	1.8	8.9	1.6	16.2	3.4	1.28
43	2.3	0.05	8.0	0.5	8.0	0.6	16.0	1.1	0.41
44	2.6	0.06	5.6	0.8	5.9	0.6	11.5	1.4	0.36
44	2.6	0.06	6.1	1.3	7.1	1.7	13.2	3.0	0.90
45	3.1	0.07	8.6	2.0	8.6	1.8	17.2	3.8	1.45
45	2.6	0.06	8.0	1.5	8.0	1.8	16.0	3.3	1.17
45	2.7	0.06	8.6	1.2	10.0	1.3	18.6	2.50	1.03
45	3.5	0.07	7.5	2.1	8.7	2.3	16.2	4.4	1.58
46	2.6	0.06	8.0	1.2	9.2	1.1	17.2	2.3	0.86
46	2.6	0.06	6.6	0.8	7.4	1.2	14.0	2.0	0.61
49	2.5	0.05	7.9	0.8	7.9	0.8	15.8	1.6	0.51
49	2.9	0.06	6.8	0.8	8.0	0.9	14.8	1.7	0.51
51	3.3	0.06	9.5	2.3	13.0	2.0	22.5	4.3	1.89
54	3.0	0.05	5.8	2.2	8.3	1.4	14.1	2.6	0.68
54	2.9	0.05	10.5	1.2	11.9	1.7	22.4	2.9	1.20
		0.06 Mean							0.93 Mean

25/IV/71									
			LEFT TESTIS		RIGHT TESTIS				
SL	AP	$\frac{AP}{SL}$	Length L_l	Width W_l	Length L_r	Width W_r	L_l+L_r	W_l+W_r	$\frac{(L_l+L_r)\ (W_l+W_r)}{SL}$
42	2.0	0.05	4.2	0.7	4.8	0.6	9.0	1.3	0.03
43	2.2	0.05	5.1	0.4	6.0	0.3	11.1	0.7	0.18
46	2.5	0.05	6.4	0.4	5.5	0.4	11.9	0.8	0.21
46	2.8	0.06	7.4	0.4	7.4	0.4	14.8	0.8	0.26
48	2.9	0.06	5.1	0.5	5.1	0.5	10.2	1.0	0.21
48	1.9	0.06	9.0	0.5	8.4	0.6	17.4	1.1	0.39
48	2.6	0.05	5.6	0.5	8.3	0.3	13.9	0.8	0.23
49	2.8	0.06	8.5	0.5	7.8	0.5	16.3	1.0	0.33
49	2.9	0.06	8.2	1.0	8.2	1.0	16.4	2.0	0.67
49	2.8	0.06	5.8	0.8	8.2	0.9	14.0	1.7	0.48
49	2.8	0.06	6.8	1.0	8.5	1.3	15.3	2.3	0.72
50	3.1	0.06	6.7	1.3	8.3	0.9	15.0	2.2	0.66
50	2.5	0.05	4.2	0.6	6.8	0.6	11.0	1.2	0.26
51	2.5	0.05	7.6	1.1	7.6	1.0	15.2	2.1	0.62
51	2.3	0.04	3.9	0.6	6.7	0.7	10.6	1.3	0.27
51	2.7	0.05	5.8	1.0	5.5	1.3	11.3	2.3	0.51
51	2.8	0.05	4.7	0.6	6.2	0.7	10.9	1.3	0.28
51	3.0	0.06	8.2	0.9	8.2	1.0	16.4	1.9	0.61
52	3.0	0.06	7.6	0.6	9.6	0.7	17.2	1.3	0.43
54	3.2	0.06	7.1	0.6	5.9	0.9	13.0	1.5	0.36
		0.05 Mean							0.38 Mean

31/V/71									
			LEFT TESTIS		RIGHT TESTIS				
SL	AP	$\frac{AP}{SL}$	Length L_1	Width W_1	Length L_r	Width W_r	L_1+L_r	W_1+W_r	$\frac{(L_1+L_r)\quad(W_1+W_r)}{SL}$
42	2.1	0.05	7.5	0.8	6.7	0.9	14.2	1.7	0.57
45	2.6	0.06	5.3	0.8	7.4	1.1	12.7	1.9	0.54
46	2.5	0.05	5.3	0.4	7.0	0.6	12.3	1.0	0.27
46	2.7	0.06	6.3	0.8	6.7	1.1	13.0	1.9	0.54
46	2.5	0.05	5.9	0.9	7.5	1.1	13.4	2.0	0.58
46	2.5	0.05	6.1	0.8	7.1	0.8	13.2	1.6	0.46
47	2.1	0.04	6.7	0.5	9.1	0.6	15.8	1.1	0.37
47	2.1	0.04	5.3	0.7	6.9	0.9	12.2	1.6	0.41
48	2.2	0.05	6.2	0.9	6.7	1.1	12.9	2.0	0.54
49	3.3	0.07	6.9	1.3	6.9	1.5	13.8	2.8	0.78
49	3.7	0.07	8.4	1.1	8.4	1.3	16.8	2.4	0.82
50	2.7	0.05	6.6	0.5	7.1	1.0	13.7	1.5	0.41
50	3.0	0.06	6.0	1.2	6.0	1.4	12.0	2.6	0.62
50	2.9	0.06	6.1	0.5	6.9	0.7	13.0	1.2	0.31
50	2.9	0.06	6.3	1.0	7.9	1.4	14.2	2.4	0.68
52	3.1	0.06	8.1	1.3	9.2	1.8	17.3	3.1	1.03
55	2.8	0.05	7.6	1.4	7.6	1.9	15.2	3.3	0.91
55	3.0	0.05	10.2	1.3	10.2	1.5	20.4	2.8	1.04
55	3.6	0.06	10.0	0.8	8.5	1.2	18.5	2.0	0.67
57	3.3	0.06	9.6	1.7	10.4	2.0	10.0	3.7	1.29
		0.05 Mean							0.64 Mean

FEMALE MEASUREMENTS.

13/IV/70

SL.	AP.	$\frac{AP}{SL}$	LEFT OVARY		RIGHT OVARY				
			Length L_l	Width W_l	Length L_r	Width W_r	L_l+L_r	W_l+W_r	$\frac{(L_l+L_r)(W_l+W_r)}{SL}$
39	1.3	0.03	6.3	1.1	6.7	1.6	13.0	2.7	0.9
43	1.7	0.04	7.8	1.8	7.8	1.4	15.6	3.2	1.16
41	1.7	0.04	6.3	2.0	8.7	2.1	15.0	4.1	1.5
38	1.2	0.03	7.0	1.2	7.6	1.3	14.6	2.5	0.96
40	1.3	0.03	6.3	1.3	6.7	1.3	13.0	2.6	0.84
41	1.6	0.04	10.4	1.1	8.4	1.3	18.8	2.4	1.10
38	1.6	0.04	7.1	1.6	8.3	1.1	15.4	2.7	1.09
38	1.3	0.03	7.8	1.2	7.1	1.3	14.9	2.5	0.98
29	0.7	0.02	3.8	0.7	4.1	0.8	7.9	1.5	0.41
35	0.9	0.03	6.0	1.0	6.3	1.2	12.3	2.2	0.77
40	1.1	0.03	5.9	1.1	7.8	1.2	13.7	2.3	0.78
36	1.3	0.04	6.4	1.2	7.7	1.1	14.1	2.3	0.90
40	1.3	0.03	7.3	1.3	7.3	1.6	14.6	2.9	1.06
31	0.8	0.03	4.1	1.0	4.1	1.0	8.2	2.0	0.53
35	1.4	0.04	6.6	1.5	7.0	1.4	13.6	2.9	1.13
38	1.1	0.03	6.0	1.0	6.0	1.0	12.0	2.0	0.63
33	1.4	0.04	5.6	1.1	6.3	1.3	11.9	2.4	0.87
33	1.3	0.04	4.5	1.2	5.4	1.1	9.9	2.3	0.83
30	0.9	0.03	3.8	0.8	4.5	0.9	8.3	1.7	0.56
35	1.4	0.04	5.8	1.1	6.2	1.5	12.0	2.6	0.62
		0.03 Mean							0.88 Mean

22/VI/70

SL	AP	$\frac{AP}{SL}$	LEFT OVARY Length L_1	LEFT OVARY Width W_1	RIGHT OVARY Length L_1	RIGHT OVARY Width W_r	L_1+L_r	W_1+W_r	$\frac{(L_1+L_r)(W_1+W_r)}{SL}$
42	1.6	0.04	7.8	1.3	7.8	1.3	15.60	2.60	0.96
44	1.4	0.03	6.6	1.5	7.9	1.5	14.50	3.00	0.98
48	1.6	0.03	7.5	3.3	8.7	1.3	16.20	2.60	0.87
48	1.7	0.03	8.2	1.9	10.1	2.0	18.30	3.90	1.48
47	1.5	0.03	8.8	1.5	8.8	1.5	17.60	3.00	1.12
40	1.2	0.03	5.8	1.2	6.6	1.2	12.40	2.40	0.74
44	1.1	0.02	7.0	1.5	7.0	1.5	14.00	3.00	0.95
38	1.4	0.04	6.2	1.2	6.7	1.2	12.90	2.40	0.81
26	0.6	3.6	9.0	4.7	1.0	8.30	1.90	0.60	
34	1.0	0.03	6.2	1.1	6.6	1.5	12.80	2.60	0.98
46	1.3	0.03	7.9	1.6	8.8	1.3	16.70	2.90	1.05
40	1.6	0.04	7.6	1.4	9.7	3.3	17.30	2.70	1.17
44	1.6	0.04	7.3	1.5	7.3	1.8	14.60	3.30	1.09
39	1.2	0.03	7.5	1.2	7.5	1.4	15.00	2.60	1.00
47	1.5	0.03	7.6	1.5	9.0	1.7	16.60	3.20	1.13
32	1.2	0.04	6.2	1.1	6.2	1.1	12.40	2.20	0.85
32	0.8	0.02	4.2	1.2	5.3	1.2	9.50	2.40	0.71
32	3.3	0.04	4.8	1.3	6.1	1.2	10.90	2.50	0.85
24	0.5	0.02	3.4	0.8	4.2	0.7	7.60	1.50	0.47
		0.03 Mean							0.94 Mean

30/VII/70									
SL	AP	$\frac{AP}{SL}$	LEFT OVARY		RIGHT OVARY		L_l+L_r	W_l+W_r	$\frac{(L_l+L_r)\quad(W_l+W_r)}{SL}$
			Length L_l	Width W_l	Length L_r	Width W_r			
45	1.1	0.02	8.7	1.8	9.2	1.7	17.9	3.5	1.39
33	1.2	0.04	6.1	1.4	6.1	1.2	12.2	2.6	0.96
32	1.2	0.04	5.3	1.2	6.2	1.2	11.5	2.4	0.86
45	1.5	0.03	7.0	1.4	7.0	1.3	14.0	2.7	0.84
43	1.0	0.02	5.6	1.2	6.7	1.6	12.3	2.8	0.80
30	1.0	0.03	4.1	1.0	4.9	1.2	9.0	2.2	0.66
27	0.8	0.03	3.9	0.9	5.3	0.9	9.2	1.8	0.61
43	1.4	0.03	7.0	1.3	7.7	1.7	14.7	3.0	1.03
39	1.1	0.03	7.5	1.4	6.7	1.4	14.2	2.8	1.02
33	0.9	0.03	3.8	0.8	5.2	0.9	9.0	1.7	0.46
26	-		3.5	0.7	4.6	0.7	8.1	1.4	0.44
39	1.2	0.03	6.7	1.4	6.7	1.4	13.4	2.8	0.96
38	1.4	0.04	6.1	1.77	6.1	1.6	12.2	a.3	1.06
37	1.3	0.03	5.3	1.6	6.7	1.3	12.0	2.9	0.94
36	1.2	0.03	6.0	1.4	7.2	1.6	13.2	3.0	1.10
32	0.9	0.03	5.2	1.1	6.2	1.1	11.4	2.2	0.78
37	1.5	0.04	6.5	1.3	5.7	1.6	12.2	2.9	0.96
30	0.7	0.02	4.8	0.9	5.6	1.0	10.4	1.9	0.66
31	0.8	0.03	4.1	0.9	4.8	0.9	8.9	1.8	0.52
30	0.8	0.03	6.2	0.7	6.2	1.0	12.4	1.7	0.70
		0.03 Mean							0.84 Mean

24/VIII/70									
SL	AP	$\frac{AP}{SL}$	LEFT OVARY		RIGHT OVARY		L_l+L_r	W_l+W_r	$\frac{(L_l+l_r)\ (W_l+W_r)}{SL}$
			Length L_l	Width W_r	Length L_l	Width W_r			
43	1.6	0.04	8.2	2.4	7.6	2.1	15.8	4.5	1.65
44	1.6	0.04	8.1	2.7	9.3	2.7	17.4	5.4	2.13
43	1.4	0.03	6.9	1.6	7.9	2.0	14.8	3.6	1.24
45	1.6	0.03	8.7	2.2	9.1	2.2	17.8	4.4	1.74
40	1.5	0.04	6.4	2.5	8.4	2.2	14.8	4.7	1.74
42	1.5	0.04	7.7	1.5	8.3	1.3	16.0	2.8	1.07
46	1.5	0.03	8.6	1.2	7.8	1.9	16.4	3.1	1.10
43	1.4	0.03	7.3	1.5	7.3	1.3	14.6	2.8	0.95
39	1.1	0.03	5.9	1.1	7.2	1.3	13.1	2.4	0.81
37	1.4	0.04	8.2	2.1	9.0	2.6	17.2	4.7	2.18
35	1.0	0.03	5.6	1.1	6.2	1.0	11.8	2.1	0.71
35	1.0	0.03	5.2	1.2	5.7	1.2	10.9	2.4	0.75
33	1.1	0.03	5.2	1.1	5.6	1.1	10.8	2.2	0.72
32	1.0	0.03	4.1	1.1	5.8	1.6	9.9	2.7	0.83
37	1.2	0.03	5.5	1.5	6.6	1.4	12.1	2.9	9.05
35	1.3	0.04	5.4	1.6	6.3	1.6	11.7	3.2	1.07
37	1.2	0.03	5.8	1.3	6.1	1.4	11.9	2.7	0.87
27	0.8	0.03	3.5	0.71	4.5	0.8	8.0	1.5	0.44
32	1.0	0.03	5.6	1.0	6.1	1.1	11.7	2.1	0.77
34	1.3	0.04	5.8	1.1	6.4	1.2	12.2	2.3	0.82
		0.03 Mean							1.13 Mean

27/IX/70									
SL	AP	$\frac{AP}{SL}$	LEFT OVARY		RIGHT OVARY		L_1+L_r	W_1+W_r	$\frac{(L_1+L_r)\ (W_1+W_r)}{SL}$
			Length L_1	Width W_1	Length L_r	Width W_r			
39	1.8	0.05	7.7	2.1	7.7	2.3	15.4	4.4	1.74
32	1.7	0.05	6.1	1.7	7.6	2.2	13.7	3.9	1.67
35	2.1	0.06	6.3	2.0	7.0	2.1	13.3	4.1	1.56
36	1.9	0.05	11.3	3.2	11.3	3.2	22.6	6.4	4.02
46	1.8	0.04	7.2	2.1	9.2	2.5	16.4	4.6	1.64
33	1.7	0.05	9.3	3.0	9.3	3.2	18.6	6.2	3.49
26	0.8	0.03	4.5	1.3	4.9	1.4	9.4	2.7	0.97
35	1.6	0.05	10.9	3.3	10.9	3.5	21.8	6.8	4.23
40	2.1	0.05	11.7	3.6	12.8	4.7	24.5	8.3	5.08
24	0.5	0.02	3.9	0.8	4.5	1.0	8.4	1.8	0.63
32	1.8	0.06	10.6	3.1	10.6	3.5	21.2	6.6	4.37
25	1.0	0.04	5.3	1.4	5.3	1.5	10.6	2.9	1.23
34	1.6	0.05	6.8	2.3	7.7	2.2	14.5	4.5	1.92
33	1.5	0.04	8.4	2.3	8.4	2.5	16.8	4.8	2.44
31	1.4	0.04	5.6	1.5	6.8	1.5	12.4	3.0	1.20
31	1.9	0.06	8.7	3.3	8.7	3.6	17.4	6.9	3.87
30	1.9	0.06	10.3	2.8	10.3	2.8	20.6	5.6	3.84
31	1.3	0.04	5.8	1.6	6.5	1.9	12.3	3.5	1.38
29	1.3	0.04	7.4	1.8	7.4	1.8	14.8	3.6	1.84
18	0.1	0.05	3.6	0.6	3.5	0.6	7.1	1.2	0.47
		0.04							
		0.04 Mean							2.38 Mean

31/X/70									
			LEFT OVARY		RIGHT OVARY				
SL	AP	$\frac{AP}{SL}$	Length L_1	Width W_1	Length L_r	Width W_r	L_1+L_r	W_1+W_r	$\frac{(L_1+L_r)\ (W_1+W_r)}{SL}$
.41	2.1	0.05	15.1	3.9	15.1	4.3	30.2	8.2	6.04
.41	1.6	0.04	6.4	1.5	6.4	1.7	12.8	3.2	0.99
.42	1.9	0.04	10.4	3.1	11.4	3.2	21.8	6.3	3.27
.48	2.2	0.04	14.5	3.6	14.5	4.1	29.0	7.7	4.65
.35	0.9	0.02	6.1	1.6	7.6	1.5	13.7	3.1	1.21
.39	1.7	0.04	13.2	3.8	13.2	3.7	26.4	7.5	5.07
.38	2.2	0.06	6.6	1.9	6.6	2.0	13.2	3.9	1.35
.39	2.1	0.05	12.5	1.8	13.7	2.0	26.2	3.8	2.55
.43	1.9	0.04	8.2	2.1	8.2	2.5	16.4	4.6	1.75
.36	1.6	0.04	5.1	1.2	6.2	1.2	11.3	2.4	0.75
.34	1.7	0.05	7.3	2.2	9.1	2.6	16.4	4.8	2.31
.45	1.9	0.04	12.4	3.3	12.4	3.5	24.8	6.8	3.75
.39	2.2	0.06	7.7	2.4	8.4	1.8	16.1	4.2	1.73
.34	1.1	0.03	6.5	0.8	7.1	1.2	13.6	2.0	0.80
.31	1.8	0.06	6.2	1.4	6.3	1.5	12.6	2.9	1.18
.40	2.1	0.05	7.4	1.8	8.1	1.6	15.5	3.4	1.32
.37	1.6	0.04	9.7	2.8	9.7	3.0	19.4	5.8	3.04
.37	2.2	0.06	13.2	3.9	13.2	3.6	26.4	7.5	5.35
.41	2.0	0.05	8.0	2.2	8.0	2.7	16.0	4.9	1.91
.38	1.7	0.04	7.5	2.0	8.5	2.5	16.0	4.5	1.89
		0.04 Mean							2.54 Mean

25/XI/70									
			LEFT OVARY		RIGHT OVARY				
SL	AP	$\frac{AP}{SL}$	Length L_l	Width W_l	Length L_r	Width W_r	L_l+L_r	W_l+W_r	$\frac{(L_l+L_r)\ (W_l+W_r)}{SL}$
35	1.8	0.05	6.1	1.3	6.5	1.3	12.6	2.6	0.94
41	1.9	0.05	8.1	2.0	8.1	2.6	16.2	4.6	1.82
40	2.2	0.05	11.0	2.5	11.0	2.7	22.0	5.2	2.86
42	1.7	0.04	7.4	1.5	8.6	1.5	16.0	3.0	1.14
38	2.3	0.06	6.5	2.1	7.8	2.0	14.3	4.1	1.54
36	1.8	0.05	11.2	3.3	11.2	3.3	22.4	6.6	4.11
33	;/7	0.05	5.0	1.1	5.0	1.2	10.0	2.3	0.69
33	0.7	0.02	6.6	0.7	6.6	0.8	13.2	1.5	0.60
28	0.7	0.02	4.2	0.6	4.5	0.7	8.7	1.3	0.40
38	1.8	0.05	6.4	1.3	7.2	1.0	13.6	2.3	0.82
31	1.1	0.03	5.3	1.5	7.1	1.8	12.4	3.3	1.32
45	1.8	0.04	6.7	1.4	7.3	1.2	14.0	2.6	0.81
38	1.9	0.05	11.4	2.8	11.4	3.4	22.8	6.2	3.72
33	1.2	0.04	5.4	1.0	6.2	1.1	11.6	2.1	0.74
34	1.4	0.04	6.5	1.7	7.0	1.5	13.5	3.2	1.27
31	1.3	0.04	6.9	1.6	6.9	1.9	13.8	3.5	1.56
33	1.6	0.04	5.1	1.2	6.3	1.3	11.4	2.5	0.86
35	2.0	0.06	9.7	2.7	9.7	3.0	19.4	5.7	3.16
28	1.1	0.04	5.6	1.6	5.6	0.9	11.2	2.5	1.00
32	0.9	0.03	6.4	0.8	6.4	0.9	12.8	1.7	0.68
		0.04 Mean							1.50 Mean

31/I/71

SL	AP	$\frac{AP}{SL}$	LEFT OVARY		RIGHT OVARY		L_l+L_r	W_l+W_r	$\frac{(L_l+L_r)\quad(W_l+W_r)}{SL}$
			Length L_l	Width W_l	Length L_r	Width W_r			
24	1.2	0.05	7.7	1.9	7.7	1.9	15.4	3.8	2.44
28	1.0	0.03	5.3	1.8	6.1	1.9	11.4	3.7	1.51
29	0.6	0.02	6.1	0.5	6.1	0.4	12.2	0.9	0.38
33	1.4	0.04	6.3	1.2	6.8	1.0	13.1	2.2	0.87
33	2.0	0.06	11.6	3.3	11.6	3.5	23.2	6.8	4.78
34	1.6	0.05	9.1	2.3	10.3	2.6	19.4	4.9	2.79
35	2.2	0.06	10.9	3.0	10.9	3.5	21.8	6.5	4.05
35	1.9	0.05	10.1	2.8	8.9	2.9	19.0	5.7	3.09
36	1.9	0.05	6.8	1.7	5.6	1.8	12.4	3.5	1.20
37	1.4	0.04	6.3	1.3	7.1	1.6	13.4	2.9	1.05
37	2.0	0.05	10.3	3.4	9.0	4.3	19.3	7.7	4.02
37	1.9	0.05	5.1	1.3	6.4	1.9	11.5	3.2	0.99
37	1.3	0.03	7.6	0.9	7.0	1.3	14.6	2.2	0.87
38	1.9	0.05	6.2	1.8	6.2	1.6	12.4	3.4	1.11
39	1.5	0.04	7.5	2.2	7.8	2.6	15.3	4.8	1.88
40	1.9	0.05	5.6	1.3	6.3	1.2	11.9	2.5	0.74
41	2.0	0.05	9.5	2.8	9.9	2.9	19.4	5.7	2.69
41	1.5	0.04	10.3	2.3	11.5	2.9	21.8	5.2	2.76
42	1.7	0.04	7.3	1.4	9.8	2.1	17.1	3.5	1.42
50	1.7	0.03	9.3	1.7	10.2	1.8	19.5	3.5	1.36
		0.04 Mean							2.00 Mean

28/II/71									
SL	AP	$\frac{AP}{SL}$	LEFT OVARY		RIGHT OVARY		L_l+L_r	W_l+W_r	$\frac{(L_l+L_r)\quad(W_l+W_r)}{SL}$
			Length L_l	Width W_l	Length L_r	Width W_r			
29	0.5	0.02	4.1	0.6	5.6	0.6	9.7	1.2	0.40
30	0.6	0.02	4.5	0.9	5.4	1.0	9.9	1.9	0.63
32	1.3	0.04	8.3	2.3	9.1	2.4	17.4	4.7	2.55
32	0.3	0.01	5.2	0.7	6.9	0.8	12.1	1.5	0.57
34	1.2	0.03	8.9	1.8	10.4	2.4	19.3	4.2	2.38
34	1.1	0.03	8.9	2.1	8.9	2.1	17.8	4.2	2.19
35	0.9	0.02	7.2	1.2	4.8	0.8	12.0	2.0	0.68
36	0.9	0.02	6.5	0.7	7.7	0.9	14.2	1.6	0.63
36	1.4	0.04	6.3	1.2	7.4	1.3	13.7	2.5	0.95
37	0.6	0.02	6.2	1.6	7.7	1.7	13.9	3.3	1.24
38	1.6	0.04	8.2	2.3	9.1	1.9	17.3	4.2	1.91
39	1.6	0.04	9.9	2.3	9.9	2.2	19.8	4.5	2.28
39	1.8	0.05	7.7	1.8	7.7	2.3	15.4	4.1	1.62
40	1.9	0.05	6.9	1.8	7.6	1.7	14.5	3.5	1.27
40	1.6	0.04	7.1	1.9	9.0	2.2	16.1	4.1	1.65
40	1.6	0.04	8.1	1.9	9.7	2.2	17.8	4.1	1.82
41	2.0	0.05	6.2	1.9	8.0	1.6	14.2	3.5	1.21
43	1.5	0.03	8.8	1.8	8.8	1.9	17.6	3.7	1.51
43	1.9	0.04	8.3	2.4	9.0	2.3	17.3	4.7	1.89
45	1.9	0.04	10.3	2.8	11.5	2.4	21.8	5.2	2.52
		0.03 Mean							1.49 Mean

31/III/71									
			LEFT OVARY		RIGHT OVARY				
SL	AP	$\frac{AP}{SL}$	Length L_l	Width W_l	Length L_r	Width W_r	L_l+L_r	W_l+W_r	$\frac{(L_l+L_r)\ (W_l+W_r)}{SL}$
32	0.5	0.01	4.9	1.0	5.6	1.2	10.5	2.2	0.72
32	0.5	0.01	4.5	0.8	5.6	0.9	10.1	1.7	0.54
34	0.8	0.02	4.5	0.9	5.0	1.0	9.5	1.9	0.53
36	1.2	0.03	5.6	1.5	6.7	1.7	12.3	3.2	1.09
38	1.1	0.03	5.8	1.0	6.9	1.0	12.7	2.0	0.67
39	1.1	0.03	6.2	1.8	7.9	1.8	14.1	3.6	1.30
39	0.9	0.02	5.6	1.0	7.0	1.0	12.6	2.0	0.65
39	1.2	0.03	6.3	1.0	7.6	1.4	13.9	2.4	0.85
40	1.1	0.03	5.8	1.5	6.7	1.3	12.5	2.8	0.87
41	1.3	0.03	7.7	2.1	7.7	1.8	15.4	3.9	1.46
41	1.0	0.02	6.2	1.3	6.2	1.1	12.4	2.4	0.72
42	1.3	0.03	7.4	1.5	7.4	1.9	14.8	2.4	0.84
44	1.2	0.03	7.1	1.2	7.1	1.4	14.2	2.6	0.84
45	1.1	0.02	8.7	1.0	9.3	1.7	18.0	2.7	1.08
45	1.9	0.04	7.6	2.0	8.9	2.0	16.5	4.0	1.47
45	1.4	0.03	9.0	2.0	9.6	1.6	18.6	3.6	1.48
46	1.0	0.02	6.2	1.2	8.9	1.2	15.1	2.4	0.78
48	1.8	0.04	10.1	2.9	11.0	3.1	21.1	6.0	2.64
51	2.6	0.05	7.7	2.0	10.9	2.1	18.6	4.1	1.49
52	2.3	0.04	10.9	3.0	10.9	3.6	21.8	6.6	2.77
		0.03 Mean							1.14 Mean

25/IV/71

SL	AP	$\frac{AP}{SL}$	LEFT OVARY		RIGHT OVARY		L_l+L_r	W_l+W_r	$\frac{(L_l+L_r)\ (W_l+W_r)}{SL}$
			Length L_l	Width W_l	Length L_r	Width W_r			
29	0.4	0.01	5.3	0.4	5.3	0.5	10.6	0.9	0.33
39	0.9	0.02	5.4	0.6	5.8	0.8	11.2	1.4	0.40
39	0.7	0.02	4.7	0.9	6.5	1.0	11.2	1.9	0.54
40	1.3	0.03	8.7	1.9	8.7	1.8	17.4	3.7	1.64
41	1.7	0.04	9.5	1.4	8.0	1.1	17.5	2.5	1.07
42	1.1	0.03	7.5	1.1	8.5	1.5	16.0	2.6	0.99
42	1.3	0.03	7.0	1.0	7.8	1.0	14.8	2.0	0.70
43	1.2	0.03	7.3	1.0	7.3	1.2	14.6	2.2	0.75
43	1.3	0.03	7.6	1.2	7.6	1.1	15.2	2.3	0.81
43	1.1	0.02	8.6	1.5	10.8	1.4	19.4	2.9	1.31
43	1.6	0.04	8.5	1.6	8.5	1.1	17.0	2.7	1.07
43	0.7	0.02	6.7	0.9	8.4	1.2	15.1	2.1	0.74
43	1.0	0.02	6.0	1.2	7.0	1.3	13.0	2.5	0.75
44	1.1	0.02	9.0	1.0	8.2	1.3	17.2	2.3	0.89
44	0.5	0.01	5.0	0.8	6.3	1.2	11.3	2.0	0.51
44	1.0	0.02	5.2	1.2	8.4	1.3	13.6	2.5	0.77
45	1.6	0.03	8.5	1.2	8.5	1.8	17.0	3.0	1.13
46	1.5	0.03	7.6	1.7	8.6	1.6	16.2	3.3	1.16
55	2.1	0.04	9.8	1.8	9.8	1.5	19.6	3.3	1.17
		0.02 Mean							0.88 Mean

31/V/71

SL	AP	$\frac{AP}{SL}$	LEFT OVARY Length L_l	LEFT OVARY Width W_l	RIGHT OVARY Length L_r	RIGHT OVARY Width W_r	L_l+L_r	W_l+W_r	$\frac{(L_l+L_r)\ (W_l+W_r)}{SL}$
37	1.4	0.04	6.0	1.0	6.9	1.2	12.9	2.2	0.77
37	1.5	0.04	6.0	1.2	7.1	1.2	13.1	2.4	0.85
38	1.5	0.04	5.9	1.2	7.0	1.3	12.9	2.5	0.85
40	0.8	0.02	6.1	0.7	7.8	0.9	13.9	1.6	0.56
41	1.6	0.04	5.9	1.2	6.8	1.2	12.7	2.4	0.74
42	1.2	0.03	6.4	0.9	5.9	1.3	12.3	2.2	0.64
43	1.8	0.04	8.1	1.4	9.4	1.6	17.5	3.0	1.22
43	1.7	0.04	7.9	1.4	8.9	2.0	16.8	3.4	1.33
44	2.0	0.04	6.9	1.1	7.8	1.5	14.7	2.6	0.87
44	2.0	0.04	6.4	1.4	7.4	1.5	13.8	2.9	0.91
44	2.3	0.05	6.2	1.2	7.6	2.0	13.8	3.2	1.00
45	2.1	0.05	9.9	1.2	8.9	1.4	18.8	2.6	1.08
45	2.2	0.05	5.8	1.3	7.6	1.5	13.4	2.8	0.83
45	1.9	0.04	9.0	1.51	9.0	1.5	18.0	3.0	1.20
45	2.1	0.05	8.9	1.7	8.9	1.5	17.8	3.2	1.26
46	1.5	0.03	3.2	1.3	4.1	1.4	7.3	2.7	0.43
46	1.5	0.03	8.6	0.9	10.6	0.7	19.2	1.6	0.67
47	1.4	0.03	8.7	0.9	8.7	1.1	17.4	2.0	0.74
48	2.2	0.04	9.3	1.1	11.3	1.8	20.6	2.9	1.24
50	1.2	0.02	9.0	0.8	7.3	1.2	16.3	2.0	0.65
		0.04 Mean							0.89 Mean

Appendix U

Meristic data recorded from 25 males and 25 females collected at Blythe Bore (locality 17) on 27.XI.69.

Males

SL mm.	D_1	D_2	P_L	P_R	A	V	C	Sc	Tr.	LGR	Vert.
37	vi	9	13	13	i,8	i,5	28	48	19	8	27
37	vi	9	13	12	i,8	i,5	27	45	17	8	27
37	vi	9	12	12	i,7	i,5	27	45	17	9	27
38	vi	9	13	12	i,7	i,5	28	48	16	8	27
38	vi	9	12	13	i,7	i,5	29	45	19	9	27
38	vi	9	14	12	i,8	i,5	28	44	18	8	27
39	vi	9	13	13	i,8	i,5	28	45	18	8	26
39	vi	10	13	14	i,7	i,5	28	45	17	8	27
39	vi	9	13	13	i,7	i,5	28	45	18	9	27
39	vi	10	13	13	i,7	i,5	26	45	17	8	27
39	vi	9	13	12	i,7	i,5	28	45	17	9	27
39	vi	9	13	13	i,7	i,5	28	44	18	9	27
40	vi	10	13	13	i,7	i,5	28	45	17	8	27
40	vi	9	12	12	i,7	i,5	27	44	18	9	28
40	vi	10	13	13	i,7	i,5	27	47	18	8	27
40	vi	9	13	13	i,8	i,5	28	46	17	8	27
40	vi	9	13	13	i,7	i,5	28	44	17	8	27
40	vi	9	12	12	i,8	i,5	28	45	17	8	27
41	vi	10	13	12	i,7	i,5	29	43	18	8	27
41	vi	9	13	13	i,7	i,5	28	48	18	8	27
41	vi	10	13	13	i,8	i,5	27	48	18	8	27
42	vi	9	14	13	i,7	i,5	26	45	17	8	26
42	vi	10	13	13	i,8	i,5	29	49	16	8	27
42	vi	9	13	13	i,8	i,5	28	46	18	8	28
42	vi	9	13	13	i,7	i,5	28	45	18	9	27
Range: 37-42	0	9-10	12-14	12-14	i,7-8	0	27-29	44-49	17-19	8-9	26-28
Mean: 39.6	vi	9.3	12.9	12.7	i,7.4	i,5	27.7	45.6	17.5	8.3	27.0

Females

SL mm.	D_1	D_2	P_L	P_R	A	V	C	Sc.	Tr.	LGR	Vert
35	vi	9	13	13	i,7	i,5	29	45	16	8	27
36	vi	9	12	12	i,7	i,5	28	46	17	8	27
36	vi	10	13	12	i,7	i,5	29	47	17	8	27
36	vi	9	13	13	i,8	i,5	27	45	18	8	27
36	vi	9	12	12	i,7	i,5	28	47	18	8	27
37	vi	10	13	13	i,8	i,5	27	47	16	9	27
37	vi	9	13	13	i,7	i,5	28	45	18	8	27
37	vi	9	12	12	i,7	i,5	28	46	18	8	27
39	vi	9	13	13	i,7	i,5	29	46	17	8	27
39	vi	10	13	13	i,7	i,5	28	47	18	8	27
39	vi	10	13	12	i,7	i,5	27	43	17	8	28
39	vi	9	13	13	i,7	i,5	28	45	17	9	27
39	vi	10	12	12	i,7	i,5	27	44	17	8	27
40	vi	9	13	13	i,8	i,5	28	44	18	8	27
40	vi	9	13	13	i,8	i,5	28	46	18	9	27
41	vi	9	14	14	i,7	i,5	28	47	16	9	27
41	vi	9	13	13	i,7	i,5	27	48	18	8	27
41	vi	9	13	12	i,7	i,5	29	48	18	8	27
41	vi	9	13	13	i,7	i,5	28	45	18	8	27
42	vi	9	13	12	i,8	i,5	27	45	18	9	27
42	vi	9	13	13	i,7	i,5	29	47	18	9	27
42	vi	9	12	12	i,7	i,5	27	45	18	8	27
42	vi	9	13	13	i,7	i,5	29	45	18	8	27
43	vi	9	13	13	i,7	i,5	29	44	16	8	27
44	vi	8	13	13	i,8	i,5	27	45	17	9	27
Range: 35-44	0	8-10	12-14	12-14	i,7-8	0	27-29	44-48	16-18	8-9	27-28
Mean: 39.4	vi	9.2	12.8	12.7	i,7.2	i,5	27.9	45.7	17.4	8.3	27.0

Appendix V

Statistical Reports of analyses made of certain physiological and behavioural observations.

Analyses carried out by statistical consultants of the Department of Statistics, University of Adelaide.

Section VI.

Report A: Comparing outlet temperatures of artesian bore and spring waters inhabited by *C. eremius* with those not inhabited by the species.

Original data in table:- 16

Inhabited Waters	Un-inhabited Waters (excluding localities 44-51 inclusive)
$\bar{x}_1 = 30.96$	$\bar{x}_2 = 28.80$
$s_1^2 = 34.07$	$s_2^2 = 74.99$
$s_1 = 5.83$	$s_2 = 8.66$

Testing equality of variances.

$$F_{9,\,11} = \frac{74.99}{34.07} = 2.2 \quad \text{(not significant)}$$

Pooled variance.

$$s^2_p = \frac{(11s_1^2 + 9s^2_2)}{20} = 52.48$$

Testing equality of means.

$$t_{m-1} = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{s_p^2(\frac{1}{n_1} + \frac{1}{n_2})}} = 0.69 \text{ (not significant).}$$

Conclusion: equal mean temperatures.

Removing Paralana Hot Spring (locality 54) data from un-inhabited group.

$\bar{x}_2 = 25.9$

$s_2^2 = 10.3$

$s_2 = 3.2$

$s_p^2 = 24.6$ and $t_4 = 2.18$ (not significant)

Report B: Testing whether there is significant difference between the critical thermal maxima means and a significant correlation between critical thermal maxima and bottom water temperatures recorded in February and June, 1968, at Coward Springs Railway Bore (locality 34).

Original data in table:- 33

c.t.m. values.	
February	June
$\bar{x}_1 = 40.8$ $s_1^2 = 1.92$ $s_1 = 1.38$	$\bar{x}_2 = 36.30$ $s_2^2 = 0.75$ $s_2 = 0.86$

$$F_{3,3} = \frac{s^2_1}{s^2_1} = 2.56 \quad \text{(not significant)}$$

$$s^2_p = \frac{(3\, s^2_1 + 3\, s^2_2)}{6} = 1.33$$

$Sp = 1.15$

$$t_3 = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{s_p^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} = 3.91$$ (re mean difference of critical thermal maxima values significan at 5% level)

Conclusion re correlation between critical thermal maxima and bottom water temperature:- There is a simple linear correlation of 0.73 between critical thermal maxima and bottom water temperature.

Comment: Cannot associate too much "cause-and-effect" from correlation between bottom water temperature and critical thermal maxima because there may be a 3rd factor influencing both.

Section VIII.

Report C: Comparing numbers of tubifex eaten in light and dark. Original data in Table 60

Assuming no differences exist between the groups used, a χ^2 test of homogeneity was performed on the total numbers of tubifex consumed under the different conditions. A χ^2 value of 0.05 on 1 d.f was obtained and since $P_r\{\chi_1^2 \geqslant 0.05$ $\doteqdot$ 0.82, the hypothesis that equal proportions were consumed was accepted.

Report D: Comparing number of live and dead tubifex worms, both under illumination. Original data in Table. 61

With the same assumption as in report C and using the same test, a χ^2 value of 6.9 on 1 d.f. was obtained. Since $P_r\left\{x_1^2 \geqslant 6.90\right\} \doteqdot 0$, the hypothesis that equal proportio of live and dead tubifex were consumed was rejected.

Report E: Comparing number of live tubifex eaten under illumination with number of dead tubifex eaten in darkness. Original data in Table 62

Proceeding as in Reports C and D, a χ^2 value of 1.88 on 1 d. was obtained. Since $P_r\left\{\chi^2_1 \geqslant 1.88\right\} = 0.17$, the hypothes that equal proportions were consumed was accepted.

Comment: On the data presented there is no way to compare dead tubifex and illumination with live tubifex and darkness.

Report F: Comparing number of approaches to control and impregnated (with macerated tubifex fluid) swabs. Original data in Table 64

In this analysis two assumptions have been made:-

(1) .that an individual subject moved independently of the other subjects.

(2) that in ordinary circumstances the subjects moved randomly about the tank.

Assuming the hypothesis of no difference between swabs and no difference between "a" and "b" trials, a χ^2 test with equal marginal probabilities was performed. A highly significant value of 116.34 on 3 d.f. was obtained, indicating a rejection of the hypothesis. When divided into components for trials, swabs and independence, componer of 92.46, 23.67 and 0.21 were obtained, each on 1 d.f. This indicates that the single factor segregation for both trials and swabs are not in equal proportions as hypothesised.

Report G: Comparing time spent in light and dark by vision-intact and blind subjects. Original data in Table 5

In the analysis the same two assumptions in Report F were made.

Since the data indicates an effect due to trials, a paired t=test was used on the 5 sets of "presences" recorded under the heading "in light" viz.

$(x_1, y_1) = (39, 18)$, $(x_2, y_2) = 44, 13)$, $(x_3, y_3) = 35, 4)$, $(x_4, y_4) = (14, 7)$, $(x_5, y_5) = (13, 4)$.

Interpreting these pairs to be relative measures of the time spent in the illuminated area by the two types of subjects, the test was now for equal mean times.

Values calculated were $\bar{d} = 19.8$ where $d_1 = x_1 - y_1$

$s_d = 10.32$

$t_4 = 4.28$ (significant at 5% level)

Consequently the hypothesis of equal mean times would not be supported by this data.

Report H: Comparing time spent over black andyellow backgrounds. Original data in Table 66

In this analysis the same two assumptions in Report F were made.

A χ^2 test assuming equal proportions in each colour category was performed giving a value of 3.83 on 1 d.f. Since $P_r\left\{\chi^2_1 \geqslant 3.83\right\} = 0.05$, the hypothesis would be accepted.

Report I: Comparing time spent over different mediums. Original data in Table 68

In this analysis the same two assumptions in Report F were made.

A χ^2 test assuming equal proportions was performed giving a value of 19.14 on 1 d.f. and consequently the hypothesis would be rejected since $P_r\left\{x^2_1 \geqslant 19.14\right\} \doteqdot 0$

Report J: Comparing mean response times of vision-intact and blind fish to effect colour change when transferred from black to white backgrounds. Original data in Table 71

Reaction of:	Vision Intact	Blind
Mean reaction time $(\bar{x}_1)$	5.90	10.20
Standard Deviation (s_1)	2.07	6.87
Number (n_1)	5	5

Using F - test for equality of variances

$$F = \frac{s_1^2}{s_2^2} = \frac{(2.07)^2}{(6.87)^2} = 0.091 \text{ (significant at 5\% level)}$$

Testing equality of means using Cochrans approximation to Fisher-Behrans test

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s^2_1}{n_1} + \frac{s^2_2}{n_1}}} = 1.33 \text{ (not significant) on 4 degrees of freedom.}$$

<u>Report K</u>: Comparing mean response times of vision-intact and blind fish to effect colour change when transferred from white to black backgrounds. Original data in Table 71

Reaction of:	Vision Intact	Blind
Mean reaction time $\bar{x}_2$	6.7	18.90
Standard deviation	1.20	7.15
Number	5	5

F - ratio is $\frac{(1.2)^2}{(7.15)^2} = 0.028$ (significant at 5% level)

Using the same method as above, $t = 3.76$ (significant at 5%) on 4 degrees of freedom.

<u>Report L</u>: Comparing trapping counts according to lunar phases. Original data in tables 76 and 77

An analysis of variance was performed on the combined data from Wobna Springs (locality 35) and Johnson's No. 3 Bore (locality 24). This combination was possible because the variances estimated separately from the two localities were not significantly different.

The Analysis of Variances table obtained was:-

Source	SS	DF	MS	VR
Johnson's No. 3 Bore (locality 24) versus Wobna Spring (locality 35)	1464.2	1	1464.2	0.24
Within Johnson's No. 3 Bore (locality 24)	141155.4	3	47051.79	7.87*
Within Wobna Spring (locality 35)	6728.2	3	2242.73	0.38
Residual	149347.8	25	5973.91	

* Highly significant variance

The pooled estimate of the standard deviation is 77.29.

The only significant difference occurs between the phases at Johnson's No. 3 Bore (locality 24). This significance is accounted for by the new moon observations, whose mean is more than 3 s.d.'s larger than the next highest mean. However reservations should be held about the results since the new moon data comprises two observations only.

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