Craterocephalus dalhousiensis n.sp., a Sexually Dimorphic Freshwater Teleost (Atherinidae) from South Australia

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ABSTRACT

Craterocephalus dalhousiensis n.sp. is described from specimens collected in shallow water of artesian springs at Dalhousie Springs, South Australia and represents the first Australian record of a sexually dimorphic atherinid. *C. dalhousiensis* appears to be closely related to *C. lacustris and C. stercusmuscarum* although meristic and morphometric differences make the new species readily distinguishable. A number of specimens of *C. dalhousiensis* has been examined internally for gonad condition, gut content and presence of parasites. Water temperature, salinity and pH were measured at the time of collection and upper and lower thermal tolerances were also determined.

INTRODUCTION

As a result of aquatic surveys conducted by the South Australian Museum in the Far North of South Australia since 1968, the known distributions of several species of fishes have been extended and some new forms have been collected, including the species described here.

Preliminary field observations and experiments on this new species' environment, activity and thermal physiology can be compared with the findings of Brown and Feldmeth (1971) on desert pupfish (*Cyprinodon spp.*) in southern California.

(A) TAXONOMY

MATERIALS AND METHODS

The technique used for counts and measurements was the same as used by Munro (1967) except for the inter-dorsal count where the scales were counted from the origin of the last spine of the first dorsal to the origin of the second dorsal. Transverse scale rows count was made diagonally across the body from the

origin of the first dorsal to the origin of the ventral fin. Relative positions of the fins were recorded in numbers of scales in front or behind the origins or tips of fins.

All measurements were made with dial calipers to the nearest one-tenth of a millimetre (mm). Body measurements were expressed as proportions of standard length or as otherwise indicated in Table 1. A mean and range (in brackets) was also given for the ten male and ten female specimens examined.

Type material has been deposited at the following institutions: Australian Museum, Sydney; American Museum of Natural History, New York; British Museum of Natural History, London; Museum National d'Histoire Naturelle, Paris; Zoologisch Museum, Amsterdam.

List of abbreviations used in Table 1:

SL	standard length
B	behind
F	in front of
OD1	origin of first dorsal fin
OD2	origin of second dorsal fin
OV	origin of ventral fin
T. Pec.	tip of pectoral fin
TV	tip of ventral fin

DESCRIPTION

Craterocephalus dalhousiensis, new species

Figure 1

Holotype—SAM F3453 (male), allotype—SAM F3453 (female), type locality, Dalhousie Springs, Main Spring, South Australia, 26° 25′ S., 135° 30′ E. (Map ref. 1:250,000 Topographic Maps, Series R502, Commonwealth Government Printer, Canberra. Map Sheet: Dalhousie SG 53-II. Grid ref.: 345718). Holotype and allotype in South Australian Museum (SAM). Paratypes in South Australian Museum and The Australian Museum, Sydney (AMS).

Material examined:

Main Spring, Dalhousie Springs, South Australia, designated holotype SAM F3453 (male), 51 mm SL, designated allotype SAM F3453 (female), 63 mm SL, designated paratypes SAM F3453, AMS I.17756-001; Spring, 2.4 km south-west of Dalhousie Main Spring, South Australia, SAM F3466.

General description—The material examined ranged from 27 to 63 mm SL. In both sexes, the lips are thick and fleshy with the skin of the upper jaw fusing with the skin over lower jaw about half way along the premaxilla. Premaxilla never reaches the anterior margin of the orbit.

The lower jaw is massive when compared with other species of this genus, the anterior end expanding to form a wide horseshoe-shaped band with many rows of small but easily visible curved teeth. Upper jaw is similarly toothed. The rest of the mouth is edentelous. Both the preopercle and opercle are covered with scales. Body scales are cycloid, round in smaller specimens but becoming elongated vertically in older fish. The ridges on scales do not extend to the posterior part of the scale in specimens examined. As in all other Australian hardyheads, the midlateral scales are pierced with pores, but in many specimens scales on the dorsal surface and on the lateral sides are likewise pierced.

Specimens preserved in alcohol are dark brown above the midlateral band due to presence of many small chromatophores uniformly dispersed along the back. Occasionally, spots immediately above the midlateral band form a faint discontinuous line. A dark band extends from the snout through the eye and opercle, then continues as a midlateral band formed by large pigment spots in the centre of each midlateral scale. Scales beneath the midlateral band have smaller pigment spots usually forming two or three discontinuous lines along the abdomen. Very young fish are dusky brown with few or no spots below midlateral band.

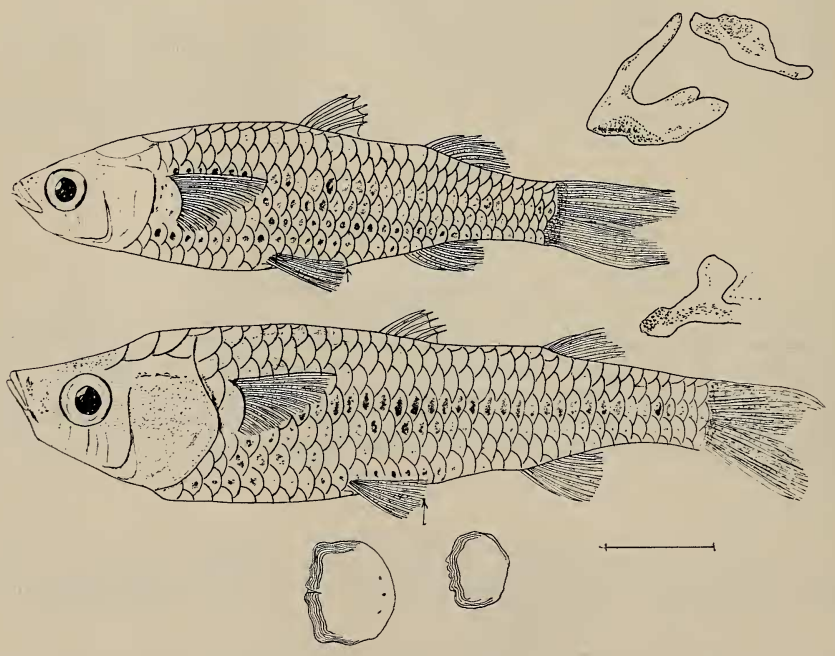

Fig. 1. Line drawings of holotype male (above) and allotype female (below) showing external features. Scales (6th along the midlateral band) from both specimens. Line diagrams of premaxilla, maxilla and dentary are also included. Position of anus is indicated by arrow. Projected scale, 10 mm.

TABLE 1

BODY MEASUREMENTS AND COUNTS OF TWENTY-TWO SPECIMENS OF *C. DALHOUSIENSIS* FROM DALHOUSIE SPRINGS

	Holotype	Allotype	Mean, range of 10 males	Mean, range of 10 females
Head in SL	3.4	3.1	3.5(3.3-3.7)	3.3(3.0-3.5)
Greatest body depth in SL	3.9	3.8	4.0(3.7-4.7)	4.1(3.7-4.5)
Premaxillary process in eye	1.1	1.1	1.3(1.1-1.7)	1.2(1.0-1.6)
Eye in the head	3.8	4.4	3.6(3.0-3.9)	3.8(3.3-4.4)
Interorbital in head	2.6	2.4	2.6(2.3-2.9)	2.6(2.4-3.1)
Snout in eye	1.1	1.0	1.1(1.0-1.3)	1.1(0.9-1.2)
Premaxilla in eye	1.0	1.0	1.0(1.0-1.4)	1.0(0.8-1.1)
Least depth of caudal peduncle in SL	8.7	10.2	9.5(8.7-10.0)	10.0(9.4-10.1)
Midlateral scales	30	31	29.6(29-30)	29.9(29-31)
Transverse scales	7.5	7.5	7.1(6-8)	7.3(6.5-7.5)
Predorsal scales	17	26	15.9(15-17)	16(15-18)
Interdorsal scales	6	8	7(6-8)	7.6(7-8)
Dorsal fin count	V,Ii6	VI,Ii6	V-VI, Ii4-6	IV-VI, Ii5-6
Anal fin count	Ii7	Ii7	Ii6-7	Ii6-8
Pectoral fin count	Iil2	Iil2	Ii11-13	Ii11-12
Gill rakers in lower gill arch	8	7	7.1(7-8)	7.1(7-8)
Vertebral count	32	32	31.6(31-32)	31.2(30-32)
OD1, in relation to TV (scales)	F 3.5	F 3.5	F 3.3(2.0-4.5)	F 3.9(3-5)
OD2, in relation to OA (scales)	B 1	B 1	B 1(0.5-1.5)	B 1.5(0.5-1.5)
OD1, in relation to T. Pec. (scales)	B 1.5	B 2	B 2.4(1.5-3.0)	B 2(1.5-3.0)
OV, in relation to T. Pec. (scales)	F 1	directly below	F 0.6(0-1.5)	F 1.1(0-3)
Position of anus to TV (scales)	B 0.5	B 1	B 1(0-2 B)	B 0.5(F0.5-B0.5)

Remarks—C. dalhousiensis is sexually dimorphic, a condition which is exceptional amongst the Australian hardyheads, except for some sexual differences during the breeding season (Llewellyn, 1971). It is, however, quite normal for blue eyes (Pseudomugilinae) and rainbow fish (Melanotaeniidae) their close relatives. Fish longer than 40 mm SL are easily sexed (see Fig. 1). externally. On the average (in a sample of 64) the adult male is shorter than the adult female. The dorsal surface in males tends to be almost horizontal from the snout to the origin of the first dorsal; the abdomen on the other hand is gently arched from the isthmus to the tips of ventrals. In the female, the belly is flat, but the head slopes sharply towards the snout with the interorbital space being flat to concave, depending on maturity. No other differences can be observed between males and females externally. Specimens less than 40 mm SL are difficult to sex although ripe gonads were

found in a 34 mm male and a 27 mm female. Immature individuals tend to resemble adult males, but the abdomen is flat. Gonads in both sexes lie below and to one side of the intestine. The ovary, a long cylindrical sac is completely enclosed by black mesovarium. It lies below and to the right side of the intestine with its duct extending past the rectum to open just posteriorly to the anus. The testis is a yellow-white mass lying below and to the left side of the intestine with its duct extending past the anus to open posteriorly as in the female. Gonads were checked histologically to confirm the relationship between sex and external morphology. In a 34 mm male collected in November, sperm was found in great abundance. In a thin section of an ovary from a 37 mm female collected in August, no ripe oocytes were visible, although the more immature stages were clearly evident.

Superficial examination of adult females suggests a close affinity with *C. lacustris* Trewavas. Apart from significant colour differences, the size range, vertebral, midlateral scale and gill raker counts are very different. Coloration and spot pattern suggests a closer similarity to *C. stercusmuscarum* (Gunther), but none of the 64 specimens of *C. dalhousiensis* examined for colour and spot pattern had more than one row of spots above the midlateral band as seen in *C. stercusmuscarum*. However, immature specimens of the two species are easily confused because of their similar pigmentation. *C. dalhousiensis* is deep bodied, *C. stercusmuscarum* is slender, the midlateral scales, vertebral and gill raker counts are also different. A comparison with other allied species also shows meristic and morphometric differences (Table 2).

TABLE 2

MERISTIC AND MORPHOMETRIC DIFFERENCES (EXPRESSED AS MEANS AND RANGES) OF FOUR CLOSELY ALLIED SPECIES OF *CRATEROCEPHALUS*

	C. lacustris	*C. stercusmuscarum*	*C. marjoriae*	*C. dalhousiensis*
Greatest body depth in SL	4.6(3.5-6.0)	4.9(3.5-5.6)	4.1(3.7-4.5)	4.1(3.7-4.7)
Midlateral scales	34.3(32-38)	32.6(30-34)	28.5(24-30)	29.8(29-31)
Transverse scales	7.3(6.0-8.5)	7	6(5.5-7.0)	7.1(6.5-7.5)
Vertebral count	36.5(35-39)	36.8(35-39)	31.4(30-32)	31.4(30-32)
Gill rakers in lower gill arch	10.7(9-12)	9.1(8-10)	10.1(9-11)	7.1(7-8)

On the basis of body colour, pattern and body shape, *C. dalhousiensis* appears to be closely related to *C. lacustris* and *C. stercusmuscarum*. Counts and measurements also suggest a close affinity with *C. marjoriae* Whitley. A comparative study of the premaxillary bone of five species of *Craterocephalus* confirms the relationship with *C. lacustris* and suggests affinity with *C. eyresii* (Steindachner) (Fig. 2). Counts and measurements do not confirm close relationship with *C. eyresii*.

Diagnostic features—*C. dalhousiensis* can be distinguished from its congeners by the following characters: it is a deep bodied fish which is dark brown above and with two to three rows of brown spots below the midlateral line, 7 to 8 gill rakers in the first lower arch, 29 to 30 midlateral scales, $6\frac{1}{2}$ to $7\frac{1}{2}$ transverse scales; females have a head which slopes sharply towards the snout whilst the abdomen tends to be flat. Mature males have a sloping abdomen and a relatively horizontal dorsal surface.

Range—At present, this species is only known from Dalhousie Springs, South Australia which is about 120 km north of Oodnadatta. It may have a wider range as has proved to be the case with *C. eyresii* which has been recorded (unpublished

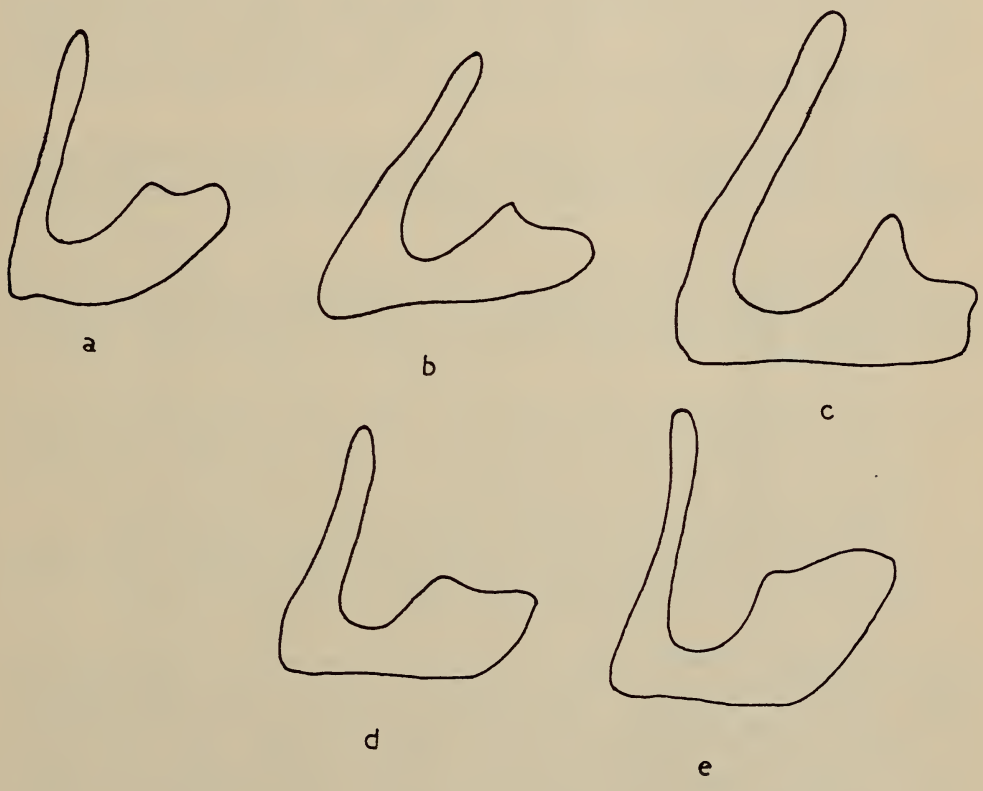

Fig. 2. Comparison of the premaxillary bones of 5 species of *Craterocephalus*.
(a) *C. lacustris*
(b) *C. dalhousiensis*
(c) *C. marjoriae*
(d) *C. eyresii*
(e) *C. stercusmuscarum*

data) from the Namoi, Peel and Murray Rivers and the inland lakes of Victoria and South Australia.

The name given to the species is derived from the name of the type locality, a major area of mound spring development, embracing about thirty-three artesian springs of varying size and activity, scattered over an area of nearly 75 km^2.

(B) BIOLOGICAL NOTES

MATERIALS AND METHODS

The fish were collected with wire mesh traps (26 gauge wire, 2 mm mesh) 31 x 15 x 15 cms. Each end of the cage had an aperture with an internal collar 3.5 cms in diameter. Traps were set both during the day and night. The size and the composition of catches was noted and recorded. Each species was identified and examined for gut content.

Water temperatures were recorded at five stations over a distance of approximately 1 km along the course of Dalhousie Main Spring stream. pH and salinity were also taken at the time of trapping.

Observations of movements of *C. dalhousiensis* were made at Dalhousie Springs (by C.J.M.G.) on two occasions. The observations were followed up by a series of simple field experiments to determine upper and lower thermal tolerances of the hardyheads.

(a) In one experiment the fish trapped in a cage were transferred to a point 5 metres upstream where the temperature recorded was higher. The experiment was repeated later in the day with a metal baffle inserted over the upstream end of the cage to reduce the force of the water current.

(b) Captive hardyheads and catfish (*Neosilurus* sp.) from Dalhousie Main Spring were held in non-heated, non-aerated tanks in which the temperature was allowed to drop to well below 20°C.

To determine whether thermal acclimation takes place, freshly retrieved hardyheads were subjected in batches of four to rising water temperature by placing the holding tank (one litre polythene beaker) in a large water bath (an enamel bucket) containing water at 100°C. The fish were taken from waters of various temperatures to determine whether fish inhabiting the warmer sections of Dalhousie Main Spring were tolerant to higher temperatures than those from cooler regions. Constant agitation of water in the holding tank by stirring with a hand-held glass bulb thermometer, produced rapid and uniform transfer of heat, enabling the upper thermal limit of fish to be reached in about 10 minutes. A total of sixteen specimens from each of the two regions of the Spring stream were tested for thermal acclimation.

RESULTS AND DISCUSSION

Trapping—Far greater numbers of hardyheads (*C. dalhousiensis*) are trapped in daylight than during equivalent periods at night. In the case of the catfish (*Neosilurus* sp.) the reverse applies. A comparison of day and night catches (Table 3), made with a wire trap set along the Dalhousie Main Spring stream for five hour periods, confirms these catch patterns which presumably reflect activity patterns.

Associated fish—In the Dalhousie Main Spring (Table 3), an extremely large population of hardyheads (*C. dalhousiensis*) is found in association with an equally abundant population of catfish (*Neosilurus* sp.) together with very much smaller populations of two other small species, the desert goby (*Chlamydogobius eremius*) and the spotted gudgeon (*Mogurnda mogurnda*).

The catfish (*Neosilurus* sp.) appears to be an undescribed form.

Similar associations were found in all but one of the other inhabited springs inspected at Dalhousie; in one large spring approximately 0.8 km west of the main spring the species collected were *C. dalhousiensis, C. fluviatilis* McCulloch and *Madigania unicolor.*

Diet—Examination of gut contents in all specimens form a series of *C. dalhousiensis* yielded a large number of small unidentified gastropods and remnants of plant tissue.
Parasites—No external or internal parasites were noted on or in any of the *C. dalhousiensis* specimens examined.

TABLE 3

NUMBERS OF FISH TRAPPED DURING FIVE HOUR SETTINGS

Temperature and pH data recorded on morning of 19/11/69.

(a) day trapping—1100-1600 hours, 18/11/69.
(b) night trapping—2100-0200 hours, 18-19/11/69.

Station	*C. dalhousiensis*		*Neosilurus* sp.		*M. mogurnda*		*C. eremius*		Surface water temp.	Water pH
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)		
a	309	0	0	0	0	0	0	0	43.0°C	7.2
b	283	0	0	136	3	3	2	0	35.6°C	7.2
c	15	0	17	126	1	0	0	0	35.0°C	7.2
d	62	0	1	24	1	0	0	0	33.5°C	7.2
e	37	0	0	0	8	5	0	0	21.6°C	7.2
Total	706	0	18	286	13	8	2	0		

Water temperature, pH and salinity—Surface temperatures recorded at five stations over a distance of approximately 1 km along the course of Dalhousie Main Spring stream during summer in 1967 varied from 43°C in a narrow channel feeding into the main body of the spring at the west end, down to 21.6°C in the shallows of the swamp at the east end into which the spring waters spread (Fig. 3).

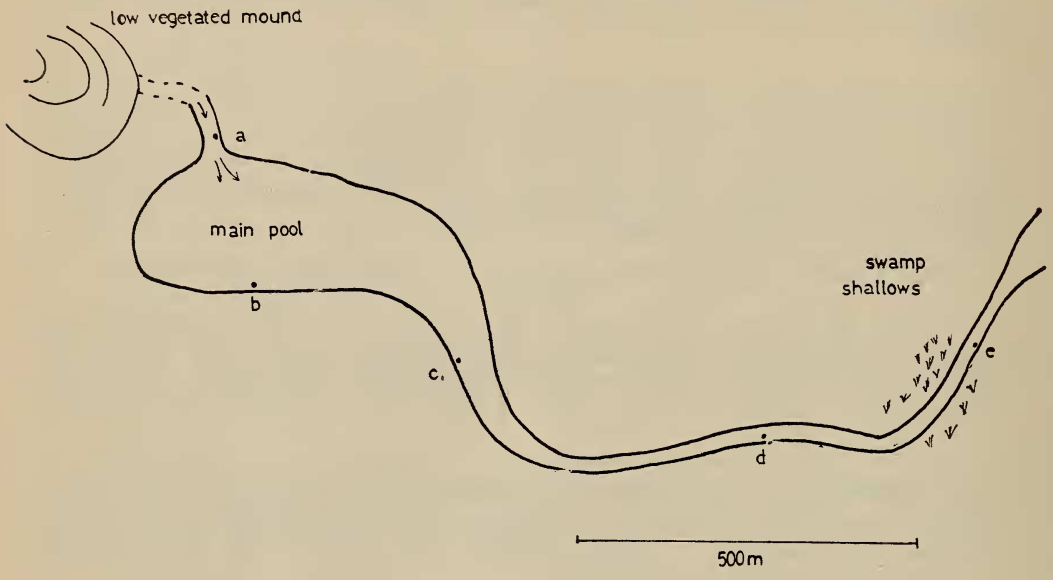

Fig. 3. Diagramatic representation of Dalhousie Spring and stream with collecting stations indicated.

Water pH (Table 3), measured at each of the above stations was consistent at 7.2, a fairly typical value for swiftly flowing artesian waters of the Lake Eyre drainage region. The pH of outflowing waters is usually about 7.0; this often rises along the stream path, minimally in swiftly flowing waters, more steeply in slowly flowing shallow streams and terminal waters, especially in the presence of large quantities of algae or other aquatic vegetation when pH may rise to very high levels.

Water sampled about mid-way along the Dalhousie Main Spring stream and subsequently analysed (Table 4), indicated relatively low salinity (as total dissolved solids) compared with other artesian waters of the central Australian region.

Thermal tolerance—(a) Upper thermal tolerance

Large numbers of *C. dalhousiensis* have been observed making brief solitary excursions of up to one minute's duration from the edge of the main body

TABLE 4

ANALYSIS* OF WATER SAMPLED FROM THE MAIN SPRING AT DALHOUSIE SPRINGS, SOUTH AUSTRALIA, 6/6/68.

(*Analysis performed by the Australian Mineral Development Laboratories, South Australia).

Constituent	ppm	Assumed composition of salts	ppm	Hardness (as $CaCO_3$)	ppm
Anions					
Cl	370				
SO_4	150	Ca HCO_3	186	Total	245
HCO_3	140				
NO_3	trace	Ca SO_4	41	Temporary	115
F					
Cations					
Na	252	Mg SO_4	119	Permanent	130
K					
Ca	58	Na SO_4	38	Due to Ca	145
Mg	24				
F		Na Cl	610	Due to Mg	100
Total dissolved solids	994			Total alkalinity as $CaCO_3$	115

of the Main Spring into the narrow channel of rapidly inflowing shallow water, originating from the spring's outlet higher up on an adjacent vegetated mound.

Specimens of *C. dalhousiensis* and *Neosilurus* sp. trapped near the entrance to the channel at 30 cm depth, where the water temperature was 38.8°C, were put back into the water about 5 metres upstream in depth of 10 cm and temperature of 41.8°C. It was observed that all the hardyheads collapsed rapidly and died within 16 minutes of the transfer. The catfish died 2 to 3 minutes later.

When the force of the current was reduced by the insertion of a metal baffle over the upstream end of the trap, the hardyheads and the catfish survived approximately 60 and 120 minutes respectively.

Clearly those fish inhabiting the surface waters in the vicinity of the channel's outlet into the spring's large pool are living close to their upper thermal limit and in fact the hardyheads intrude briefly into water which, if their stay is prolonged, proves lethally warm.

Although the motivation for these incursions is not clear it is probable that they are foraging upon blue-green algae that grows abundantly over the bed of the channel, parallelling the findings of Brown (1971) who reported that the desert pupfish (*Cyprinodon* spp.) in southern California feed on blue-green algae in water of about 42°C which is close to their upper thermal limit.

(b) Lower thermal tolerance:

Fish held in tanks where temperature was allowed to fall below 20°C rapidly became comatose. None survived overnight in this situation by which time the water temperature had dropped to 8.7°C.

In one experiment where water temperature had fallen to 16°C, a comatose catfish was revived by raising the water temperature above 20°C. This experiment was not repeated with the hardyheads.

Thermal acclimation:

The results obtained for thermal acclimation are summarized in Table 5. The data collected suggest the occurrence of direct acclimation by *C. dalhousiensis* to the thermal gradient along the Main Spring stream. Similar results were obtained with the catfish from the same spring and with desert gobies (*Chlamydogobius eremius*) elsewhere (C.J.M.G., unpublished data).

TABLE 5

SUMMARY OF RESULTS FOR THERMAL ACCLIMATION BY *C. DALHOUSIENSIS*

Station	Surface water temperature at collecting station	Standard lengths range (16 specimens)	SL mean	Critical thermal maxima range	Critical thermal maxima mean
a	38.8°C	30-52 mm	36 mm	41.8-44.6°C	43.6°C
d	32.8°C	37-50 mm	43 mm	37.8-42.5°C	40.2°C

These results are similar to those of Brown and Feldmeth (1971) who found that the upper thermal limit of desert pupfish (*Cyprinodon* spp.) freshly collected from thermal springs correlated with the temperatures of their habitats.

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