OBSERVATIONS ON THE TASMANIAN MUDFISH, *GALAXIAS CLEAVERI* (PISCES: GALAXIIDAE)

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(with two tables, one text-figure and two plates)

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Meristic and morphometric comparisons are made of the three known populations of the Tasmanian mudfish; mainland Tasmania, Flinders Island and Victoria. The results of observations on the ecology and behaviour are reported.

Key Words: **Tasmanian mudfish, taxonomy, ecology, behaviour.**

INTRODUCTION

Most members of the genus *Galaxias* are small to medium-sized, fast-swimming, mid-water fishes that can be either lacustrine or diadromous (Whitley 1935). However, one species, *Galaxias cleaveri* Scott 1934, differs so markedly from typical Tasmanian members of the genus that at one stage it was referred to the genus *Saxilaga* by Scott (1936).

Meristic and morphometric comparison of the mainland Tasmanian, Flinders Island and Victorian populations indicate that the three are conspecific.

The principal non-taxonomic differences between *G. cleaveri* and other *Galaxias* are ecological and behavioural and the results of studies on these aspects of the species are reported here.

MATERIALS AND METHODS

The methods used to collect galaxiid fishes, as described in Andrews (1976), by the use of baited wire cage traps were unsuitable for *G. cleaveri* because of its benthic and secretive nature. However, since the species almost always occurs in small, discrete waterways, dip-netting was successful in most areas. Specimens for meristic and morphometric study were narcotised in the field with quinaldine and fixed in 10% formalin. After fixing, the specimens were transferred to 70% ethanol.

Ecological observations on *G. cleaveri* were made at Port Davey (southwestern Tasmania) at sites about 4 km south of Bathurst Harbour, in the Dover area (southeastern Tasmania), at sites near the mouth of the Esperance River, and in the Bridgewater area of the Derwent estuary, Hobart.

Observations on the behaviour of *G. cleaveri* and other species of *Galaxias* were made in the field and on specimens maintained live in aquaria for periods of up to six months. The aquaria were of all glass construction measuring 0.3×0.6 m and 0.4 m deep. In setting up the aquaria, every effort was made to duplicate as closely as possible the conditions under which the specimens were collected in the field. For *G. cleaveri,* the bottom of each tank was covered to a depth of 80–100 mm with sand, mud and coarse decaying vegetable material collected at the field sites and the tank was filled with water to a depth of 0.3–0.35 m.

No form of aeration was provided other than maintaining the aquaria in shaded, well-ventilated positions with the tops open to the air. Food consisted of live plankton and a proprietary flake food. This diet was supplemented occasionally with small pieces of finely chopped worms and crayfish.

TAXONOMY

The taxonomy of *G. cleaveri* has been considered (Andrews 1976) at both generic and specific levels, and subsequent authors, such as McDowall & Frankenberg (1981) and Jackson & Davies (1982), have neither made nor suggested any alterations. In 1976, *G. cleaveri* was known only from the Tasmanian mainland. The species has been subsequently recorded from two Victorian localities (Wilsons Promontory — Jackson & Davies 1982; Wye River, Otways — Koehn & O'Connor 1990), and from Flinders Island (Green 1984).

Meristic and morphometric comparisons of the three *G. cleaveri* populations were based on a series of 39 specimens from various Tasmanian localities and a series of six specimens in the collection of the Queen Victoria Museum and Art Gallery, Launceston (QVML No 1984/5/6), collected from Patriarchs Reserve, Flinders Island, grid reference FR020750. The ten specimens from Wilsons Promontory, now in the Museum of Victoria, Melbourne (MOV No A2037), were also examined.

Measurements and counts made follow Andrews (1976), except that all segmented rays, branched and unbranched, were counted in the dorsal and anal fins.

The meristic and morphometric data for the three *G. cleaveri* populations are given in tables 1 and 2. Jackson & Davies (1982) concluded that the Victorian and Tasmanian populations were conspecific, using data from Andrews (1976) for the Tasmanian *G. cleaveri.* The results of the present study confirm their findings and indicate that the Flinders Island population is also conspecific with these populations.

The meristic data indicate a slight tendency towards fewer anal and ventral rays in the Flinders Island specimens but the differences are small and the ranges of the Flinders Island and Victorian specimens are within the range of the Tasmanian specimens. The morphometric data indicates a longer and narrower caudal peduncle in the Victorian population and a tendency towards longer paired fins, shorter jaws and narrower heads. Again, however, these differences are small and the possible reasons for such variations are discussed elsewhere.

TABLE 1
Meristic variation in *G. cleaveri*

	Dorsal rays						Anal rays						Pectoral rays					Ventral rays			
	9	10	11	12	13	SD	11	12	13	14	15	SD	12	13	14	15	SD	5	6	7	SD
Tasmania	2	3	13	16	5	0.97	6	6	13	12	2	1.13	2	24	12	1	0.36	2	11	26	0.28
Flinders Is	1	2	2	1		1.25	5	1				0.37	2	4			0.30	1	5		0.12
Victoria	1	2	5	2		0.44	2	6	2			0.45		8	2		0.17		2	8	0.17

TABLE 2
Morphometric variation in *G. cleaveri**

Parameters†	Tasmania				Flinders Island				Victoria			
	Min	Mean	Max	S D	Min	Mean	Max	S D	Min	Mean	Max	S D
Head/LS	19.0	20.4	22.8	1.05	18.5	19.2	21.0	0.70	20.3	21.2	22.0	0.59
S–DO/LS	72.4	74.6	78.7	1.80	68.3	73.5	77.5	3.20	69.0	71.3	74.8	1.64
S–VO.LS	50.6	53.3	57.8	2.29	50.2	52.5	56.5	2.00	49.3	51.9	54.6	1.51
PL/PB–VO	31.5	35.6	42.0	3.25	31.0	35.4	37.6	2.20	34.3	39.1	43.4	2.77
VL/VB–AO	34.0	39.1	46.4	3.85	32.4	38.1	46.3	4.60	38.7	42.2	45.4	2.08
DCP/LCP	62.5	71.3	81.0	7.33	58.3	77.0	91.6	11.40	42.0	50.7	56.7	4.32
LCP/LS	10.8	11.9	13.4	0.85	9.9	11.2	12.3	0.80	15.7	17.1	18.3	0.89
ED/HL	8.0	11.3	14.0	1.75	11.4	12.1	12.4	0.80	10.9	13.2	15.0	1.21
UJL/HL	22.6	27.5	31.4	2.62	25.6	29.7	31.7	2.30	23.2	24.8	27.1	1.25
LJL/HL	23.1	28.3	32.0	2.74	28.1	32.6	36.5	3.10	21.9	25.0	28.4	1.95
GW/HL	28.1	35.9	42.8	3.70	35.5	39.2	44.5	2.90	27.7	32.0	39.3	4.02
IW/HL	33.9	36.7	39.1	1.70	35.5	38.1	41.3	2.10	35.8	40.2	45.1	2.97
HW/HL	48.1	61.4	68.4	6.20	59.5	66.0	74.8	4.90	52.2	58.1	65.8	5.21

* Numerator written as a percentage of the denominator
† Abbreviations used are as follows: LS standard length (snout tip to hypural joint), HL head length (snout tip to posterior edge of opercular flap), S–DO snout tip to dorsal fin origin, S–VO snout tip to ventral fin origin, PL pectoral fin length, PB–VO pectoral fin base to ventral fin origin, VL ventral fin length, VB–AO ventral fin base to anal fin origin, DCP minimum depth of caudal peduncle, LCP dorsal length of caudal peduncle, ED eye diameter, UJL upper jaw length, LJL lower jaw length, GW gape width, IW interorbital width, HW head width.

DISTRIBUTION AND ECOLOGY

The presently known distribution of *G. cleaveri* is illustrated in figure 1, which includes data from Andrews (1976), McDowall & Frankenberg (1981), Jackson & Davies (1982) and Koehn & O'Connor (1990), together with the results of the present study.

In comparison with the distributions of some of the diadromous species such as *Galaxias maculatus* and *G. truttaceus*, as recorded by McDowall & Frankenberg (1981), *G. cleaveri* is fairly restricted. However, it is far less restricted than some of the lacustrine species, such as *G. johnstoni*, which are often confined to a single body of water (Andrews 1985).

The preferred habitat of *G. cleaveri* is in low-lying coastal areas, virtually at sea level. The species appears unable to invade inland and upland waterways, and during the present study only two collection sites were recorded at any marked distance from the coast (fig. 1). These two sites, in the Derwent and Tamar estuaries, consisted of small stagnant anabranches of streams flowing into the rivers at points well within the tidal limits.

At no time during the present study were adult *G. cleaveri* either observed or collected in free-running water; the usual sites were small pools up to 2 m in diameter and 0.5 m deep.

Most of the observations on *G. cleaveri* in the field were made at Port Davey, southwestern Tasmania. The study area consisted of a flat alluvial flood plain, about 4 km south of Bathurst Harbour, grid reference DM320920 (pl. 1). The plain is sparsely vegetated with low (1 m high) shrubs and buttongrass (*Gymnoschoenus* sp.), and is drained by a number of small streams which flow north into Melaleuca Lagoon. Significant deposits of alluvial tin (cassiterite) occur in the area and these have been mined from the mid 1940s until recent years. The deposits are in the form of lens-shaped pockets of ore located 0.5–3.0 m below the surface.

The ore pockets were located by the mining leaseholder by digging rectangular test holes approximately 1.0 m square by 0.5–1.0 m deep (pl. 2). These test holes were invariably filled with ground water which was stained a dark brown with humus and formed an ideal habitat for *G. cleaveri*.

Specimens were collected from the holes by dip-netting, each hole yielding two, sometimes three or four *G. cleaveri*, usually within the standard length range 70–80 mm, but juveniles about 25–30 mm were also taken.

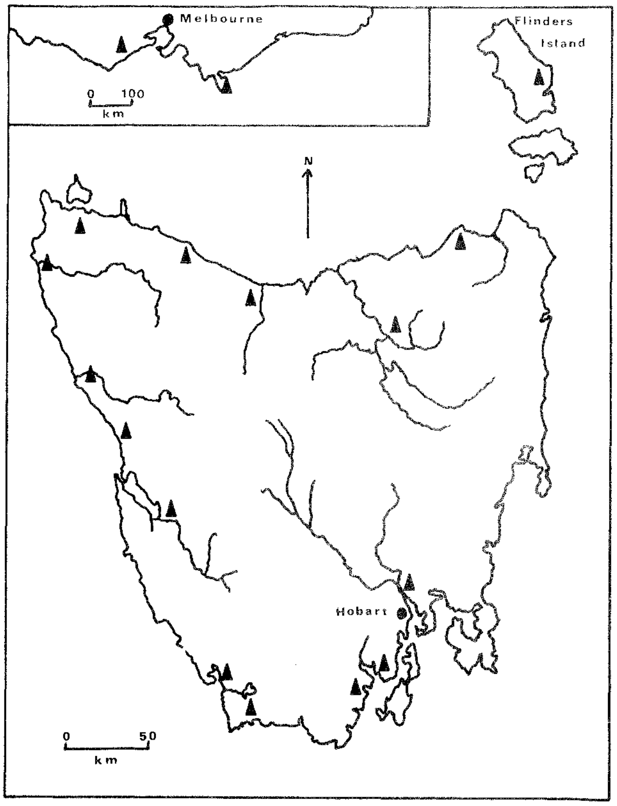

FIG. 1 — Distribution of Galaxias cleaveri *(inset: Victoria).*

PLATE 1
Typical habitat of Galaxias cleaveri, *Port Davey.*

PLATE 2
Pond containing Galaxias cleaveri, *Port Davey.*

The small surface streams which crossed the plain in places (pl. 1) were also sampled for *G. cleaveri.* None were collected but a few post-larval specimens of *G. maculatus* were occasionally found.

Two of the test holes were emptied by pumping out the water and straining the bottom sediment with a net. This consisted of a dark-brown layer of decaying plant material some 100–150 mm thick, liberally mixed with coarse quartzite sand. The water was acidic with pH values of 5.0–5.5 being recorded. Microscopic examination of the sediment revealed numerous insect remains, but these were too fragmented for species to be determined.

For comparative purposes, fish trapping was carried out in nearby Moth Creek using the methods described in Andrews (1976). Abundant adult *G. maculatus* and *G. truttaceus* were recorded but no *G. cleaveri,* despite trapping over several days.

In the Dover and Bridgewater areas, *G. cleaveri* was found in stagnant pools in non-running stream beds and roadside drainage ditches. In these localities, the water was 0.25 m or less in depth and the substrate consisted of black mud and decaying vegetable material. At one of the Dover localities the water was often covered with a metallic film, a phenomenon also recorded by Jackson and Davies (1982), who attributed it to the presence of metallic sulphides formed under anaerobic conditions.

The habitat of *G. cleaveri* on Flinders Island and southern Victoria is essentially the same as that in Tasmania. The Flinders Island specimens were taken from a drain leading to landlocked lagoons and a marsh in Patriarchs Reserve, some 2 km from the sea. On Wilsons Promontory, where the Victorian specimens were collected, the habitat was described by Jackson and Davies (1982) as a small, swampy tributary of Freshwater Creek on the southeastern side of the promontory. There was no discernable flow, the mean depth was 0.16 m and the substrate was composed of mud.

The feeding and life history of *G. cleaveri* were discussed in Andrews (1976), but it was not known if the life cycle included a marine juvenile stage. Juveniles were collected at Trial Harbour, on the west coast, from a small pond at the outfall of a stream flowing across the beach about 1.0 m from the high tide level. The pond contained black peaty sediment and water that was strongly saline to the taste. It was concluded from this that juvenile *G. cleaveri* were salt tolerant.

McDowall (1980) and McDowall & Frankenberg (1981) reported that the entire life cycle was spent in fresh water. More recently, however, Fulton (1986) identified juvenile *G. cleaveri* in runs of whitebait, *Lovettia sealii,* caught in a number of rivers around the state.

It seems likely, however, that other Tasmanian populations are confined entirely to fresh water. At Port Davey, many of the pools containing *G. cleaveri* were completely surrounded by dense grass and undergrowth, with no aquatic connections to other bodies of water. The pond shown in plate 2 is one such example, with the nearest running water some 8.0 m distant. In such cases, both juvenile and adult *G. cleaveri* were collected from the same pond.

A specimen in the Tasmanian Museum, No D1235, was one of several collected from small cavities in a 0.3 m layer of damp mud and sediment being removed from an empty farm dam at Huonville by a bulldozer. On being returned to water, all the fish began swimming normally without showing any signs of stress or dehydration. The dam was located about 0.75 km from the nearest running water.

It seems, therefore, that, in common with several other galaxiid species in Tasmania, notably *Galaxias brevipinnis*, the marine juvenile stage is facultative rather than obligatory in *G. cleaveri*.

The ability of *G. cleaveri* to survive dry periods by burrowing in damp mud has been noted by a number of authors, most recently by Fulton (1986). Hall (1901) described a fish he identified as *Galaxias* sp. being dug up at Strahan in decayed peat and sand 20 mm below the surface. From Hall's brief description it is likely that the fish was *G. cleaveri*. Scott (1934), in his original description of the species, noted that his specimen had been found in a damp hollow in a rotten log.

Unlike other members of the genus, *G. cleaveri* appears tolerant of quite wide variations in temperature. During the summer of 1978, a field trip to the Dover area yielded adult examples of both *G. cleaveri* and *G. maculatus*. The specimens were placed in a black polythene 50 litre drum, which was left open at the top. However, during the return journey the vehicle in which the fish were transported was inadvertantly left parked in direct sunlight for several hours. Although the rise in the water temperature was estimated at not more than 3-4°C at the most, it proved fatal to the *G. maculatus* but the *G. cleaveri* showed no signs of distress.

Both the Dover and Bridgewater collecting areas are subject to frost and, during severe winter conditions, the ponds from which *G. cleaveri* had been collected would occasionally ice over. By contrast, these ponds, being very shallow, can heat up quickly when exposed to direct summer sunlight. Virtually all those examined in the Dover and Bridgewater areas were devoid of any shade cover, and early afternoon water temperatures as high as 19°C were recorded during the study.

BEHAVIOUR

The only comparable studies of galaxiid fishes in aquaria appear to be those of Davidson (1951) and Eldon (1969). Davidson kept the New Zealand brown mudfish, *Neochanna apoda*, in aquaria with varied success, while Eldon maintained various New Zealand species of *Galaxias* in aquaria, including the brown mudfish. Eldon (1969) also reported on the keeping of the black mudfish, *Neochanna diversus*, in aquaria, again with varied success.

According to McDowall (1970), *G. cleaveri* and the three New Zealand species of *Neochanna* are counterparts, possibly phylogenetically related, and share similar ecological niches.

Typical members of the genus *Galaxias*, such as *G. maculatus* and *G. truttaceus*, are shoaling mid-water species. When placed in aquaria, they confined most of their activities to the middle and upper third of the water column. They rarely surfaced but often foraged on the bottom, picking up and ejecting mouthfuls of sand. When light food particles were placed on top of the water, however, the fish fed rapidly with quick darting movements, often breaking the surface.

Locomotion is by lateral oscillation of the tail and that part of the body posterior to the ventral fins. Rapid oscillation, to increase the speed, is usually done in short bursts with breaks in between, resulting in a fast darting movement. When at rest, the mid-water position is maintained by a gentle undulating movement of the vertical fins and occasional stabilising movements of the paired fins.

The shoaling behaviour of both *G. maculatus* and *G. truttaceus* became evident when two or more specimens were placed in the same aquarium. After a while, individual fish grouped closely together and moved as a co-ordinated unit. Occasionally, members of the group would separate for short periods in order to forage or carry out some activity of their own.

By contrast, *G. cleaveri* is benthic, solitary and sedentary. When first placed in the aquarium, the fish immediately swam to the bottom and remained partially, and sometimes completely buried in the sediment. If undisturbed, they remained in this position for up to 4–5 hours at a time, occasionally making short exploratory trips to other parts of the aquarium. Once acclimatised, specimens spent most of the time motionless on the bottom, often partially submerged in the sediment.

Occasionally, individuals were observed burrowing vigorously through the sediment, stirring up large quantities as though searching for food.

No difficulty was experienced with acclimatising adult *G. cleaveri* to aquarium life, and a similar situation was found by Eldon (1969) with adults of the New Zealand brown mudfish, *Neochanna apoda*.

Locomotion in *G. cleaveri* differs markedly from that in other members of the genus. When specimens on the bottom of the aquarium were suddenly disturbed, they swam rapidly and vertically to the surface, often emerging completely from the water to a height of 50–60 mm and immediately diving back to the bottom. This manoeuvre would be repeated two or three times in quick succession before the fish again buried themselves in the sediment.

This aspect of the behaviour of *G. cleaveri* could be used to advantage when collecting specimens in the field. Ponds suspected of containing *G. cleaveri* were agitated vigorously for a second or two with a pole to disturb the bottom. Simultaneously, a long-handled dip-net was swept through the water to collect the fish.

The swimming method observed in *G. cleaveri* was an undulating, eel-like motion, the undulations commencing at the head and extending over the entire length of the body. This method was used for both horizontal and vertical swimming as well as burrowing, with little, if any, use being made of the paired and vertical fins.

No evidence of shoaling or other social behaviour was observed in *G. cleaveri*. When two or more individuals were placed in the same aquarium, they remained apart and gave no indication of being aware of each other's presence. When chance meetings occurred, such as bumping into each other while foraging, they immediately resumed their former activities, apparently regarding each other with complete indifference. By contrast, Eldon (1969) found that, when two or more specimens of the New Zealand mudfish, *Neochanna apoda*, were placed in an aquarium, they spent the daylight hours under cover on the bottom, packed together in close physical contact.

Both Davidson (1951) and Eldon (1969) reported instances of aggressive behaviour in *Neochanna apoda*, but no such behaviour was observed during the present study, either between individual *G. cleaveri* or with other species.

DISCUSSION AND CONCLUSIONS

Most Australian members of the genus *Galaxias* are agile, fast-swimming fishes which typically inhabit cool, clear, well-oxygenated water. By contrast, *G. cleaveri* has adapted to an environment which virtually all other members of the genus would find intolerable. Adaptations include the ability to remain dormant for long periods and to tolerate low oxygen levels, both indicative of a very low metabolic rate and probably a fairly modest food requirement. Jackson & Davies (1982) collected *G. cleaveri* from water which they reported as having no measurable dissolved oxygen. These adaptations undoubtedly account for the ability of *G. cleaveri* to aestivate in damp mud and sediment in the absence of free water.

As noted previously, *G. cleaveri* can tolerate wide, and often sudden fluctuations in temperature that are lethal to other *Galaxias*. This ability is obviously essential for a fish which inhabits small, shallow ponds that are exposed to direct sunlight.

In comparison to the lacustrine and fluviatile *Galaxias*, the ecological niche occupied by *G. cleaveri* seems to be rather a precarious one. However, an advantage could well be that, when the ponds dry up, forcing the fish to aestivate, the refilling after rain often results in a hatching of insects and other aquatic fauna. This would provide a readily accessible food supply, completely free from competition with other fish species.

The results of the meristic and morphometric comparisons undertaken in the present study indicate that the three populations discussed are all clearly referrable to *G. cleaveri*. The small differences that exist between them are undoubtedly due to the effects of geographic and genetic isolation and, perhaps, the influence of environmental factors. These aspects of freshwater fish populations have been discussed in detail by McDowall (1972).

More detailed statistical comparison of the three populations was not made for two reasons, viz. the small size of the Flinders Island sample in comparison with the Tasmanian sample, and the fact that all six Flinders Island specimens were large, gravid females with distorted body shapes which would have made such comparisons meaningless.

With the extension of the known range of *G. cleaveri* to Flinders Island and Victoria, the distribution now resembles that of another galaxiid species, *Galaxiella pusilla* (Mack) (Andrews 1976, McDowall & Frankenberg 1981).

However, whereas *G. cleaveri* is quite widespread in Tasmania, *Galaxiella pusilla* is restricted to a few areas in the northeast of the state.

Although in separate genera, these two species share somewhat similar ecological niches. Both are sedentary, limited in range and confined to low-lying coastal areas. Both species also favour small, stagnant water bodies, *Galaxiella pusilla* thriving in those with weed growth and algae.

Andrews (1976) explained the distribution of *Galaxiella pusilla* by the hypothesis that the species may have been distributed widely over southeastern Australian coastal areas but that the three present populations became isolated by the formation of Bass Strait some 8000–10 000 years ago, at the end of the Quaternary Period.

The results of the present study lead to the suggestion that the distribution of *G. cleaveri* can also be explained by the same hypothesis.

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