Behavioural repertoire of *Carlia rostralis* (Scincidae) in the Wet Tropics of Queensland, Australia

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ABSTRACT

The behavioural repertoire of the diurnal rainbow skink *(Carlia rostralis),* a common species found along eastern creeks in the Wet Tropics of northern Queensland, was documented as part of a larger study of the animal's reproductive biology. Focal observations of assertive, exploratory, maintenance, escape, aggressive, and courtship behaviour were made in the field during the early part of the breeding season and in the laboratory with males and females in staged encounters. Although much of the behavioural repertoire of this species is typical of diurnal lizards, several features of the behaviour of *C. rostralis* are notable. Female *C. rostralis* exhibit a high frequency of head bobbing and conspicuous perching, two assertive behaviours that appear to be related to their maintenance of female-exclusive home ranges during the breeding season. Another assertive display, the head raised posture, is exhibited by both males and females in encounters. The head raised posture prominently displays the sexually dimorphic gular colouration of adult *C. rostralis* and is used as a visual sexual recognition signal. In addition, copulatory postures in which the male grasps the female with a lateral mid-flank bite, are described and depicted, with this representing the first portrayal of these postures for any member of the genus *Carlia.* Overall the complexity of social and sexual behaviour exhibited by *C. rostralis* is greater than that previously attributed to scincid lizards which have been studied elsewhere. These observations suggest that more attention to comparative behavioural study of Australian scincid lizards would be productive.

INTRODUCTION

Although the Australian reptilian fauna is large and diverse, little is known of the behaviour or natural history of the majority of species. Most of what is known of lizard behaviour has come from the study of New World iguanids and teiids and Old World agamids (Carpenter and Ferguson 1977; Stamps 1977, 1983). A few behavioural studies of scincid lizards have focused on chemosensory behaviour in secretive fossorial New World species (Mount 1963; Vitt and Cooper 1985; Cooper and Vitt 1987a, 1987b, 1988). In Australia, the family Scincidae has undergone extensive radiation, with members of this family occupying ecological niches typical of those filled by iguanids and teiids elsewhere.

In this study the behavioural patterns of the rainbow skink *Carlia rostralis*, an oviparous, diurnally active scincid, are described. Aspects of social behaviour and dominance of *C. rostralis* have been detailed in a related laboratory study (Whittier and Martin 1992). Male *C. rostralis* form linear dominance hierarchies with the most dominant individuals having the greatest body size (snout-vent length; Whittier and Martin 1992). Limited data on interactions between males in the field suggest that in areas of high population densities, such as those found along creeks in northeastern Queensland, social hierarchies similar to those shown in the laboratory are established in the field (J. M. Whittier, unpubl. obs.). Males and females of this species exhibit a high degree of sexual dimorphism in both size (males attain a larger body length and mass) and in colouration (Whittier 1993).

The genus *Carlia* comprises a total of 20+ recognized species endemic to Australia, Papua New Guinea, and nearby islands (Ingram and Covacevich 1989). Although the behaviour of this genus has never been systematically studied, the thermal ecology and reproductive biology of a few species have been investigated. Wilhoft (1961, 1963a, 1963b) and Wilhoft and Reiter (1965) concluded that *C. rhomboidalis* and *C. schmeltzii* reproduced during the summer wet season in northeastern Queensland (reported as *Leiolopisma rhomboidalis* and *L. fusca*; current identification verified by examination of specimens, MVZ 77687–93 and MVZ 77702–12, collected by Wilhoft and held in the Los Angeles County Museum, California, by J. Whittier). Similar associations between reproduction and the onset of the wet season have been observed in *Carlia* in the Alligator River region of the Northern Territory of Australia, and in eastern Papua New Guinea (James and Shine 1985; Zug 1982). However, recent investigation of the reproductive cycle of *C. rostralis* in the Wet Tropics of Queensland suggest that although egg-laying normally occurs at the time of the wet season, it is not dependent on seasonal rainfall (Whittier 1993).

Breeding in this species commences in November and continues until February even in years of drought when no wet season occurs. This study was conducted both in the field in the Wet Tropics of North Queensland and with captive specimens in the laboratory, as part of a larger study of the reproductive biology of *C. rostralis*.

METHODS

Field Sites

C. rostralis were observed at two field sites. One site was located along a permanent water course, Waterfall Creek, (18°55′S, 146°10′E, Ingham State Forestry District, Waterview Shire, Queensland) draining east to the Coral Sea from the Great Dividing Range. A second field site was located along Murray Falls Creek (Murray Falls State Park, north-west of Tully, Queensland). Both sites, included in the World Heritage Wet Tropics Management Area, were characterized by riparian vine thicket vegetation present at low elevations. This rainforest-like vegetation extended approximately 100 m to either side of the creek and was surrounded by open wet sclerophyll forest. During the behavioural portion of the study, November and December of 1988, the wet season commenced in December and females were laying the first clutch of the year (Whittier 1993).

Field Observations

Focal, one hour observation periods (for a total of 73 hr) were made over 14 days of an area of 50 m^2. Animals were hand captured using flies as lures. A total of 43 animals (21 males and 22 females) were captured, marked by toe clipping and painted with a small dot of nail polish to allow identification at a distance. Captured individuals were weighed (±0.2 g) and measured (±0.5 mm) snout to vent. Individuals appeared to rapidly habituate to capture, handling and observation.

Laboratory Study

In July 1990, 11 adult male and female *Carlia rostralis* were collected in the field at Waterfall Creek for establishment of a laboratory colony. Animal housing and maintenance has been detailed in Whittier and Martin (1992). The animals were housed for nine months under these conditions, and were quite healthy during the entire period.

Laboratory Observations

The behavioural interactions of four females, randomly paired with one of seven males, was studied using focal 30-min or 15-min observation periods. Each pairing was considered an encounter. Encounters in which intense fighting occurred were terminated before the observation period was over to avoid injury to the lizards; the duration of the actual encounter was noted. Encounters were conducted in the female's home cage. A total of 20 encounters were observed for 8.58 hr. All observations were made between 0900 and 1300 hours over a five day period. Ten encounters were conducted in August 1990, shortly after arrival in the laboratory, and 10 encounters were conducted in December 1990, at the beginning of the breeding phase in the laboratory colony.

Behavioural Assessment

Behavioural patterns were assessed both in the field and in the laboratory using similar methods, although few interactions were observed in the field. Behaviour was documented and categorized as outlined in previous behavioural studies of this species (Whittier and Martin 1992). Associated behavioural acts were grouped according to terminology defined in Carpenter and Ferguson (1977). Totals of the number of behavioural acts were tallied and are presented in graphical form for males and females in the field and in laboratory encounters.

RESULTS AND DISCUSSION

Both male and female *Carlia rostralis* exhibited behaviour that in lizards is associated with territorial behaviour, although sex differences in behaviour were noted in both the field and in laboratory encounters (Figure 1A and B, respectively). In the field, resident males spent more time patrolling whereas females spent time perching conspicuously and head bobbing with no apparent individual target present. These behaviours exhibited by females are considered assertion displays (Carpenter and Ferguson 1977); few assertion displays were enacted by males. In the field and the laboratory males and females exhibited assertive, exploratory, maintenance, escape, aggressive, courtship, and a few undefined behavioural displays in specific interactions with other individuals of both sexes (Table 1).

Animals were frequently involved in active feeding and exploratory behaviour interspersed with resting and basking behaviour or periods of inactivity where retreats were sought. Tail wiggling, a behaviour observed in several contexts, was seen during feeding and in encounters. Perching, patrolling and resting behaviour occurred in non-exclusive contexts

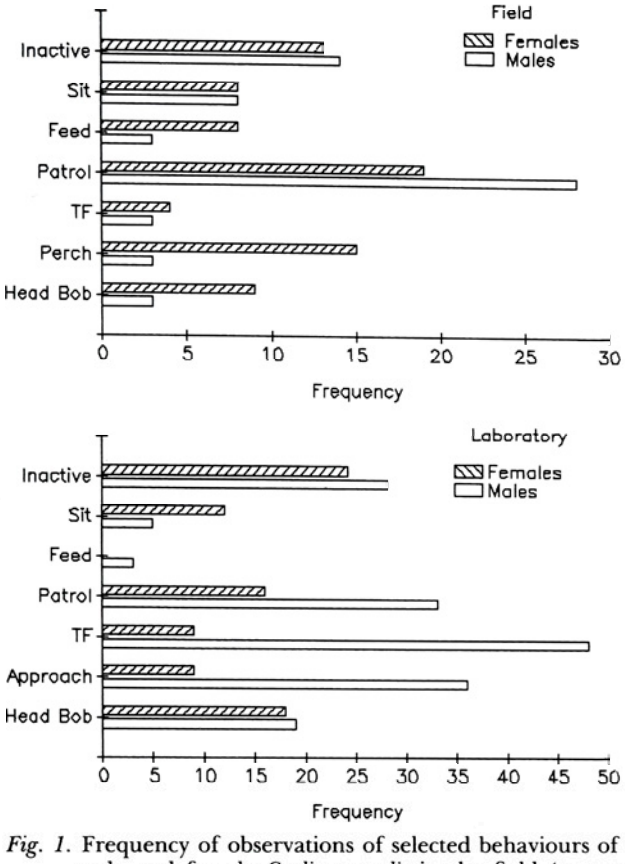

Fig. 1. Frequency of observations of selected behaviours of male and female *Carlia rostralis* in the field (upper panel) and in the laboratory (lower panel). Females exhibit a large amount of assertive behaviours, particularly when they occupy female-exclusive home ranges in the field. Note differences in scale and behaviours in field and laboratory studies.

associated with active foraging, sit and wait foraging and basking as well as in social contexts described above. Arm waving, in which either arm is lifted from the substrate and moved in a dorsoventral plane, occurred infrequently and the context of this behaviour was not determined. Arm waving is usually attributed as a submissive or dominant behavioural sign to conspecifics (Carpenter and Ferguson 1977).

In the field, intraspecific encounters during the 14 days of observations in the early portion of the breeding season (Whittier 1993) occurred between males and females (5 incidents) and between two males (5 incidents), but interactions between two females were never observed. This is most likely due to the maintenance of female exclusive home ranges by females at the time of year observed, while the males overlap extensively with both other males and several females (Whittier 1991). Female encounters may occur at other times of year, perhaps just prior to the beginning of the breeding season when female home ranges are expanded (J. M. Whittier, unpubl. obs.). Many of these encounters involved repeated observations of interactions between the same individuals, as *C. rostralis* have high site fidelity in the field.

Table 1. Behavioural repertoire of *Carlia rostralis* compiled from field and laboratory observations.

Behaviour	Incidence Female	Male
Assertive behaviour		
Head bobbing	X	X
Head raise	X	X
Perching conspicuously	X	X
Crouch/Body flattening	X	X
Exploratory behaviour		
Tongue flick/trailing	X	X
Patrolling	X	X
Maintenance behaviour		
No activity	X	X
Resting	X	X
Basking	X	X
Feeding	X	X
Drinking	X	X
Jaw wipe	X	—
Chin rub	X	—
Digging	X	X
Defecate	X	X
Escape behaviour		
Escape	X	X
Hiding	X	—
Aggressive behaviour		
Approach (same or opposite sex)	X	X
Jump	X	X
Circle	X	X
Lunge	X	X
Chase	X	X
Body tilt/Lateral present	X	X
Bite	—	X
Courtship behaviour		
Approach (opposite sex)	X	X
Jerky move (courtship)	—	X
Throat extension	X	X
Flank bite	—	X
Copulation	X	X
Undefined behaviour		
Arm wave (dominance/submissiveness?)	X	X
Tail wiggle (alert?)	X	X
Cloacal rub (scent marking?)	—	X

In nearly every intraspecific encounter in the field and the laboratory, both male and female *C. rostralis* exhibited a characteristic head raised posture (Fig. 2). In this posture the head is elevated from 30–45 degrees above the substrate, the forelimbs are extended and the conspicuous gular colouration is displayed. In adult males, the gular colouration is jet black, whereas in all females and most immature males, the gular colouration is white to grey. Individuals of either sex immediately exhibited the head raised posture when another individual (male or female) was perceived in the visual field. Both individuals in an encounter displayed the head raised posture as soon as they appeared to be aware of a conspecific's presence. No pattern of sex, residency, or dominance was noted in the initiation of the display by either of the two individuals involved in an encounter. The head raised posture appears to be one of the most important

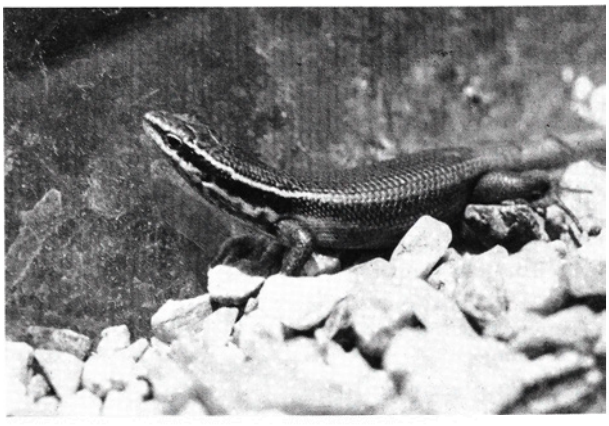

Fig. 2. An assertive, age and sex recognition posture, head up, is expressed commonly by both male and female *Carlia rostralis* (male illustrated) during the initial portion of intraspecific encounters. The head is elevated 30–45 degrees above the substrate and forelimbs are extended, exposing the throat coloration that is sexually dimorphic in adults.

initial signals of age, sex and reproductive status and provides a distinctive visual cue that can be assessed by individuals at a distance. Tongue flicking of females by males also appears to be an important signal that is used at a closer range for assessment of the sex of conspecifics. Tongue flicking enables the males to distinguish between females and juvenile males (J. M. Whittier, unpubl. obs.). Therefore both visual and chemosensory cues appear to be important in sexual recognition in this species.

Male-female interactions that did not result in copulation included several types. When no courtship behaviour was expressed by the male, the male would not approach the female following an exchange of the head raised posture. In these instances the males would either randomly move about the cage, while the female remained still, or hid from the male in a plant in the cage or, in the field under a leaf or substrate. In these instances in the laboratory the male would often eat whatever food was available and then both lizards would remain inactive for the remainder of the observation period.

When courtship behaviour was expressed by the male in an encounter with a female, three outcomes were observed. These included 1) courtship followed by rejection of the female, 2) courtship followed by no copulation, but no obvious rejection by the female, and 3) courtship followed by copulation. Courtship behaviour of the male in all three types of encounters was not distinguishably different: after an initial exchange of the head raised posture the male approached the female, or the female approached the male, and head bobbing, alert postures, tongue flicking of substrate, and other non-aggressive behaviours ensued. In some encounters the male also adopted a flattened posture or crouch as a closer approach to the female was attempted, possibly indicating a submissive display. Jerky movement of the male, in which movements became exaggerated and highly stereotyped as the male approached the female, was clearly associated with courtship behaviour. Jerky movement always preceded the attainment of a copulatory flank bite when copulation occurred; thus it is a consumatory stage in courtship behaviour. However, jerky movement was also observed commonly in encounters in which copulation was not the outcome. Female rejection behaviour included obvious escape and hiding behaviour where the female concealed herself in a plant or under a leaf on approach of the male. Females on occasion were observed to wiggle their tail during courtship, a behaviour that occurs in several contexts associated with heightened alertness.

In a few laboratory encounters, females exhibited aggressive behaviours directed at the males. Some of these behaviours have not been observed to be exhibited by females in the field. Females in two laboratory encounters exhibited aggressive behaviour, behaviour that previously had only been observed to be enacted by males (Whittier and Martin 1992). This included chasing, lunging, body tilting and lateral presenting (Fig. 3). Although these behaviours have not been seen in females in the field, it is of interest that females have the potential to express these behaviours when encountered by males in a confined situation.

Fig. 3. Aggressive posture defined as lateral present and body tilt, expressed in paired encounters of *Carlia rostralis*. Usually exhibited by males, individuals laterally present and dorsoventrally compress their bodies while tilting to the side facing the challenger. The bright orange sides of the males are conspicuous in this posture. Lateral present and body tilt may be the primary posture in which male snout-vent length, a strong correlate of dominance, is assessed.

Fig. 4. Copulatory posture in *Carlia rostralis*. In this photograph taken in the laboratory, the male has grasped the female's left side with a secure flank bite while he intromits his right hemipenis. Both of the right limbs of the male rest on and hold the female. The female rests with her tail lifted and is quiescent during intromission.

A total of four copulations was observed in the laboratory and one copulation was observed in the field. The copulatory postures observed in the laboratory (Fig. 4, where the male initiated a flank bite on the left side and intromits with his right hemipenis) were similar to that observed in the field. Males can approach and obtain a flank bite from either side of the female, and use either hemipenis. In the field, copulation took place under a clump of grass on a high sloping bank. After the initiation of a flank bite by the male, which in this instance was on the right mid-lateral portion of the female, the male pushed the female sideways several centimetres. The male intromitted the left hemipenis, approaching from the right side of the female, continuing to hold the female with a bite grip on her right side. The male's left rear leg encircled the female at the base of her tail. The female remained motionless for the 3–5 min. duration of copulation. The male had repeated whole body spasms with a frequency of 1/sec, then 1–4/sec during the last 30 sec of intromission. The male's hemipenis was retracted at the end of copulation. In several laboratory copulations, it was noted that the male's hemipenis remained everted for up to one minute while it was dragged along substrate in the cage. Both the right and left hemipenis may be used on different occasions by the same male.

Male–male interactions were observed only in the field; descriptions of male–male interactions in the laboratory have been detailed elsewhere (Whittier and Martin 1992). Male–male interactions involved chases, fights and displacement behaviour associated with territorial defence. These behaviours were exhibited by the resident males and were directed against other males wandering into the resident male's home range area.

The lateral presenting and body tilting posture (Fig. 3) is an important visual signal used by male *C. rostralis* in dominance/subordinance interactions. The posture was exhibited only by males during aggressive encounters in the field. The occurrence of lateral presenting and body tilting behaviour is much less commonly observed in the field than it is seen in staged laboratory encounters with males (Whittier and Martin 1992). In the lateral presenting and body tilting posture, males exaggerate their body size and profile and expose their bright orange lateral colouration. This may be used by males to assess the body length (or size) of a contesting individual. Both lateral presenting and tilting postures have been described as components of aggressive behaviour in other male skinks, but not in combination (Mount 1963; Cooper and Vitt 1988). In addition, orange colouration is an important aggressive signal in other skinks (Fitch 1954; Cooper and Vitt 1988). As mentioned above, these behaviours are characteristic of males, but in highly charged aggressive encounters in the laboratory they are also exhibited by female *C. rostralis*.

Maintenance behaviour such as feeding and drinking was observed in both the laboratory and the field. Males and females were observed to feed in close proximity of one another in the field. In addition, several incidences of "pirating" of insect prey from green ants were observed in the field. *C. rostralis* appeared to be visually stimulated by swarming green ants. On these occasions the lizards seized the insects from the ants and shook the prey to remove the ants, which were not consumed. Drinking behaviour also was observed regularly in the field. The lizards moved along regularly used pathways to gain access to pools of water which in some cases were up to 10 m away from the usual home range area.

These behavioural observations of *C. rostralis* suggest that this species exhibits a wide range of social and interactive behaviours commonly observed in other species of lizards. However, males and females overlap extensively in the expression of many behaviours and females of this species exhibit a high degree of assertive and aggressive behaviour compared to other lizards elsewhere. The expression of these behaviours by female *C. rostralis* are most likely related to the social and spatial organization of the species, in which females occupy female-exclusive home ranges while males overlap

extensively with females and other males (Whittier 1991). Moreover, high levels of circulating testosterone in females correlate with the expression of what would be traditionally regarded as male-like assertive and aggressive behaviour in lizards (Whittier 1991). However, whether elevated levels of testosterone in females increases the incidence of male-like behaviours in *C. rostralis* remains to be determined.

In contrast to the female behavioural organization, social interactions between males take the form of linear dominance hierarchies based primarily on body size (Whittier and Martin 1992). In the field males appear to recognize conspecific males individually and to defer to larger, socially dominant males with little conflict. Few assertive and aggressive behaviours are exhibited by males in the field.

The study of behaviour in *C. rostralis* has revealed a complexity previously undocumented for scincid lizards. There are many opportunities for future studies of basic behaviour and social structure in the genus *Carlia*, as well as in other Australian scincids. Comparative work of this nature would be of great value in contributing to our understanding of the evolution of sexual and social behaviours in this diverse and unique fauna.

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