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# Notes on Stephen's Banded Snake *Hoplocephalus stephensii* Krefft, 1869

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## ABSTRACT

Observations on the habitat, behaviour, prey, mating and subsequent birth of young in *Hoplocephalus stephensii* in the Sydney Basin is presented. A record of envenomation from this species is also reported. We compare our observations with the published data on the genus, with particular reference to that of Shine (1983a).

## FIELD OBSERVATIONS

Two adult *Hoplocephalus stephensii* were observed at 1200 hrs on 31 October outside a large crevice at the top of an extensive sandstone outcrop 5.3 km NNW of Ourimbah, New South Wales (Lat. 33° 19' S. X Long. 151° 21' E., GR: 459124 on Gosford 1:100 000 map). The weather was fine and sunny, approximately 25°C, with a slight south-easterly breeze and about 15% cloud cover.

This outcrop formed a distinctive knoll on the hill (altitude 200 m), in an area of tall open-forest (wet sclerophyll - Type 3 *Eucalyptus pilularis* alliance in Specht, Roe, and Boughton, 1974). The habitat was mainly composed of Blackbutt (*E. pilularis*), but also included a few scattered Casuarinas, with a ground cover of bracken fern. The forest had been selectively logged in the past and much of the surrounding tree growth represented an even-age regenerating stand; many of the old stumps in the vicinity were partly charred from previous fire also.

The outcrop also had evidence of past aboriginal occupation. A small gallery of stenciled hand prints of white ochre were present on the ceiling of a cave-like overhang, and a few metres away several grinding pot-holes were present in the surface of a boulder.

The rock crevice where the snakes were found was in full sunlight on the western aspect of the outcrop and both were partly obscured among Hare's Foot Fern (*Davilla pixidata*) growing at the entrance of the crevice. When disturbed, the snakes attempted to retreat into the crevice.

It was not until the snakes were captured, that it was noticed they were in the act of mating. During *coitus* it appeared that the female had been fully exposed in direct sunlight, whilst the male had remained partly within the crevice.

Interestingly, the female appeared to be already in an advanced gravid state when found.

Soon after the above discovery (at 1600 hrs) and only some 4 metres down the hillslope, and about 4.5 metres to the NNW of the mating pair, another adult male (with a truncated tail) was discovered basking in filtered sunlight between two large rocks also on the western aspect of the outcrop. The snake made no attempt to move until touched.

The temperature was slightly higher at ca 27°C, and cloudier (ca 20% cover); the breeze had slightly increased also (SE/SSE).

Other species of reptiles found during the afternoon, in the immediate vicinity of the *H. stephensii* were: *Lampropholis guichenoti* (cf) *lunneyi*, *Lampropholis delicata* (cf) *longleyi*, *Rankinia diemensis boylani*, *Amphibolurus muricatus*, *Amalosia lesueurii*, *Demansia psammophis*, and *Cryptophis nigrescens*.

The area was again visited on 4 March and a hatchling *Rankinia diemensis boylani*, several hatchling *Lampropholis delicata* (cf) *longleyi*, several mature *Lampropholis guichenoti* (cf) *lunneyi*, an adult *Amalosia lesueurii* and a juvenile *Cryptophis nigrescens* were observed. A search of a nearby outcrop, revealed an additional species, *Phyllurus platurus* (adult), beneath a sandstone exfoliation on the western aspect.

Other published records on the regions' herpetofauna, are those of Wells (1988 *et seq.*) who reported his field observations in the Ourimbah State Forest region as a series of brief notes. No *Hoplocephalus stephensii* were reported by Wells, but his studies were concentrated in the drier western and northern sections of the forest where commercial logging operations were carried out during the 1960's.

The discovery of three mature specimens in such close proximity to one another seems unusual. That two were in the act of copulation when found and that the second male later copulated with the female in captivity would appear to suggest that breeding was the common purpose. However, their occupation of the rock outcropping could be quite usual, as other specimens of *H. stephensii* have been noted in this area previously.

The utilisation of rock outcrops by *Hoplocephalus stephensii* might be confined to the deeper boulder-crevices rather than the smaller exfoliations. This would account for the apparent failure of herpetologists to find them in outcrops as collectors tend to lift exfoliated rocks, rather than search deeper crevices by torchlight. This species has excellent eyesight, so basking specimens could easily slip into a crevice as an observer approached, and thus remain unnoticed in the area. Perhaps field naturalists should search for this species during the late Spring-early Summer, and either use torchlight to search deep crevices during the day, or examine suitable rock outcrops during the evenings.

Should more rigorous searching of outcrops reveal this species, it could have implications for conservation. It is interesting to note that the area where these specimens were found had been logged several years ago. The habitat represented for the most part an even-aged stand of regenerated tall open wet sclerophyll forest, although some quite old trees had been left in the vicinity of the outcrop. With this in mind, Mirtschin and Davis (1983) comment that this species' protection is linked to the conservation of rainforest might not be entirely correct. During the logging of this species' habitat, protection of rock outcrops by creating buffer zones around them (as along streams) could be necessary, for such outcrops would have obvious refuge value for reptiles. Unfortunately, this particular outcrop has been very badly vandalised by the past removal of rock exfoliations by "landscapers".

In the Sydney Basin, *Hoplocephalus stephensii* is only known from isolated remnants of Wet Sclerophyll forest on the central coast (Wells, in press).

### LABORATORY OBSERVATIONS

Observations were made on the three specimens under the following captive conditions: Initially all were housed together in a heated enclosure 900 X 450 X 450 mm. Light and heat were provided by a Grolux tube and 60 W. incandescent bulb. The floor-covering was newspaper. A hide-box measuring 300 X 300 X 25 mm was also included. Soon after, the conditions of the enclosure were altered by adding a substrate of pebbles, sand and leaf-litter, the hide-box was replaced with a sandstone exfoliation and slabs of pine bark; a branch was also added for climbing purposes.

All were secretive in habit, but both males became very aggressive if disturbed. The female however was quite placid, even when disturbed (prior to 7 December) during routine cage maintenance.

When all three occupied the same enclosure, specimens would utilise separate retreats. The female would shelter beneath a slab of rock at the rear of the enclosure, and would bask atop this rock also. It would tend to allow only minimum exposure of its body at the edge of the rock-slab during basking, so that it could quickly slip off the edge, then retreat into the rock crevice if disturbed. The males used bark at the other end of the enclosure, and were often noticed sheltering under the same piece of bark.

The temperature range (recorded by thermometers on the substrate of the enclosure) was usually 22°C to 26°C, but when the temperature exceeded 26°C it resulted in the snakes retreating under cover for long periods.

#### ***Thermoregulatory Behaviour***

The snakes would tend to actively thermoregulate from early morning, to about 1000 hrs. From around midday, through the afternoon, they would either remain under cover, or intermittently bask. The female basked beneath the heat globe daily for up to 7-8 hrs., positioning the body with the rear closest to the heat source. After about 7 December, a slight disturbance (e.g. someone walking into the room), would immediately cause the female to retreat under cover, but it would return to bask under the globe within 20-30 minutes. The female normally used the same position in the enclosure each day (probably because of the position of the radiated heat source), whereas both males tended to utilise various positions during their activity periods.

On 22 December, the males were removed to separate enclosures with each having similar conditions to that of the female's enclosure.

#### ***Feeding Behaviour***

All specimens were observed feeding by using "active foraging" as well as "sit-and-wait" strategies. But "sit-and-wait" predation would take place from secluded positions such as under rock or bark. When prey was visually located, the snake would erupt from concealment and directly seize it (mice were usually seized on the head). None of the snakes were observed to practice "snap-release" prey seizure and although full constriction was not observed, some degree of prey immobilisation took place, by the snake forcing the "prey" (mice) against a rock with its body while it seized the animal in its jaws.

The female fed initially in captivity (up to 19 December), but thereafter refused to eat right up to the birth of young several weeks later on 6 February. At the time of writing (2 March) the female had not resumed feeding. It was obvious from the speed and co-ordination exhibited during feeding that this species has excellent eyesight.

Feeding episodes are presented in Table 1.

**Table 1** - Feeding Episodes in captive *H. stephensii*. Male #2 was observed copulating with the female in the wild. Note: m = mouse, *Mus musculus*, g = gecko, *Amalosa lesueurii*.

DATE	FEMALE	MALE#1	MALE#2
2 November	-	-	1 m
7 November	1 g	-	2 m
8 November	1 m	-	1 m
16 November	-	-	1 m
17 November	-	-	1 m
20 November	2 m	-	-
22 November	-	1 m	2 m
24 November	3 m	1 m	2 m
2 December	2 m	-	-
4 December	-	1 m	1 m
6 December	1 m	1 m	2 m
9 December	1 m	-	-
10 December	1 m	1 m	1 m
14 December	2 m	-	-
16 December	-	2 m	1 m
19 December	1 m	-	-
23 December	-	1 m	-
25 December	-	1 m	-
26 December	-	2 m	4 m
29 December	-	-	1 m
30 December	-	1 m	-
31 December	-	1 m	-
2 January	-	1 m	-
4 January	-	1 m	-
5 January	-	1 m	2 m
6 January	-	2 m	1 m
15 January	-	-	2 m
18 January	-	1 m	-
23 January	-	-	2 m
29 January	-	-	1 m
2 February	-	-	1 m
5 February	-	-	1 m

### **Reproductive Behaviour**

**Copulation** - Mating behaviour was observed to continue sporadically in captivity for some 6<sup>1</sup>/<sub>2</sub> weeks, even though the female was obviously in a gravid state. Both males were observed to copulate with the female. The original male from the wild mating continued sporadic copulation with the female up to about 24 November, but a "divorce" apparently occurred on this date, and the other male then continued mating up to 9 December.

Mating occurred mostly in the open. Prior to *coitus* the interested male would appear agitated, pursuing the female around the cage and attempting to align his body with hers. At various times the male would be observed moving his head back and forth along the female's back. Frantic tail-twitching often accompanied this, and this latter behaviour was sometimes practiced by the female. In *coitus* both snakes would lie in loose coils near a heating lamp with the male cloaca beneath that of the female, and with the tails entwined. During *coitus* the male would slowly move his body across that of the female. The male would normally lie with his head alongside or above that of the female. Times (durations) of observed captive matings are presented in Table 2.

Table 2 - Observed captive matings in *Hoplocephalus stephensii*

Time	Date	Male
0750-0930 hrs	20 November	(with original Male)
1700-1815 hrs	20 November	(with original Male)
2110-2345 hrs	20 November	(with original Male)
0655-0720 hrs	22 November	(with original Male)
0710-0855 hrs	22 November	(with original Male)
0850-1030 hrs	23 November	(with original Male)
0800-0950 hrs	24 November	(with second Male)
1820-1930 hrs	24 November	(with original Male)
0530-0645 hrs	25 November	(with second Male)
0630-0905 hrs	3 December	(with second Male)
0815-0830 hrs	7 December	(with second Male)
0725-0800 hrs	9 December	(with second Male)

Owing to this species highly nervous disposition, it was considered necessary to reduce observer-disturbance to a minimum during the initial period of confinement. Therefore, it was not possible to observe any mating behaviour prior to 20 November. The above times of matings are observed times only. Specimens had already begun copulation when recording started, so these times must be considered as minimum periods. The termination time is that time when mating was actually observed to cease. The intervening periods were not monitored as the observer had to go to work, so matings might have conceivably continued throughout the day, and with either male.

#### Birth of Young

On 6 February, some 98 days after collection, a total of 9 young were born between 1200 and 1400 hrs. The female measured (mm) SVL 773.0 and VTL 121.0. One of the neonates was still-born, being only days from full-term, but the other 8 were born alive. Prior to giving birth, the female had been placed in an enclosure with only paper on the floor. After giving birth the female was observed "nosing" the young around the enclosure, and in the days following birth all the young remained coiled with the female in seclusion. From the instant of birth and subsequently, all the young were highly defensive when disturbed by the observer's presence. All would raise the head, open the mouth threateningly, and then rapidly move towards the observer. The colouration and patterning of the juveniles was most similar to the dorsal and lateral areas of juvenile *Vermicella annulata*, with their distinctive black and white banded appearance. The juveniles were observed to essentially confine their activity to the evening (between about 2000 and 2300 hrs). All neonates fed on juvenile to sub-adult *Lampropholis guichenoti lunneyi* within 3 weeks of birth. Measurements of the neonates are presented in Table 3. Measurements of the young and the female were delayed (recorded on 15 February) to prevent unnecessary disturbance of the snakes.

Table 3 - Measurements (mm) of neonatal *Hoplocephalus stephensii*.

No.	Snout-vent length	Vent-tail length	Total Length
1	210.0	30.0	240.0
2	206.0	41.0	247.0
3	206.0	37.0	243.0
4	207.0	33.0	240.0
5	203.0	34.0	237.0
6	203.0	35.0	238.0
7	204.0	38.0	242.0
8	200.0	32.0	232.0
$\bar{X}$	204.9	35.0	239.9

### ***Venom Toxicity and Record of Envenomation***

There are no definitive reports on the effects of a bite from this species, but venom toxicity has been reported in several publications (eg Kellaway, 1934; Broad, Sutherland and Coulter, 1979; Sutherland, 1983; Mirtschin and Davis, 1983). The venom has been reported to be neurotoxic, containing a powerful coagulant factor and is weakly haemolytic.

Shine (1983a) stated that *Hoplocephalus* species have highly toxic venoms "but the bites are not usually fatal". We are unaware of any conclusive evidence that a bite from any of these species has resulted in a fatality, but the following record of a bite from *H. stephensii* may be of interest.

As the adult female *H. stephensii* was being measured on 15 February, it bit a male herpetologist (age 36 years) on the finger at 1115 hrs. Blood flowed quite readily from the fang punctures immediately, and a makeshift constrictive bandage was applied within 5 minutes of receiving the bite, by wrapping tea-towels tightly along the affected hand and arm.

Localised discolouration and swelling soon occurred and the patient quickly became flushed and hot in appearance. Headache and nausea along with intense localised pain developed between 1120-1125 hrs. By 1125 hrs he had become weak and unsteady on his feet, including a feeling of overall tiredness; the enlargement of lymph nodes was already apparent.

At 1150 hrs. blood pressure was 142/70, and Pulse 100 pm.

At 1203 hrs an intravenous line was applied (Hartman's Solution).

At 1208 hrs. blood pressure was 193/83 and pulse 76 pm.

Transferred to major Hospital that had Intensive Care facilities at ca. 1215 hrs.

During transfer the pain became so intense that the patient had to be given oxygen in the ambulance, then Morphine on his arrival at the Casualty Ward of the regional hospital.

Arrived at Casualty Section of hospital at ca 1230 Hrs.

At 1304 hrs. the patient developed an apparent reaction to the Morphine, with an intense bodily itch, but this cleared in approximately 2 minutes, following the intravenous injection of 25 ml Phenergan.

At about 1320 hrs the constrictive bandaging was removed (duration ca. 2 hrs).

Transferred from Casualty Ward to Intensive Care at ca 1430 hrs.

At 1630 hrs. the blood pressure was 138/75 and the pulse rate 77 pm.

Released from Hospital during the evening of 16 February. Antivenom was not used in this case.

For days after release from hospital he was weak, and had a slightly discoloured complexion. The bitten area remained discoloured, as did the forearm, with a sickly yellow for several days following the bite. Minor superficial skin loss occurred at the bite site after several days.

After 2 weeks the patient had recovered sufficiently enough to return to a regular work schedule. The role of the constrictive bandage (duration of application) in the degree of pain experienced must also be considered.

The rapid onset of symptoms could indicate that *Hoplocephalus stephensii* venom may have a powerful Hyaluronidase activity. Hyaluronic acid is a ubiquitous mucopolysaccharide which functions as a jellylike sticky cell surface coat, serving to cement cells together. Hyaluronic acid also forms a large part of the extracellular ground substance of connective tissue in vertebrates; hyaluronic acid is highly soluble in water in which it forms a very viscous solution. Hyaluronidase catalyzes the hydrolysis of hyaluronic acid, resulting in a decrease in viscosity. This presumably would accelerate the penetration of other venom components by loosening the intercell cement and connective tissue, thus enabling the venom to affect more cells.

It is hoped that the Commonwealth Serum Laboratories may formally report on this bite in the medical literature, and so we have made our general observations available to them for use.

## DISCUSSION

Until recently, it was widely held that the genus *Hoplocephalus* comprised only three species, *H. bitorquatus*, *H. bungaroides* and *H. stephensii*. In 1985 however, Wells and Wellington added a fourth species, *Hoplocephalus revelatus* (De Vis, 1911). They referred the population of "*H. bitorquatus*" on the Atherton Tableland of north-east Queensland to another, previously unjustifiably synonymised species (*H. revelatus*) that was readily identified with its 19 mid-body scale rows (instead of 21 as in *H. bitorquatus*).

It is also possible that two separate forms of *H. stephensii* exist, one being the northern (SE Qld) unbanded population, and the other being the nominate (banded) form (Gosford to SE Qld).

The taxonomic status of *H. bungaroides* has remained stable.

The reproductive biology and ecology of Australia's small venomous snakes (in particular *Hoplocephalus*) is still poorly known. Most recent work has centred upon the examination of museum specimens of snakes (eg Shine, 1980a,b,c,d, 1981a,b, 1982a,b, 1983a, b, c, 1984, 1987a,b, ), rather than on captive studies of live animals, or ideally the direct field observation of the species concerned.

Shine (1983a), in a study on arboreality in snakes, reported on the diet and fecundity of *Hoplocephalus*, as adaptive evidence of arboreality in the genus. This study was based largely on the dissection of museum specimens of the reputedly arboreal snakes *H. bitorquatus*, *H. bungaroides* and *H. stephensii*, and the comparison of the derived data with previously published records. To our knowledge, Shine had virtually no field experience with the species concerned when his paper was published, his data being almost entirely derived from museum specimens and personal communications. Our recent observations on *Hoplocephalus stephensii* allow the opportunity of specific comparison with the findings of Shine (1983a).

### Comments on Feeding and Growth Rates in *Hoplocephalus*

A potential complication for studies in ecology or physiology concerns the taxonomic status of the particular species. If it is subsequently shown that *Hoplocephalus bitorquatus* (sensu Cogger, 1975, 1979, 1983, 1986) is indeed composed of more than one species, as Wells and Wellington (1985) maintain, then how can Shine's work on *Hoplocephalus* be aligned with consequent changes to classification if he fails to list the material used?

The unfortunate side effect from this failure, is that one cannot check his identifications or build upon the data that is presented. Identification of *Hoplocephalus* species has proven difficult for some workers, a good example of which was the past misidentification of *Hoplocephalus stephensii* as "*Hoplocephalus bungaroides*" in the Queensland Museum. This resulted in the erroneous distribution and growth data for *H. bungaroides* that eventually appeared in Worrell (1963) who used the information supplied by the Queensland Museum; a number of subsequent publications quoting Worrell only compounded the errors. Another avenue for possible misidentification, concerns the unbanded *H. stephensii* population with *H. bitorquatus*.

But regardless of taxonomic questions, it is also important to know the locality of the specimens owing to the potential for geographic variation in diet and reproduction.

#### *Natural prey or Unnatural food?*

Although Shine reports that *Hoplocephalus* species differed in dietary habits (check data in Shine's Table 2), one cannot determine the extent of individual dietary variation from the data presented, because he did not identify the actual specimens containing "prey" items.

According to Shine, *Hoplocephalus bitorquatus* eats more geckos than other lizards but this conclusion is based on only 3 out of a total of 4 records of lizards in stomach/s. Geckos were considered a more significant dietary component in *H. bitorquatus* than in either of the other *Hoplocephalus* (but only 8 lizards were recorded in the other two species of *Hoplocephalus* combined).



But the big surprise from Shine's study is that *Hoplocephalus bitorquatus* feeds primarily on unidentified frogs. Shine's prey data on *H. bitorquatus* is really rather thin, when one realises that 14 of the total prey items recorded (26), were not specifically identified. If 10 of the 15 Pelodyadids were unidentified, how did he know that they were "tree-dwelling", rather than "ground-dwelling" Pelodyadid species?

Shine also suggested that *Hoplocephalus bitorquatus* feeds throughout the year. This observation appears somewhat contrary to his rationale for his time-constrained sample of *Hoplocephalus bitorquatus* for the determination of growth. If the species eats throughout the year, it would seem likely that it would grow throughout the year also. In any case he does not give the dates of collection of the specimens used for any species.

Scant, but useful, information is provided on two of the species (*H. bungaroides* and *H. stephensii*), but the weighting of the data in favour of one species (*H. bitorquatus*), makes generalisations on the other two species unwise. For instance, data from his Table 2 reveals that of the 52 *H. bungaroides* examined only 4 food items were recorded (one of which was specifically unidentified, and another likely misidentified).

Of 65 *H. stephensii* examined, only 9 food items were recorded, and 4 of these were actually domestic mice that could have easily been fed to the specimen/s in captivity, and the remainder of the recorded prey were not specifically identified. The natural prey species in the diet of *H. stephensii* must still remain speculative, but a record of a feather taken from the stomach of a freshly killed specimen 840 mm SVL from Dorrigo, was reported by Webb and Rose (1986).

Interestingly, when comparing the diet of *Oxyuranus* with that of other Australian venomous snakes in another paper, Shine (1983b) reported that *Hoplocephalus stephensii* diet is comprised of 44% mammals. Is Shine's paper on *Hoplocephalus* (1983a) the basis for this powerful statement? Remember, only 9 prey items were recovered from *H. stephensii* and 4 of these were *Mus musculus* - domestic mice - that could have easily been the result of captive feeding before the specimen/s found their way into the museum! This appears to be an example of the way such superficial data can have its significance blown out of all proportion by subsequent usage that conveniently neglects to mention its basis.

Curiously, his Table 2 did not reveal the actual specimens (by Museum No) that contained prey items, or indeed the number of specimens that contained prey, thus making it virtually impossible to verify or re-evaluate his observations. Inconsistencies between the data presented in Tables 2 and 3 only compound the potential for confusion or misleading inference. In Table 2, Shine records frogs, lizards and mammals in the prey found in *H. bitorquatus* stomachs, but in Table 3 ("present study") records only "frogs and geckoes" for this species. In *H. stephensii*, Table 2 records the finding of lizards, frogs and mammals, but in Table 3 ("present study") Shine records only "lizards, mice".

In Table 3 Shine presents a review of published data on *Hoplocephalus* "ecology" (diet and fecundity). However, this data is largely drawn from captive observations on the species by others. We know of no one who has previously observed a species of *Hoplocephalus* feeding or reproducing in the wild state.

Unfortunately, the data in Table 3 appears to have been presented to partly support an ecological hypothesis that would otherwise be untenable if Shine had presented the data realistically. With *H. bungaroides* Shine's "present study" data is reported as "lizards", but he chose to slickly ignore Wells' (1981) report on the diet of this species when compiling his Table 3. In that particular study, Wells recorded lizards, snakes, frogs and mammals as food items in captivity. Two specimens of the species in the Australian Museum that were dissected contained lizards, one being an immature Mountain Dragon *Rankinia diemensis boylani*; Shine apparently misidentifies this specimen as a Jacky Lizard, *Amphibolurus muricatus* in his Table 2 when he later examined the same specimen.

All things considered, the paucity of "prey" data in Shine (1983a) makes it difficult to determine trends or patterns at even the broadest level. In effect, when faced with such a low number of specimens carrying prey remains in museum collections, Shine chose to conclude that *Hoplocephalus* didn't eat very often, rather than accept that museum material may be unreliable. Instead, we consider that Shine's data on the low proportion of snakes in museum collections containing food items could really be a reflection of the pre-preservation history of the specimens. An important consideration regarding the assessment of predator-prey data derived from museum specimens, must be that its value is influenced by the collection history of the specimen.

Studies based upon museum specimens can be very useful for taxonomical and even ecological studies, but may also have serious limitations owing to the possibility of misidentification of species in collections, erroneous collection data, inconsistent methods of collection and preservation, and usually, inadequate sample sizes to allow meaningful population estimates. General trends may be identified from the examination of such collections, but even then only after specimens have been rigorously "screened" to reduce the possibility of error. Conclusions on diet and reproduction are particularly vulnerable to error when analysing such data.

The problem is simply that, between the time of collection and lodgement in a museum collection, specimens may have completely digested natural prey, and may have even been fed "unnatural" prey.

Furthermore, various stages of reproduction may be inferred incorrectly, being instead due to the stresses of captive conditions. Reproductive cycles could be altered due to maintenance under different light regimes in captivity, resulting in testicular regression or premature development in males and in females unseasonal follicular development, and even the possibility that embryos could be resorbed or even aborted. Pre-preservation confinement commonly occurs with snakes, and is particularly the case with rare, poorly known or highly attractive species such as *Hoplocephalus*.

We recommend that studies on diet and reproduction from museum collections (such as Shine's) be regarded as superficial or at least preliminary. Shine has either failed to appreciate this problem, or prefers to try and wash any "noise" out of the results by selectively manipulating the data by the use of statistical placebos such as time-constraints upon pooled (ie unscreened) material to develop hypotheses on diet, growth and reproduction. This can be of some value, but it's really no substitute for actually going out into the field and observing the species in the raw. We would also disagree with his comment that a low rate of food intake is often seen in captive *Hoplocephalus*. In particular, our experience also conflicts with Mirtschin and Davis' (1983) comment that *H. stephensii* is difficult to maintain in captivity. Admittedly this species, like *H. bungaroides*, is highly nervous and tends to be somewhat secretive in captivity, but this is not so unusual for a largely nocturnal species.

In captivity, *Hoplocephalus* species will consume food items offered readily (given suitable conditions), but appear to be lizard-eaters mainly (in particular, geckos). *H. stephensii* and *H. bitorquatus*, once settled in an enclosure, will take mice and lizards without any trouble at all. *H. bungaroides* although apparently preferring geckos (*Amalosia lesueurii*), consumes skinks, small dragons, mice and occasionally frogs, and will even consume other snakes (see Wells, 1981 for records; J. Edwards pers. comm. 28/2/1988 also reported that he once had a *H. bungaroides* approx 45.0 cm in total length in captivity seize and consume an immature Yellow-faced Whip Snake, *Demansia psammophis*).

#### Growth

According to Shine (1983a) *Hoplocephalus bitorquatus* is the smallest species in the genus. We believe that *H. bungaroides* is the smallest species, and this is a good example of how exclusive reliance on museum specimens can again be misleading. *H. bitorquatus* can reach over 1.2 m in length, and at that size are of much more massive build than any *H. bungaroides* at its maximum size. Shine also stated that *Hoplocephalus bitorquatus* "from NSW tended to be larger than those from Queensland..."

On the contrary, we have observed that the reverse of this situation seems to be the case. Specimens of *H. bitorquatus* from Queensland seem to be much larger than those from the southern area of the range.

The size data for *Hoplocephalus bitorquatus* in Table 1 of Shine's paper did not provide locality data. Separation of the data set by State boundaries cannot allow the resolution of environmental effects on growth.

His growth rate technique that resulted in Figure 2 is highly questionable. The significance of his results hinge heavily on the assumption that a series of specimens collected at one time of the year over a 90 year period is representative. A few problems with his analysis immediately come to mind. There is no indication that it was a randomly collected sample - in fact it is likely a heavily biased sample. The specimens were presumably not taken from a single population and therefore it is not possible to know if the relative numbers of specimens from various size classes is representative.

The only realistic way this technique could work is if a known population was sampled in a statistically unbiased way so that relative abundance of various age classes could be determined. There is absolutely no way Shine can extrapolate like this from his data set based solely from museum specimens with no consideration of collection history or the population from which they were taken.

Even with all of the above criteria considered, estimating growth rates by only analysing the body-size frequency distribution of snakes collected during the cooler months of the year (time-constraint) would only have meaning if you knew the feeding behaviour of the species. Shine has inferred age classes in *H. bitorquatus* based on such size distributions, because he believes that "growth rates should be minimal" during the cooler May-September period.

On the surface, this would appear to be a reasonable assumption, however it should be realised that at least one species of *Hoplocephalus* (*H. bungaroides*) is known to feed in captivity mainly during the cooler part of the year. White (1973) was the first to formally point this out in the literature, when he remarked "...most feeding takes place at night. I and others have found that they [*Hoplocephalus bungaroides*] consume more food during Spring and Winter than any other time of the year."

Shine may very well be right in his growth estimates for *H. bitorquatus*, but we would have liked to know which "population" of *H. bitorquatus* this data was based upon (were all available specimens pooled, regardless of Latitude?).

It really is very important to include locality data when presenting such a manipulation of a total database, owing to the potential for influence of environment on growth rates and reproduction.

### Comments on the Reproduction of *Hoplocephalus*

Sydney University was once world renowned for its work in the field of reproductive biology particularly in studies of reptiles. The pioneering work of Weekes and Harrison for instance back in the 1920's and 30's set unparalleled high standards which would be difficult to maintain in today's age of slash and rip physiology. Weekes (1927, 1929, 1930, 1935) showed that simple and even more complex forms of chorio-allantoic placentation have been recorded in many Australian reptiles including several species of snakes - *Austrelaps superbus*, *Suta suta* and probably *Notechis scutatus*.

#### *Mode of Reproduction*

Shine regarded *Hoplocephalus* as "viviparous" (we prefer to consider them as being ovoviviparous ie. eggs retained within the oviduct throughout embryonic development), because he found oviducal embryos in all three species. It isn't any wonder why Shine takes the safe way out and refers to the reproductive mode simply as "viviparous" because his description of the state of development of the oviducal embryos is pitiful.

In light of the fact that Shine has an apparent interest in reptile reproduction and in particular the evolution of "viviparity" (see Shine and Bull, 1979), it is all the more amazing that aspects indicating the possible formation of this simple type of placenta are not even considered. After all, he does cite some of Weekes' work in the above paper, but we suppose this is no guarantee that he read or understood it. Could Shine and Bull (1979) be mainly Bull?

He fails to indicate the degree of vitellogenic accumulation and how this relates to embryo size, whether or not the embryos were surrounded by shell membranes or only extra-embryonic membranes, whether there was any juxtaposition between these membranes and the oviduct wall, whether there was any increased vascularisation in the region, or whether there was any yolk-sac reduction indicative of maternal transfer; even the actual stage of embryonic development is not mentioned.

We can only assume that Shine would have at least noticed any more obvious and intimate interconnection such as Stage II chorio-allantoic placentation (Weekes, 1935), if present, as he prised them out for measurement. However, doesn't it seem rather quizzical that he compared their size to ovarian follicles in his, (Shine 1983a) Figure 3 graph? One could understand the comparison of follicular development with time but it is surely unreasonable to compare them to oviducal oocytes or more amazingly to developing embryos directly! If embryos and ovulated (fertilized?) eggs are deleted from his Figure 3 graph, the remaining follicle measurements show an almost random range in size, and yet from this Shine refers to this data as being strongly indicative of a "biennial" reproductive cycle!

It is a real pity that Shine did not make more out of his examination of the specimens. But they're history now.

A more realistic method of establishing the reproductive cycle without sacrificing large numbers of individuals would be to measure changing levels of vitellogenic proteins directly in the blood stream in either captive specimens maintained under strict light regimen or wild caught specimens sampled throughout the year; similar techniques measuring blood oestrogen levels would also prove useful.

#### *Size at Birth*

The smallest specimen of *H. stephensii* available to Shine measured 16.7 cm SVL. Three full-term *H. stephensii* still-born to a captive female measured 16.7 (is this the smallest specimen referred to above?), 19.2, and 21.6 cm SVL (Queensland Museum records). Five neonates of *H. stephensii* were recorded as being between 23-24 cm in total length, but Shine doesn't state whether the neonates were actually measured or merely estimated at birth, and whether the five young represented the total brood (because this data was from a personal communication).

Our litter size for *H. stephensii* of 9 (one still-born), with measurements (mm) ranging from a SVL of 200.0 to 207.0 ( $\bar{X}$  204.9), and VTL from 30.0 to 41.0 ( $\bar{X}$  35.0), is larger than the data reported in Gow (1976) - 5 young, of approx 170 mm (SVL or TL?), or that recorded by Shine (1983a). But Shine found between 3 and 8 young in 7 gravid specimens of *Hoplocephalus stephensii* dissected. Our observations, however, are generally within his proposed estimates.

The reproductive data for the other two species mentioned by Shine is also rudimentary. Three full-term embryos of *H. bitorquatus* measured 19.5, 20.1 and 20.2 cm SVL. However, Shine determined that *Hoplocephalus bitorquatus* has between 2-11 young with an average of 4.7 - derived from dissecting 17 reproductive females.

Only two oviducal litters of *H. bungaroides* were recorded (4 and 8) but no data was provided on specific birth size.

The most complete data for a *Hoplocephalus* species female reproductive cycle was provided for *H. bitorquatus*.

Shine stated that vitellogenesis in this species commences during May - July, continuing into "Spring", with ovulation occurring in October - December. But, what were the localities of these reproductive females and neonates, and what are their Museum Numbers for verification purposes? Reduced reproductive activity in snakes due to environmental conditions has already been reported by Shine (1981b), yet his reproductive and growth data on *H. bitorquatus* was pooled apparently without regard for potential geographic influences.

Shine (citing a personal communication) reported a record of a captive *H. bitorquatus* giving birth in February, but no other details were provided (for instance, how many young were born?).

*Hoplocephalus stephensii* have been observed mating in captivity during October (Shine, 1983a) (again citing a personal communication), and giving birth in December (another, but different, personal communication). Was this birth of *H. stephensii* in December, the same one that gave rise to the five neonates referred to earlier, or is this another record of a birth where the number of young or their measurements were not recorded?

Shine maintains that the young of *Hoplocephalus* must be born in February-March, "based on the seasonal appearance of young in museum collections". Our litter of *H. stephensii* was born on 6 February, which is consistent with Shine's estimate from the extrapolation of the *H. bitorquatus* data, but differs from his cited personal communication of birth of *H. stephensii* in December. Our observations on wild (October) and captive (November-December) matings in part agrees with Shine's data on mating in *H. stephensii*.

However the fecundity of either *H. bungaroides*, (only 2 females gravid) or *H. stephensii* (only 7 females gravid) must at present remain fairly speculative, because the sample sizes for both species are just too low. Unfortunately, the value of the records provided by Shine is reduced due to the localities of the specimens not being stated and the pre-preservation history of the particular specimens being unknown.

Our field observation of a specimen of *Hoplocephalus stephensii* being already in an advanced gravid state in October, could indicate that this species might actually have a longer gestation period than implied by Shine's data. Hayes' (1973) record of interspecific mating between *H. bungaroides* (male) and *H. stephensii* (female) in March could have greater significance than it seems. Subsequent Spring and Summer mating may indicate that sperm storage by females could be practised also. Shine's conclusion that all species of *Hoplocephalus* probably reproduce only biennially is tantalizing, but possibly premature.

The rationale to support his contention of low reproductive frequency in *Hoplocephalus* is essentially the theory that a species evolves this reproductive strategy when the "costs" of reproduction are independent of fecundity, and the species requires low rates of food intake, while having high survivorship.

As Wells (1981) pointed out, *H. bungaroides* can be long-lived (over 20 years) and it is known that one specimen survived a fast of 12 months (Marion Anstis, pers. comm.), thus indicating at least a potential for low energy requirements. *H. bungaroides* seems to have high survivorship, as they can be quite "common" in their restricted natural habitat, where the only snake more abundant appears to be *Cryptophis nigrescens*. When this is combined with the species' low litter number of large young, and that mature specimens have been known to utilise the same exfoliation or its immediate surrounds on ridges for years, there appears to be strong support Shine's contention of high survivorship in *Hoplocephalus*, and thus low reproductive frequency.

### Comments on "Arboreality" in *Hoplocephalus*

If an organism is "arboreal" it must either live in, or have some significant physical or biological connection with trees. Does the fact that all species of *Hoplocephalus* are able to climb trees at least *some* of the time make them "arboreal" snakes *all* of the time, or even "arboreal" at all?

The morphological adaptations for "arboreality" cited by Shine (viz. slender body form, and keeled ventral scales) could also be adaptations for rock-dwelling. Most "arboreal" snakes also tend to have a long, even prehensile tail - yet the tail of *Hoplocephalus* species appears little different to the rest of the "terrestrial" venomous snakes. Another point worth considering is that truncated tails are notable in species of snakes that practice crevice-retreat evasive behaviour patterns (ie "terrestrial" species), rather than in "arboreal" species. Such behaviour often results in the tail being left unintentionally exposed to a potential predator, after the snake has sought concealment under a rock or in an earth-crack. It would be very interesting to see a study of tail-damage in "arboreal" vs "terrestrial" snakes, but at least we know of several instances of this injury in the three species of *Hoplocephalus* dealt with in Shine's paper (and Shine's illustration of *Hoplocephalus bitorquatus* actually has a truncated tail also).

Additionally, all of the species in the genus *Hoplocephalus* actually live among rock outcrops, at least in part of their range. The most southern (primitive?) member of the genus (*Hoplocephalus bungaroides*) is almost entirely saxatile. Its closest relative, *Hoplocephalus stephensii* will live under leaf-litter on the forest floor, in rock outcrops, inside stumps, and hollow logs, and is known to climb trees. Griffiths (1987) states "Its [*Hoplocephalus stephensii*] favourite resting place during the day is beneath large sheets of bark on upright or fallen trees." However Griffiths (pers. comm.) has not had any personal experience with the species, his published statement being derived from "common knowledge" (hearsay?). *Hoplocephalus bitorquatus* has been found beneath exfoliated granite, beneath bark at the bases of eucalypts, as well as beneath bark on tree trunks (up to 10 metres from the ground), and *Hoplocephalus revelatus* has also been collected amongst rock outcroppings on the verge of rainforest.

If "arboreality" is really the primary ecological domain of any *Hoplocephalus*, it seems likely (admittedly on superficial evidence) that only *H. bitorquatus* is the candidate to really consider. But regardless of where the adult specimens of *Hoplocephalus* live, where do the juveniles live? The juveniles of *Hoplocephalus stephensii* herein reported were so like juvenile *Vermicella annulata* in their colour and patterning, it would not be surprising at all to find that *H. stephensii* is actually more "terrestrial" than "arboreal".

Another anomaly for a classification of "arboreality", is the reproductive mode of *Hoplocephalus*. As an ovoviviparous genus, *Hoplocephalus* would tend to be in contradiction to the apparent world-wide trend for "arboreal" snakes to be oviparous. There is obvious scope for all sorts of fun and games in the trees, and an "Ecology of Arboreal Reproduction" would be another interesting study, regardless of where *Hoplocephalus* live.

Shine's piecemeal accumulation of prey and fecundity data appears to be offered in support of the notion that this genus of snakes is "arboreal".

One of the strong arguments Shine uses to justify arboreality is diet, manifested by his discovery of Pelodyadid frogs in the diet of *Hoplocephalus bitorquatus*. His continual reference to them as "Tree" frogs doesn't really strengthen his argument as much as he hopes, since only two of these frogs were actually specifically identified and in any case, many Pelodyadid frogs are more ground-dwelling than arboreal. Furthermore, even the two species he did manage to identify are just as frequently encountered on the ground as in trees.

A comparison of Shine's conclusions on the significance of the diet of *Hoplocephalus*, with his studies on the diets of "terrestrial" Elapids, reveals that "tree" frogs are not regarded as evidence for "arboreality" in these other species' diets. Why the inconsistency? For example *Demansia atra* were recorded feeding on "*Litoria rothi*" (Shine, 1980d), *Cryptophis nigrescens* eating "*Litoria dentata*" (Shine, 1984), *Hemiaspis damelii* eating the "tree" frogs "*Litoria bicolor*", "*Litoria dentata*", "*Litoria fallax*", "*Litoria gracilentia*" and *Hemiaspis signata* eating "*Litoria bicolor*" and "*Litoria dentata*" (Shine, 1987b); even Shine's (1987a) report on *Austrelaps* species recorded a proportion of "tree" frogs in the diet.

These species of snakes are known to be "terrestrial", so Shine readily explains that such species of "tree" frogs are eaten by such snakes during daytime foraging in the "tree" frogs' "terrestrial" retreats. So why couldn't *Hoplocephalus* forage for "tree" frogs the same way? Shine's use of the world-wide literature on prey-preferences in some 103 species of "arboreal" vs 221 species of "terrestrial" snakes to prove his point of arboreality unfortunately lacks enough detail for proper evaluation. The reason for this is simply that he only provides a string of references and basic statistical results instead of a tabulation showing reference, species, and diet, with the appropriate (sensu Shine) ecological classification so that the reader can evaluate the data. Similar problems are presented in his comparison of "Colubrids" vs "Non-Colubrids".

Instead, anyone interested enough in this would either have to squeeze the data out of the cited references, or dismiss Shine's statistics outright as unconvincing. We chose the latter. Shine's conclusion that "arboreality" in snakes is more common in areas of higher rainfall (and thus more vegetation) isn't exactly Earth-shattering stuff, but it does leave us wondering...What does it all really mean?

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**Figure 1**

General view of surrounding habitat. Note the even-age stand of regenerating *Eucalyptus pilularis*.

**Figure 2**

Outcrop at GR 459124 where the *Hoplocephalus stephensii* were located.

**Figure 3**

The crevice where the mating pair of *H. stephensii* were located.

**Figure 4**

The female *H. stephensii* with some of the neonates, on 15 February (7 days after birth).

