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The deadly duo. Sperm storage and synchronized breeding, identified via the world's first captive breedings of Australian Copperhead Snakes (*Austrelaps* Worrell, 1963) and also in captive bred Tiger Snakes (*Notechis* Boulenger, 1896).

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ABSTRACT

Tiger snakes *Notechis scutatus* (Peters, 1861) and Copperheads *Austrelaps superbus* (Günther 1858) are well known large and dangerously venomous snakes from Australia (Hoser, 1989). While they are a popular captive among herpetoculturists and government licensed wildlife demonstrators it is common knowledge that few if any are actually bred in captivity.

Young are routinely sourced from gravid females as detailed by the relevant demonstrators on various internet chat forums including "Aussie Pythons" and "Facebook".

Excess snakes are then illegally sold to others wanting to keep the said species.

Selling snakes in itself is not illegal, but the taking from the wild without appropriate licenses is.

Contrary to this has been this author who for many years has been successfully breeding both Tiger Snakes and Copperheads as detailed in Hoser (2007).

To ensure that no claims are made against me that gravid snakes are being used to source young for profiteering purposes, no reptiles of any kind have ever been sold by myself to anyone and this includes species and animals typically otherwise valued in the hundreds of dollars that are regularly bred here.

In fact this author is the only person known to have genuinely bred the Copperhead in Australia, so it is important that the materials and methods be set out as done in this paper, so that others can emulate the methods, so as to reduce taking of specimens from the wild.

Significantly when breeding both species, most mating is in late summer and autumn, not in spring as generally assumed, even though ovulation is clearly in the spring, with young being born late in the summer.

This means a full one year breeding cycle and when including cooling over two winters may mean a full two year cycle for breeding these species is in fact the normal situation.

Assuming the adult snakes are kept in the same conditions at a given time and place, young tend to be born at the same time in any given season, even if the females mated at widely varying dates the previous year. This clearly indicates sperm storage in the two relevant species and may in fact be far more common in southern Australian elapid snakes than is generally known.

Keywords: Australia; Victoria; Snake; elapidae; Copperhead; Tiger Snake; captive breeding; sperm storage; synchronized breeding; *Austrelaps*; *superbus*; *Notechis*; *scutatus*; *Acanthophis*; *antarcticus*.

INTRODUCTION

Since 2003, to present (2018), this author has kept and regularly bred Lowland Copperheads *Austrelaps superbus* (Günther 1858) and as of 2018 is now onto the F3 generation, with all relevant snakes being bred at the author's facility. The same applies for other species of elapid held including Tiger Snakes *Notechis scutatus* (Peters, 1861), which are also up to F3 stage.

Also bred here in the same time period have been several litters of Death Adders (*Acanthophis spp.*), Eastern Brown Snakes *Pseudonaja textilis* (Duméril, Bibron and Duméril, 1854), Red-bellied Black Snakes *Pseudechis porphyriacus* (Shaw, 1794) and various species of pythons.

The taxonomy of Copperheads (Genus *Austrelaps* Worrell, 1963) is dealt with by Hoser (2009 and 2018), with Hoser (2018) confirming that *Austrelaps superbus* (Günther 1858), is a separate and distinct species from the morphologically similar Highlands Copperhead *Austrelaps ramsayi* (Krefft, 1864).

Hoser (2007) details the breeding of Tiger Snakes and in spite of many breedings since then, not much has changed, save for a greater emphasis on mating snakes in Autumn as opposed to the spring, although inducing that species to mate at most times of year is not difficult.

For snakes of given species unwilling to mate, this author was the first in the world to breed them using artificial insemination (AI) as detailed by Hoser (2008).

This paper lays out what is needed to successfully breed both *A. superbus* and *N. scutatus* in captivity, with an emphasis on the Copperheads *A. superbus* and the wider ramifications in terms of the species in the wild and other relevant species.

While I kept and bred Highland Copperheads, sourced from Oberon, New South Wales in the early 1970's at Lane Cove (Sydney), New South Wales, I have not kept that taxon since being in Victoria since 1985.

However in terms of husbandry and breeding, it appears all species of *Austrelaps* are much the same in terms of requirements, and results from given actions by the keeper.

The wider ramifications of the results of the captive breeding of Copperheads and Tiger Snakes, in terms of wild snakes is also outlined.

MATERIALS AND METHODS

Due to the busy schedule at our Melbourne reptile education business, no scientific experiments were planned and executed. Instead a sizeable number of elapid snakes have been maintained

at our facility since 2003 for the primary purpose of doing educational venomous snake displays.
Because we have never had a shortage of specimens of the relevant species *A. superbus* and *N. scutatus*, breeding was never required for our own use. Instead it was merely done because it could be done and we knew that any excess offspring could easily be passed on to other appropriately licensed potential reptile keepers.
Of note also is that most of our snakes have been made venomoid (surgically devenomized) using the operation detailed in the papers of Hoser (2014a, 2014b and 2015). It should be noted that there is no evidence whatsoever that the snakes are materially altered in any other way (besides removal of venom glands) as they eat, behave and breed in a perfectly normal manner.
Of course it need not be mentioned that the venomoid snakes benefit from being "free handled" with human hands on all occasions and are relieved of the stress and burden of being stick handled.
There is also zero safety risk to myself and the handlers I employ to do our educational wildlife shows.
All snakes were housed in plastic tubs as detailed in Hoser (2009), see page 24 for the photos and as similarly explained in Hoser (2007).
Nothing at all has changed in the housing of the snakes in the intervening decade as the husbandry methods worked well, were effectively incident free and there has been no reason to change what appears to be the best and most time saving method of maintaining the snakes in a healthy condition.
To all intents and purposes the only common cause of death of the snakes have been ailments associated with extreme old age, meaning many relevant snakes live well beyond a decade.
The snakes are invariably housed one per cage and as a rule kept one per box when moved around for wildlife displays.
Exceptional to this is when snakes are grouped in a box for a publicity photo of myself or staff holding a bunch of venomous snake species, when one or more defecate in a box and it is decided to make it share with another as a time saving alternative to cleaning a box during a busy public display, or similar kind of situation, but grouped snakes is not the usual position for us.
Snakes are placed together for intended matings and most of the time expected matings result in successful copulations.
This is due to a knowledge of the cooling and ovulation cycles of the snakes and which males of our males are most inclined to mate. However I should note this is usually ascertained with a significant amount of "trial and error" in that snakes are introduced to one another to see likely interactions and/or males are checked for semen, semen plugs or other evidence of fertility.
The other evidence of fertility may include the male pacing the cage at times of falling air pressure or similar behavioural changes at other times.
The cage set up for all our elapid snakes as detailed in Hoser (2009) pages 24 and 25 is copied here in the two following pages, so that readers of this paper have an accurate view of the relevant caging set up.
The same is used for our Tiger Snakes (*N. scutatus*).
Our breeding programs took a major hit in the period post dating an illegal armed raid and gunpoint shutdown of our business on 17 August 2011 by corrupt Victorian wildlife officers, as detailed by Court of Appeal Victoria (2014) and the Victorian Civil and Administrative Tribunal (VCAT) (2015).
This violent raid included the unlawful execution of many breeding snakes and beyond that the twin burdens of ongoing litigation and the threat of having all our snakes seized at gunpoint on any given day, meant that breeding snakes was largely discontinued in this period.
We did not want to have our gravid snakes unlawfully seized by the wildlife department, handed to their own dysfunctional "Zoos Victoria" business; with the result they would then be able to tell the media that they had bred them.
Following all false charges against us being thrown out by the courts in 2014 (see Court of Appeal 2014), we were then able to put our minds to breeding our elapid snakes and so have had significant successes since then.
Across the board with all our snakes, by extending the length of the winter cooling and the severity of it (as in making the snakes colder for longer) commencing the winter of 2014 and then extending even further in 2015, we found that snakes were more inclined to mate in spring and produced greater quantities of sperm.
In the winters of 2015, 2016 and 2017, most elapids at our facility were "hibernated" for between 5 and 7 months.
(The correct term for inactivity in reptiles over cooler periods is brumation, or brumated, but the colloquial term hibernate or hibernation is most widely used by people and understood in the context of reptiles and hence is used in this paper).
In that period the snake's cages had no heat source and dropped to a room temperature usually between 10 and 20 degrees Celsius.
Added to that, Copperheads and Tiger Snakes that had sometimes previously failed to become gravid after being mated were housed for a period of 8-10 weeks in a small locked outdoor shed, with a stable 24 hour ambient temperature that in June to August sat at an average of about 10 degrees Celsius.
Other species we bred also got shorter stints in the same conditions, on top of other hibernation, including tropical Australian pythons which besides not falling ill, also bred successfully, these being Queensland Black-headed and Coastal South-east Queensland Carpet Pythons..

RESULTS

In the springs of 2015, 2016 and 2017, both Copperheads and Tiger Snakes mated. However only one of several males would mate and semen production by all was weak.
In early February (second half) to March (the whole month) in 2015, 2016 and 2017, the Copperheads and Tiger Snakes were given shorter heated periods in their cages each day (12 hours on and 12 off most days, versus 24/7 previously), with added stretches of time where no external heating was applied to the cages at all and temperature never got above the mid 20's (deg, C) and also was regularly below 20 Deg. C.
All years saw the Tiger Snakes and Copperheads mate strongly in the February/March period, with males typically mounting and mating females as soon as they were introduced into the cages.
Mating snakes are in no way agitated or stressed with human intervention or viewing of their actions and quite happy to be handled (gently), photographed with flash, be video recorded or both video recorded and photographed at the same time and then placed back into their cage, where they continue to mate.
This mating preceded the full winter cooling as outlined previously in this paper, but it should be noted this did occur in the years preceding the summers of 2015/2016 to that of 2017/2018..
In February/March of 2016, 2017 and 2018, both Tiger Snakes and Copperheads produced litters of young, most being from matings almost exactly 12 months prior, confirmed by the fact that the relevant snakes (all the Copperheads and some of the Tiger Snakes) had not been mated in the preceding spring.
In one case in March, a male and female Copperhead were mated 48 hours after she had given birth to a litter of 14 healthy live young.
Clearly it does not take 12 months for these snakes to develop young, and clearly there was no ovulation at the time of mating (recall a female had given birth two days earlier in one case) meaning that the females were storing sperm for some time prior to parturition.
With an estimated 4-5 months for young to develop in the females before being born, it is clear that the warming in spring, or some aspect of it, is causing the snakes to ovulate and begin the development of young, using viable sperm that has been stored over winter.
Also never previously reported, but apparently standard for both Copperheads and Tiger Snakes in our care over many years is that once an apparently successful copulation has taken place, females will avoid mating with other males introduced to them.
These same males (the later ones), try unsuccessfully to mate with the previously mated females, but have success in mounting and mating unmated females.
Exceptional to this was one particular female Tiger Snake, who regularly allowed herself to be mounted and mated (copulated) with more than one male over a period spanning several weeks.

DISCUSSION

The significance of the preceding is that people intending breeding Copperheads and Tiger Snakes in captivity by natural means (not via AI), should be both cooling the snakes severely over winter and for long periods and plan matings to coincide with a late summer/ autumn cooling of the relevant snakes, in preference to spring after the full winter cool-down, as is done for most other Australian snake breedings.
My breeding strategy for these two cold climate species (and the

tropical ones here as well), has been to cool the snakes as much as possible over winter, without harming their health, meaning that snakes are monitored closely during this relatively inactive phase. Snakes that appear to be in any way unhealthy, or perhaps losing condition faster than expected, noting they cannot be fed when cold, are brought out of hibernation early or earlier than the main collection.

Having said this, planning in the autumn, means that most if not all relevant snakes are well fed before being hibernated and so all can be held at low temperature for many months. Countering this to a limited extent in our somewhat unique situation is the continued use of these same snakes in our educational reptile shows (often daily for days on end), causing them to lose condition at a considerably faster rate than otherwise inactive snakes.

Hence, we tend to have our snakes slightly obese when going into the cooling phase and they are thinner than many peers in other collections when finally heated again in the spring.

Spring matings and breedings can work for both Tiger Snakes and Copperheads, but the general success rate is lower, due at least in part to a reluctance of the snakes to mate or because ovulation may have already occurred and the female is not apparently receptive to sperm. This applies mainly to Copperheads, who clearly have a strong spike in mating in Autumn, whereas Tiger Snakes, who also have a mating peak in autumn, will more commonly mate through winter and into the early spring.

While Tiger Snakes mate at almost any time of year, except the height of Summer in early to mid January, clearly autumn matings appear to have the highest likelihood of success.

I note that a female Tiger Snake mated in the spring of 2016 produced slugs the following autumn. But when mated shortly thereafter (March 2017), produced a healthy litter of 24 young on 1 February 2018.

Clearly the warming in Spring is what causes the snakes to ovulate and breed (when fertilized) in both wild and captive specimens of Tiger Snakes and Copperheads.

As all snakes in a given place are affected by the same weather events (such as the first spring heatwave) it makes sense that development of young is generally synchronised, explaining why in the wild in an area such as Melbourne, Victoria, most years one sees Tiger Snakes or Copperheads commonly all give birth within a timeframe of a few weeks.

Birth of captive snakes in Copperheads and Tiger Snakes is similarly tied to when the females are warmed up in the spring. Synchronized birth in a given species is thought to be a predator defence, in that at least some of the tidal wave of young can escape being eaten by predators at one short time.

This may or may not be the case in Copperheads and Tiger Snakes. More likely the breeding cycle and the synchronisation of parturition is merely an artefact of the physical needs and constraints of the breeding cycle, caused by the seasonal weather fluctuations, as opposed to any specific anti-predator defence.

Also of note is the activity patterns of wild Copperheads and Tiger Snakes as seen by myself as a Melbourne's busiest licensed snake catcher over some decades.

The trends seen year on year are consistent and based on a season average of more than 5 incoming "snake calls" a day. The snake season is taken as being from 1 September to end April each year, although often not all snakes emerge from hibernation in Melbourne until October and many go back into hibernation from late March onwards, meaning that April is commonly the quietest month for snake call outs even when the weather is conducive to snake activity (i.e. warm and sunny).

That Copperheads and Tiger Snakes mainly mate in late summer and early autumn (Feb/March) is seen through the massive preponderance of large males caught moving through people's properties.

Captive males subjected to a parallel seasonal heating cycle also become more restless in their cages and as already mentioned are most inclined to mate.

By contrast, the activity of Eastern Brown Snakes (*Pseudonaja textilis*) in Melbourne is limited in the autumn.

Also in contrast to Copperheads and Tiger Snakes, Eastern Brown Snakes mate in the wild and in captivity mainly in the early spring (Hoser, 2006).

As a snake catcher in Melbourne, I rarely get calls to catch more than one snake at a time, as in pairs fighting or mating, although each season I get a few such cases.

Invariably they conform to the pattern just outlined. Tiger Snakes are mainly found paired up and mating in the late summer / autumn period, as in February to March in particular.

For them, the mating activity usually starts after the peak of summer in early to mid February, when the nights show a distinctive cooling trend.

In 2018, quite unusually, I caught a pair of mating Tiger Snakes at Healesville, mating on a porch on 27 January 2017, during a heatwave which was also during the height of summer.

Copperheads are less often seen mating or fighting on call outs, but large numbers of large testosterone charged males are caught roaming through people's properties throughout the late summer / autumn period.

Whenever an attempt has been made to extract semen from the said wild-caught snakes in the late summer / autumn, this has been easy to do. In fact some wild caught males have ejaculated when tailed at time of capture.

Also noteworthy is that similar ejaculation at time of capture is common in Red Bellied Black Snakes, when caught in spring, which is their (strict) mating season and the only time of year that males appear to produce semen.

For Red Bellied Black Snakes, semen production is strongest in late August to late November.

SUMMARY

For maximum breeding success in captive Copperheads and Tiger Snakes, late summer and autumn matings are best, noting that the relevant snakes should have been severely cooled the previous winter.

Due to cannibalism risks, snakes should otherwise be held in separate cages and watched closely when introduced to one another.

Sperm storage is a fact of life for both Copperheads and Tiger Snakes, as is synchronized birth in the wild.

Hoser (1989) and sources cited therein provided evidence of sperm storage in Sydney, NSW, Australia Death Adders *Acanthophis antarcticus* (Shaw and Nodder, 1802) that mate in autumn.

How widespread both sperm storage and synchronised parturition is in other Australian squamates is yet to be determined.

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CONFLICT OF INTEREST

The author has no known conflicts of interest.