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Reproduction and diet in four species of burrowing snakes (*Simoselaps* spp.) from southwestern Western Australia

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Abstract – The reproductive pattern and diet of four *Simoselaps* species were examined from 259 museum specimens collected from southwestern Western Australia. Few reproductively active females were recorded from the four species (*S. bertholdi, S. bimaculatus, S. calonotos* and *S. fasciolatus*) but yolked ovarian follicles and oviductal eggs were observed between October and February with a peak in November and December. Male *S. bertholdi* had significantly larger testes in October than other months, but no significant seasonal variation was apparent in the small adult sample of other species. The prey of all species consists of scincid and pygopodid lizards. There is a pronounced separation in the diet of *S. bertholdi* and *S. calonotos* with the former feeding on surface dwelling skinks and the latter on fossorial skinks and pygopodids.

INTRODUCTION

The knowledge of the biology of Australian snakes has expanded rapidly over the past two decades (Shine 1991). A considerable amount of new information has resulted from detailed examination of museum specimens for both their reproductive and dietary information (Shine 1983, 1984a, 1984b, 1986, 1988).

Previous studies of burrowing snakes in the genera *Neelaps, Simoselaps* and *Vermicella* document the reproductive pattern and season, size at maturity, inferred growth rates and diet (Shine 1984a). These data were acquired from 953 specimens of 13 species in collections at Australian museums and were collected over extended time frames from species, often with large geographic ranges, that covered numerous climatic zones. Shine (1984a) found that there was a marked season of reproductive activity in these species; that at least five species were oviparous with larger females having larger clutches; that females were larger than males and that there was a clear specialisation in the diet of many species.

A study of 736 specimens of 11 species of *Simoselaps* and *Vermicella* occurring in Western Australia (Clarke and How 1995) showed that it was possible to determine the sex of each individual by recording the tail to body ratio of specimens. Females of all species had smaller ratios than males and these ratios did not overlap (Clarke and How 1995).

This study examines the reproductive biology and diet of four of the six species of *Simoselaps* [*S. bertholdi* (Jan), *S. bimaculatus* (Duméril, Bibron and Duméril), *S. calonotos* (Duméril, Bibron and Duméril) and *S. fasciolatus* (Günther)] that are broadly sympatric in southwestern Australia. Together with *S. semifasciatus* (Günther) these four species may occur syntopically in several sandplain habitats on the Swan Coastal Plain (How and Dell 1990). Southwestern Australia has a pronounced Mediterranean climate with cool wet winters and dry hot summers; a climate that invokes a period of pronounced reproductive activity in the spring and early summer in several lizard species (Chapman and Dell 1985; How and Kitchener 1983; How *et al.* 1986, 1987, 1990). It is also a region where the diversity of potential lizard prey items is well documented (How and Dell 1993). Of the two sympatric species not considered in this study, *S. semifasciatus* has a markedly specialised dietary and reproductive pattern (Shine 1984a), while *S. littoralis* Storr, although represented in collections, is the focus of an independent study (Jennings, personal communication).

METHODS

Specimens in the collections of the Western Australian Museum were selected to encompass the winter-rainfall dominated biogeographic regions, approximating the area of southwestern Australia west of a line from Geraldton to Esperance (Figure 1).

Specimens were measured to the nearest millimetre for both snout to vent length (SVL) and

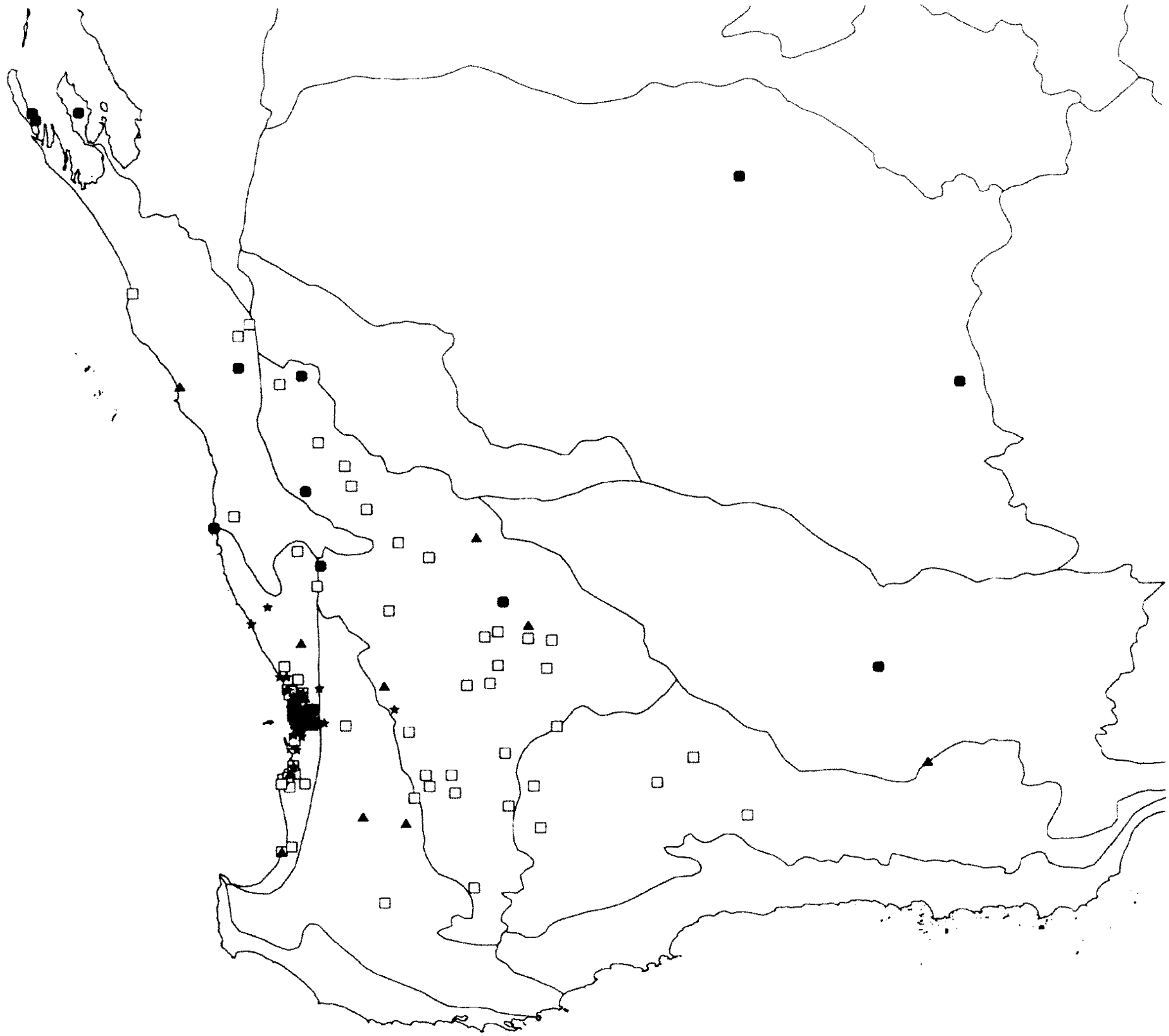


Figure 1 Distribution of *Simoselaps bertholdi* (□), *S. bimaculatus* (▲), *S. calonotos* (★) and *S. fasciolatus* (●) specimens from southwestern Australia examined for this study. The outline of the Interim Biogeographic Regionalisation for Australia (IBRA) regions of southwestern Australia are also depicted.

tail to vent length (TVL). After dissection of the lower abdomen with scissors the gonads were measured to the nearest 0.01 of a millimetre using digital callipers. The length (l) and width (w) of each testis was recorded as was the length and width of all yolked ovarian follicles and oviductal eggs. The volume of each testis was combined to provide a measure of testes volume, while clutch volume was calculated by combining the volumes of individual oviductal eggs.

Stomach contents were removed for later examination and identification. Prey items were identified to the species level by comparison with the extensive reference material of lizard taxa in the collections of the Western Australian Museum.

Calculations were made on the volume of testes, yolked ovarian follicles or oviductal eggs using the formulae for a prolate spheroid:

$$\text{Vol.} = 4/3\pi(w/2)^2(l/2)$$

The number of specimens of each *Simoselaps* species examined was: *S. bertholdi* 117; *S. bimaculatus* 52; *S. calonotos* 62; *S. fasciolatus* 28. These comprised 32%, 75%, 94% and 55% of individuals that had been examined previously by Shine (1984a) for the respective species.

Statistical comparisons were made using the Statistix (1996) program. Significant ANOVA's were further examined using the Least Significant Difference test (α=0.05) to compare means.

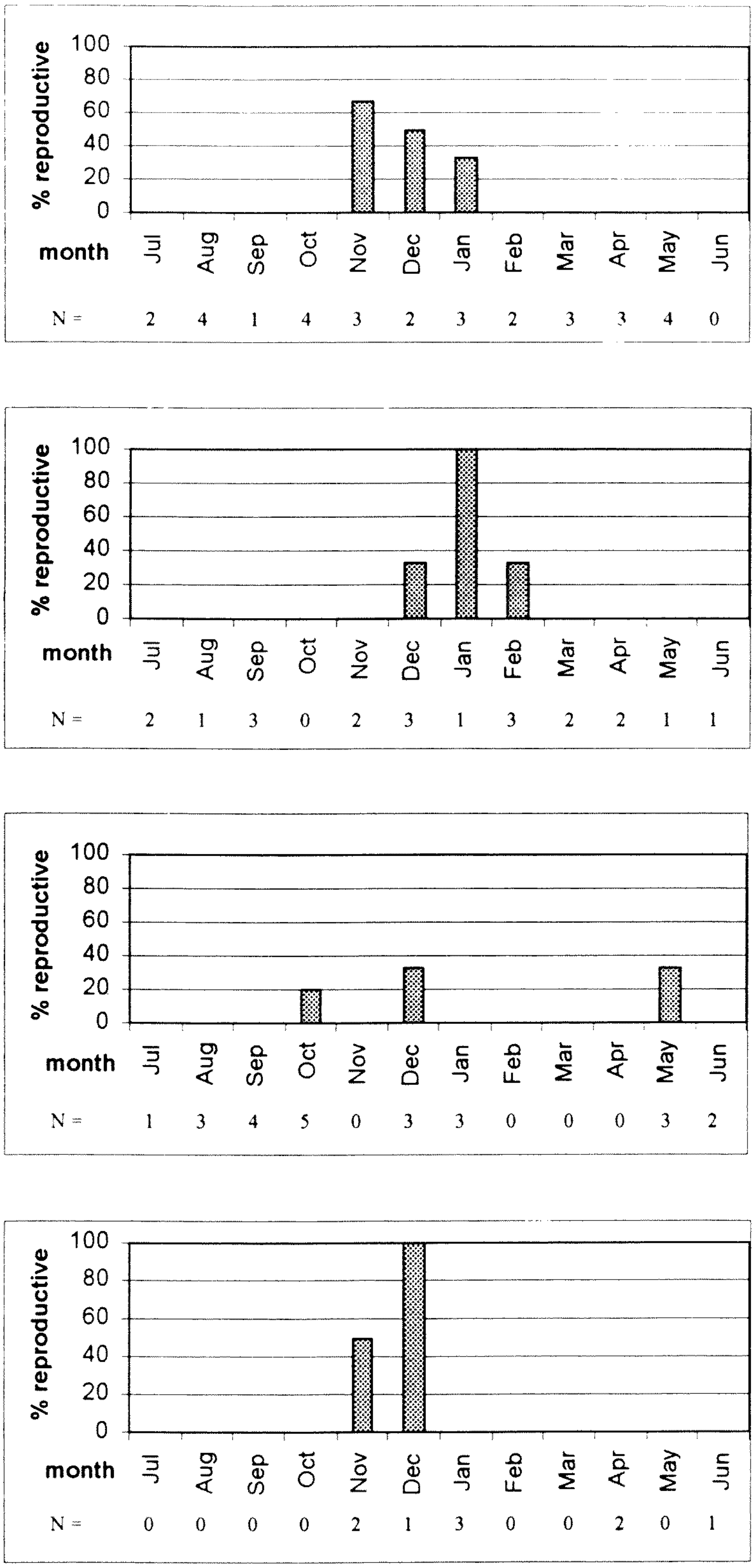
RESULTS

Reproduction

Maturity

The size range of adults and the number of adults of each sex of *Simoselaps* examined during this study are presented in Table 1.

The sample sizes of *Simoselaps* species available from southwestern Australia were small and, as such, probably present a very conservative estimate of size at sexual maturity amongst the species of *Simoselaps* examined in this study.



S. bertholdi

S. bimaculatus

S. calonotos

S. fasciolatus

Figure 2 Percentage of adult females that were reproductively active in each month of the year (N = sample size) for *Simoselaps* spp. from southwestern Australia in Western Australian Museum collections.

Consequently, adult specimens were determined as those larger than the smallest reproductively active specimen examined in either this study or that of Shine (1984a), who examined the reproductive state of a larger sample of each of these *Simoselaps* species from throughout their range. Table 1 indicates the size range of adults of both sexes determined from this study and by Shine (1984a).

The SVL of the smallest female with yolked

Table 1 Size range and number of each sex for the adult specimens of *Simoselaps* species examined in this study and by Shine (1984a).

STUDY	*S. bertholdi*	*S. bimaculatus*	*S. calonotos*	*S. fasciolatus*	*S. semifasciatus*
Adult ♂♂	147–196(44)	244–339(15)	171–280(25)	201–306(10)	–
Adult ♀♀	172–264(33)	237–406(22)	226–254(25)	288–363(9)	–
Adult ♂♂-Shine	143–225(105)	230–403(25)	182–230(30)	202–300(18)	192–336(68)
Adult ♀♀-Shine	164–312(98)	264–406(22)	186–251(32)	231–352(13)	196–334(74)

ovarian follicles or eggs for each *Simoselaps* species in our samples from southwestern Australia was 172 mm in *S. bertholdi*, 237 mm in *S. bimaculatus*, 226 mm in *S. calonotos* and 288 mm in *S. fasciolatus*. These data are in close agreement with those of Shine (1984a).

Male reproductive maturity was assessed from a plot of testes volume on SVL and determined as occurring at a size above the smallest male with markedly enlarged testes size (Tables 1, 2). These sizes are again in close agreement with those of Shine (1984a), who used the opaqueness of efferent ducts as an additional criterion for determining maturity in males.

Reproductive Season

All females contained small ovarian follicles throughout the year, but very few females from southwestern Australia had oviductal eggs or enlarged yolked ovarian follicles.

The proportion of adult females that were reproductively active in each month of collection is presented in Figure 2. Reproductive activity generally occurred between October and February with a peak in November, December and January.

Reproductively active individual female *S. bertholdi* were recorded in November (7 eggs, 1 egg + 1 yolked follicle), December (5 yolked follicles) and January (5 eggs); reproductively active *S. bimaculatus* occurred in December (3 eggs), January (2 eggs) and February (2 yolked follicles), the two reproductively active *S. fasciolatus* were in November (4 eggs) and December (5 eggs), while two reproductively active *S. calonotos* occurred in October (4 eggs) and December (3 eggs) and another female had a small, slightly yolked follicle in May.

The volume of the testes of adult *Simoselaps* males showed no significant variation between months, except in *S. bertholdi*. In *S. bertholdi* testes volume was significantly larger in October than in November, June, September, December, January, August and April, but not other months (Table 2). In all other species the monthly sample sizes were very small and, although the largest testes volumes were recorded in spring for *S. bimaculatus*, summer for *S. calonotos* and spring-summer for *S. fasciolatus*, the monthly variation was not statistically significant (Table 2).

Diet

The food items in the stomachs of specimens from the collections of the Western Australian Museum are presented in Table 3. The majority of specimens had empty stomachs. Most of the prey items were identifiable to the species level and consisted of scincid and pygopodid lizard species. The large number of skink tails present in the stomachs were identified to species level by comparison with the extensive reference material in the collections of the Western Australian Museum.

Table 2 The testes volumes (mm^3) of adult males of each *Simoselaps* species. Data are presented by month of collection and as mean volume, standard deviation and sample size.

MONTH	*S. bertholdi*	*S. bimaculatus*	*S. calonotos*	*S. fasciolatus*
January	16.2±16.2 (2)	14.6 (1)	46.0±33.2 (5)	103.8 (1)
February	19.6 (1)	23.5 (1)	–	104.4±99.0 (2)
March	43.0±48.3 (2)	–	45.1±06.1 (2)	–
April	12.8±00.7 (3)	9.5 (1)	–	–
May	43.0±56.0 (2)	97.2 (1)	25.4 (1)	–
June	23.7±11.5 (3)	–	21.5±14.4 (5)	–
July	40.6±08.8 (2)	30.2 (1)	9.1 (1)	–
August	15.2±01.8 (2)	25.2 (1)	18.6±02.0 (3)	72.6 (1)
September	20.8±14.3 (4)	50.8±15.0 (2)	18.0±03.1 (3)	133.2 (1)
October	64.5±30.2 (6)	80.2±79.5 (4)	39.2 (1)	85.7±33.4 (2)
November	27.3±10.9 (7)	–	19.0±03.7 (3)	103.5 (1)
December	20.5±14.4 (7)	23.3±08.4 (3)	38.2 (1)	100.0 (1)

Table 3 Number of individual *Simoselaps* specimens from southwestern Western Australia with prey items in their stomachs. The number with only tails of prey species is indicated in brackets.

PREY SPECIES	*S. bertholdi*	*S. bimaculatus*	*S. calonotos*	*S. fasciolatus*
Aprasia repens	1	–	4(1)	–
Ctenotus fallens	–	–	–	1
Eremaescincus richardsonii	1	–	–	–
Hemiergis quadrilineatus	1(1)	–	–	–
Lerista elegans	6(4)	–	–	–
Lerista lineata	–	1(1)	–	–
Lerista praepedita	1(1)	–	7(2)	1(1)
Lerista lineopunctulata	1(1)	–	–	–
Menetia greyii	7	–	1	–
Plant material	1	–	–	–
Reptile egg	–	–	–	1
Stomachs with prey (tails)	**19(7)**	**1(1)**	**12(3)**	**3(1)**
Unidentifiable fragments	5	1	–	1
Total stomach examined	*117*	*52*	*62*	*28*

The majority of stomachs with food contained only a single item. However, three *S. bertholdi* specimens contained either two or three bodies of *Menetia greyii* Gray in their stomachs, while one *S. calonotos* had two *Lerista praepedita* (Boulenger) bodies and another two *L. praepedita* tails. The *Ctenotus fallens* Storr in the stomach of *S. fasciolatus* was adult. The size of *S. bertholdi* individuals with tails in their stomachs [174.0±7.0(7) mm] was not significantly different from those [185.0±13.3(11) mm] with whole prey.

The diet of *S. bertholdi* and *S. calonotos* differs substantially. The diet of the former is principally of small litter inhabiting skinks [*Lerista elegans* (Gray), *Menetia greyii*] while in the latter the diet consists principally of fossorial lizards (*Aprasia repens, Lerista praepedita*). There was insufficient information on the stomach contents of *S. bimaculatus* and *S. fasciolatus* from southwestern Australia to determine if their dietary preferences were specialised (Table 3).

DISCUSSION

Shine (1984a) determined from his detailed examination of museum specimens that all species of *Neelaps* and *Simoselaps* were oviparous. Vitellogenesis commenced in *Simoselaps* species during the late spring (October-November) followed by ovulation and oviposition during the summer months of December-January (Shine 1984a). This pattern of spring and early summer reproductive activity is reflected in most of the species examined in this study from the southwest of Western Australia. However, the period of reproductive activity in the genus may be longer than previously determined. Oviductal eggs were found in *S. calonotos* collected during October and in *S. fasciolatus* and *S. bertholdi* in November. Enlarged yolky follicles were also recorded for *S. bertholdi* in December and in *S. bimaculatus* collected as late as February. One anomalous case of a small but yolked ovarian follicle was observed in a *S. calonotos* collected in May, the same month as one *S. bertholdi* was observed with enlarged follicles by Shine (1984a).

The small sample sizes of most taxa over the reproductive season precludes a definitive assessment of the proportion of adult females reproductively active during this period. The fact that all species except *S. calonotos* have one month during the reproductive season when most females are reproductively active suggests that adult females could breed each year. The extended period over which *Simoselaps* females can be gravid supports this, as well as indicating that there could be considerable annual variation in the proximate factors determining the onset of reproduction. The evidence from this study would tend to support Shine's (1984a) suggestion that only a single clutch of eggs is produced annually.

Clutch sizes were relatively small in all species examined by Shine (1984a). By an examination of species with ten or more gravid females, he found a significant increase in fecundity with increasing size in both *S. bimaculatus* and *S. bertholdi* but not in *S. calonotos* and *S. semifasciatus*. In this study clutch size varied from 2 to 7 eggs but, although the largest females had the largest clutches in both *S. bertholdi* and *S. fasciolatus*, sample sizes of reproductive females were too small to examine the relationship between body size and clutch size.

In male *S. bertholdi* the testes volume was significantly greater in October than in almost every other month. However, in all other species males showed no significant variation in testes volume over the year, a result that may be attributable to the small sample sizes in each month.

The pronounced bias towards males in the sex ratios of *Simoselaps* captured in natural populations and noted in Table 1 is the subject of a separate study (How, unpublished data).

Many snakes have been found to be specialist predators on lizards (Shine 1991). Some only specialise on skinks, such as the small-eyed snakes [*Cryptophis nigricens* (Günther) and *C. pallidiceps* (Günther)] of eastern Australia which forage nocturnally for sleeping skinks (Shine 1984b), and the eight species of *Unechis* (Shine 1988), which have between 83% and 100% of their diet composed of scincid lizards. In the study of diets of eleven species of the small nocturnal *Neelaps* and *Simoselaps*, Shine (1984a) showed that most were predators on skinks, two also preyed on pygopodids and three specialised on the eggs of squamate reptiles.

A major finding of our study is the clear separation in the prey species of *S. bertholdi* and *S. calonotos* in southwestern Australia. The former feeds principally on epigaeic lizard species and the latter on fossorial lizard species (Table 3). This separation was not apparent in the earlier study by Shine (1984a) where a broad array of scincid and pygopodid lizard species was consumed by each species. The dietary information on *S. bimaculatus* and *S. fasciolatus* is inadequate to determine if they have a specialised dietary niche in southwestern Australia where up to six species of *Simoselaps* are broadly sympatric. However, the relative abundance of prey species has been assessed in five habitats at Bold Park near Perth, where five species of *Simoselaps* are syntopic (How, unpublished data).

One of the six sympatric *Simoselaps* species in southwestern Australia (*S. semifasciatus*) is known to be a specialist feeder on squamate eggs (Shine 1984a). The specialisation of *S. semifasciatus* to feeding on squamate eggs was a principal reason that this species was not examined along with other *Simoselaps* during this study. This species was also shown by Shine (1984a) to have the most restricted reproductive activity seasons of all the *Neelaps* and *Simoselaps* examined by him with yolked ovarian follicles restricted to the months of November and January; no oviductal eggs were recorded. This period of reproductive activity in *S. semifasciatus* coincides with the peak period of oviposition of eggs by squamate reptiles in southwestern Australia, viz. late-spring to early summer (Chapman and Dell 1985, How *et al.* 1986, 1990), while November-December is also the peak period of activity in naturally occurring populations of the species near Perth. This restricted period of peak activity by adults raises the question of the trophic pattern of hatchling *S. semifasciatus*, which should emerge after the hatching of eggs of their principal prey species in February and March.

The stomach contents of several *Simoselaps* individuals contained only tails of skinks which were not associated with any other part of the body. This demonstrates that tails are often the only body-part of the prey consumed. Tail harvesting by predators has been recorded previously by desert pygmy varanids (*Varanus gilleni* Lucas and Frost, *V. caudolineatus* Boulenger) on the tails of geckos (Pianka 1969), while *Simoselaps littoralis* on the west coast of Western Australia feeds extensively on the tails of lizards (Jennings, personal communication).

Five species of *Simoselaps* in southwestern Australia show a strong seasonality in reproductive pattern with ovulation occurring in the late spring and early summer period, a pattern similar to many other southwestern reptile taxa. It is also apparent that there is a strong dietary niche separation in at least three of the five species which may, in part, explain their sympatry in southwestern Australia.

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