Acta Herpetologica 8(1): 47-52, 2013

Going out tonight? When insular *Hierophis viridiflavus* breaks the Whip Snakes Rules

Delaugerre Michel-Jean

Conservatoire du littoral, 3, rue Luce de Casabianca F20200 Bastia, France. E-mail: m.delaugerre@conservatoire-du-littoral.fr

Submitted on: 2012, 11th November; revised on: 2013, 20th January; accepted on: 2012, 5 th February.

Abstract. *Hierophis viridiflavus* has a strong diurnal rhythm as demonstrated by many field studies. It belongs to the "Whip snakes" characterized by slender bodies, large eyes, high speed, saurophagy and diurnality. On Giraglia island (Corsica) the snakes do forage also nightly. This unexpected shift in the circadian rhythm might be related to a local adaptation to trophic requirements.

Keywords. Activity pattern shift, microinsular adaptation, Corsica, Mediterranean, nocturnal.

In insular contexts, characterized by genetic isolation and peculiar ecological constraints, animals often display geographic variations affecting their morphology such as body size and proportions, pigmentation, pattern (Case, 1978; Lomolino, 2005; Meiri, 2007; Pafilis et al., 2009; Novosolov et al., 2012); biology and ecology such as diet and foraging modes, ecological interactions, micro habitat selection and many other features of their life history traits and behaviour (Pérez-Mellado and Corti, 1993; Traveset and Sáez, 1997; Van Damme, 1999; Zuffi, 2001; Filippi et al., 2003; Olesen and Valido, 2004; Herrel et al., 2008; Delaugerre et al. 2012).

According to Shine (1980) "whip snakes" are conspicuous elements of the terrestrial snake fauna in most parts of the world. These phylogenetically unrelated taxa (families Colubridae and Elapidae), characterized by convergent evolution, display morphological, ecological and behavioural traits such as slender bodies, long tails, large eyes, alertness, diurnality, terrestriality, saurophagy, oviparity and high speed. A broad ecological study of the Western Whip Snake *Hierophis viridiflavus* (Lacépède, 1789) in central Italy (Capula et al., 1997) partially corroborated Shine's (1980) views.

We report and discuss preliminary data regarding the micro insular activity pattern shift of the Western Whip Snake, occurring on Giraglia Island.

Giraglia Island (43°01'30"N; 9°24'24"E; 10 hectares, 65 m a.s.l., distance from the main island 1.4 km) is located at the northernmost point of Corsica (Fig. 1). It was severed from the coast by sea level rise some 5000 years ago (Lambeck and Bard, 2000). The dense and low vegetation is dominated by *Allium commutatum* and *Halimione portulacoides* (with a total of 60 vascular plants, Rivière et al., 2012). It hosts two geckos *Euleptes europaea* and *Tarentola mauritanica*, one Lacertid *Podarcis tiliguerta pardii* and one Colubrid Snake *Hierophis viridiflavus* (Lanza and Brizzi, 1974). Except for *T. mauritanica*, the Giraglia herpetofauna is supposed to be native. The island is rat (and mammal) free. Nesting birds are *Calonectris diomedea*, *Larus michaellis* (since the 90's), *Phalacrocorax aristotelis desmarestii*, *Apus pallidus* and *Columba livia; Falco tinnunculus* and *Falco peregrinus* often visit the island. Giraglia has hosted a small human settlement (2-5 men and few cattle) since the end of the 16th century until the end of the 20th century when the lighthouse has been automated. Included in a site of community importance (EU), the island is a protected area. The public access is forbidden, except for the lighthouse maintenance and biodiversity monitoring.

Nocturnal investigations (initially focussed on gecko's monitoring) were performed on 12 September 2000, on 5 and 9 August 2012 and on 6 October 2012.

ISSN 1827-9635 (print)
ISSN 1827-9643 (online)

Figure 1. The Giraglia island seen from the North-East. © F. Rombaldi/assoc. Finocchiarola.

In August 2012 additional data (Table 1) were gathered by naturalists monitoring Cory's Shearwater. The moonlight was very bright in 2000 and sampling occurred during all moon phases in 2012. While rocky outcrops were thoroughly investigated with head lamp, Western Whip Snakes were seen, foraging from 19:30 h to 2:00 h. They were actively crawling on rocks, on footpaths and on vegetation, tongue flicking while slowly exploring the substrate surfaces and crevices. Two snakes were seen in 2000 and seventeen in 2012. In 2000 both were sub-adults; in 2012 all age classes were represented, with a majority of young and youngsters (Table 1). One adult was also observed inactive under exsiccated plants.

During the last fifteen years, many Italian and French publications have been devoted to various aspects of the biology and ecology of *H. viridiflavus*. These studies have been performed at different latitudes, from Vendée on the French Atlantic coast, Switzerland, to Northern and Central Italy. In all these papers the activity pattern of this snake is considered as diurnal. Capula et al. (1997) assessed a bimodal (and lower) daily activity in summer. Lelièvre et al. (2010, 2011) confirmed the diurnal habits of this thermophilous species, even radio tracked animals were only recorded during the daytime, so did Ciofi and Chelazzi, (1991) and Scali et al. (2008). Ciofi and Chelazzi (1994), who recorded activity rhythms 24 h long, also stated that "*Coluber viridiflavus* was definitely diurnal; the primary and secondary shelters were used overnight…" The recent synthesis (Vanni and Nistri, 2006; Vanni and Zuffi, 2010) asserted its diurnality; only (Santos et al., 2010) stated "Sin embargo, no es extraño observar actividad crepuscular en los meses más calurosos"(however, it is not unusual to see crepuscular activity in the warmer months).

Although no nocturnal habits were documented in literature, could these studies, performed mainly by "diurnal herpetologists", with visual encounters and some radio tracking performed only in the daytime, have missed a point? Our field data have been investigated. Intensive nocturnal searches (224 hrs) were performed in Corsica (and Sardinia), for geckos in rocky habitats and, to a lesser extent, for amphibians in wetlands. Those investigations occurred in many localities of Corsica and also on the satellite islands where the density of the Western Whip Snake is very high, as on Lavezzu island (Table 2). Except for Giraglia, only one observation of true nocturnal activity has been recorded (Bonifacio, 13 June 1983, 21:30 h, dark moon, air temperature 20.8 °C, juvenile snout vent length 33 cm, tail 8 cm). A crepuscular sighting of a young animal has also been recorded on 16 July 2006 (Cape Corse, Moulin Mattei).

The nocturnal activity of *H. viridiflavus* does not occur or is very rare. This snake appears to have a strong rhythm for a specific diel activity pattern despite seasonal changes in temperature (Gibbons and Semlitsch, 1987) and latitudinal variations. Among Western European snakes (Corti et al, 2010; Salvador and Marco, 2010), most diurnal species (16) are variable; they adjust their circadian rhythm to season and environmental temperature with crepuscular or nocturnal foraging in sum-

Table 1. Nocturnal activity of *Hierophis viridiflavus* sighted (or captured) on Giraglia Island on 2012 (5 and 9 August and 6 October M. Delaugerre; 12 to 22 August A. Prudor and N. El Ksabi). In August night air temperature range 23-25 °C; relative hygrometry 73-82%; in October night air temperature range 18-19 °C; relative hygrometry 68-83%.

Date	Universal Time	Micro habitat	Approximative age class	SVL (cm)	Tail (cm)	Weight (g)	Body temperature (°C)
05/08/12	21:43	Lighthouse pavement	Juvenile	26.0	8	4.2	
05/08/12	1:10	Rocks	Juvenile				
05/08/12	1:40	Rocks	Adult	69.0	24		
09/08/12	20:07	Footpath	Adult	71.0	26		
09/08/12	21:12	Stone wall	Sub adult	55.6	20	38	
12/08/12	19:40	Stone wall	Sub adult				
13/08/12	20:30	Vegetation	Sub adult				
14/08/12	23:49	Lighthouse pavement	Adult	72.5	23.5		
15/08/12	0:00	Lighthouse pavement	Juvenile				
15/08/12	22:15	Footpath	Juvenile				
17/08/12	19:30	Footpath	Juvenile				
19/08/12	20:00	Vegetation	Juvenile				
19/08/12	20:40	Vegetation	Juvenile				
21/08/12	23:15	Footpath	Sub adult				
06/10/12	18:50	Stone wall	Sub adult	44.0	14.0	17	28.0
06/10/12	18:45	Rocks	Juvenile	29.0	9.5	6.5	25.8
06/10/12	23:25	Footpath	Sub adult	50.5	19.5	24	26.0

mer, whereas other species are strictly diurnal (eight) or nocturnal (two). These later species (including *H. viridiflavus*) having supposedly an activity pattern "genetically determined to the extent that their response to the light-dark is endogenous and invariable" (Gibbons and Semlitsch, 1987). The nocturnal activity reported on Giraglia island is an outstanding exception. There, young and also adult snakes (Corsican Whip Snakes are small sized according to Cheylan, 1992 and Vanni and Zuffi, 2010) forage also nightly, and not only during the hottest months. This enlargement of the activity spectrum isn't related to the moon phase, nor to the light intensity. Although these preliminary data will need further study, they raise an array of questions.

Taking into account, at a broad level, the value of a phylogenic perspective in understanding patterns of evolution in behavior, morphology and physiology (Autum et al, 2002) and also the suggested possibility that nocturnality might be the primitive condition of squamates (Sites et al., 2011), we consider that the observed enlargement of the temporal niche probably results of a rather recent local insular microevolution.

Hypotheses for possible advantages of such nocturnal shift may be related to: 1) avoidance of diurnal predators; 2) avoidance of high temperatures; 3) easier acquirement of preferred/available food at night; or combination of these factors (Crawford, 1934; Gibbons and Semlitsch, 1987).

1) Avoidance of diurnal predators. *Falco tinnunculus* is well known to predate young and subadult snakes. But empirical observations (to be confirmed) suggest that whip snakes of all age classes are also pretty active in the daytime. Furthermore, during the *Larus michahellis* nesting season, the *F. tinnunculus* avoids the island. Nevertheless if a strong interaction between whipsnakes and this raptor is not likely to occur nowadays, we cannot discard its occurrence during the past history of the island. 2) Avoidance of high temperatures. *H viridiflavus* is a thermophilous species and the island is complex enough (rocky outcrops, soil, low but thick vegetation) to provide natural shelters with medium temperatures. 3) Easier acquirement of prey. The prey items available are mostly *Podarcis tiliguerta* lizards (high density), the nocturnal gecko *Euleptes europaea*, Invertebrates and presumably passerine birds in spring migration. Should the microinsular limitation of prey type diversity lead to increase the intraspecific competition for food between young and adult snakes and thus favor an enlargement of the temporal niche for the younger snakes? (see Luiselli, 2006 for tropical vipers in a context of habitat alteration). But these intraspecific interactions are less likely to occur with high density (= availability) of the main food resource (lizards). An alternative hypothesis would be a local adaptation to a peculiar behavior of the prey. On Giraglia island, *Podarcis* lizards are often resting by

Table 2. Nocturnal investigations performed in Corsica (and Sardinia) from 1980 to 2012. Sighting per Unit Effort (SPUE) = n / (TO)100; where n = number of *H. viridiflavus* sighted; T = duration of searches in minutes; O = number of observers.
Observers: if n = 1= M-J. Delaugerre and M. Biaggini (Caprera 2012, Lavezzu 2010, 2011, 2012), Ch.-H. Bianconi (Gargalu 1985); C. Corti (Caprera 2012, Lavezzu 2010, 2011, 2012); F. Grita (Lavezzu 2010, 2012), P. Lo Cascio (Caprera 2012, Lavezzu 2010, 2012). Some of the Giraglia data of Tab 1 are not reported here because SPUE could not be calculated.

Locality	Year	Month	N minutes prospection	N obs.	N minutes observation	Snakes sighted	**SPUE**
Corsican satellite islands							
Giraglia island (N Corsica)	2000	9	360	1	360	2	0.556
Giraglia island (Corsica)	2012	8	406	1	406	5	1.232
Giraglia island (Corsica)	2012	10	260	1	260	3	1.154
Lavezzu island (S Corsica)	1982	5	300	1	300	0	0.000
Lavezzu island (S Corsica)	1984	9	120	1	120	0	0.000
Lavezzu island (S Corsica)	2010	6	275	2	550	0	0.000
Lavezzu island (S Corsica)	2011	6	427	1	427	0	0.000
Lavezzu island (S Corsica)	2012	6	180	4	720	0	0.000
Mezzumare island (W Corsica)	2011	6	180	1	180	0	0.000
Mezzumare island (W Corsica)	2012	8	213	1	213	0	0.000
Gargalu island (W Corsica)	1985	4	530	2	1060	0	0.000
Gargalu island (W Corsica)	1990	7	505	1	505	0	0.000
Corsica main island							
Trinité (Bonifacio, S)	1983	6	300	1	300	1	0.333
Acciola (Sartene, SW)	1980	5	60	1	60	0	0.000
Conca-Senetosa (SW)	1986	8	180	1	180	0	0.000
Pianottoli (S)	1986	8	120	1	120	0	0.000
Galeria (W)	1981	5	60	1	60	0	0.000
Galeria (W)	1983	4	60	1	60	0	0.000
Galeria (W)	1982	5	60	1	60	0	0.000
Galeria (W)	1985	4	180	1	180	0	0.000
Galeria (W)	1985	7	180	1	180	0	0.000
Galeria (W)	1986	4	130	1	130	0	0.000
Scandola (W)	1982	5	2105	1	2105	0	0.000
Scandola (W)	1982	6	1465	1	1465	0	0.000
Scandola (W)	1983	4	595	1	595	0	0.000
Scandola (W)	1983	6	490	1	490	0	0.000
Scandola (W)	1985	7	100	1	100	0	0.000
Villanova (Ajaccio, W)	1981	5	810	1	810	0	0.000
Villanova (Ajaccio, W)	1981	6	125	1	125		0.000
Piana (W)	1981	5	60	1	60	0	0.000
M.on Forestière Lumio (1000m)	1981	5	60	1	60	0	0.000
A Serra (Calvi, W)	1981	5	60	1	60	0	0.000
Lucciana (NE)	1985	4	60	1	60	0	0.000
Capandula (Cap Corse, N)	2012	8	270	1	270	0	0.000
Sardinia							
Itiri (Sardinia)	1982	6	90	1	90	0	0.000
Caprera island (Maddalena, N)	2012	5	240	3	720	0	0.000
Sum in minutes			11,616		13,441		
Sum in hours					224		

night in very exposed spots, not hidden in refuges, while *E. europaea*, a slow moving gecko, forages on rock surfaces. Snakes might have learned a way to easily pick some preys by night. If so, it would mean an important ecologic change in an evolutionary perspective: the quick pursuit foraging strategy (Capula et al., 1997), relying on diurnal vision, being replaced by a slow search conducted by nocturnal vision or/and by the use of chemosensory cues. Chemical scents would be used for the localization of the prey, as males are able to do for trailing and sexually discriminate conspecifics (Fornasiero et al., 2007). In snakes, saurophagy is compatible with nocturnality, for instance in *Coronella* and *Macroprotodon* (Cheylan, 1986). As stated by Shine (1980): "Apart from *Demansia*, the only Australian elapids that definitely are known to feed primarily on lizards (> 70% of the diet) are small fossorial nocturnal species… All of these fossorial saurophagous snakes capture their prey at night when the lizards are inactive (an African elapid… forages in the same way…). Prey items probably are located by scent… This foraging strategy is fundamentally different from that of the whipsnakes, which locate their prey items visually, during the day, and capture them by direct chasing."

The expression of adaptative "inventiveness" is highly stimulated in microinsular context, is that the reason why the Giraglia Island' *H. viridiflavus* have broken the Whip Snakes Rules?

ACKNOWLEDGMENTS

The access to the island was permitted by the Préfecture de Haute-Corse and the "phares et balises" authorities. Collection permits were issued by the Dreal Corse. Thanks to Aurélien Prudor and Nory El Ksaby for their interest and valuable help in the field. Thanks to Claudia Corti for the experienced comments on the manuscript and to the editor and the reviewers.

REFERENCES

Autumn, K., Ryan, M. J., Wake, D. B. (2002): Integrating historical and mechanistic biology enhances the study of adaptation. Q. Rev. Biol. **77**: 383-408.

Capula, M., Filippi, E., Luiselli, L., Trujillo-Jesus, V. (1997): The ecology of the Western Whip Snake (*Coluber viridiflavus* Lacépède, 1789) in Mediterranean Central Italy. Herpetozoa **10**: 65-79.

Case, T.J. (1978): A general explanation for insular body size trends in terrestrial vertebrates. Ecology **59**: 1-18.

Cheylan, M. (1986): Mise en évidence d'une activité nocturne chez le serpent méditerranéen *Elaphe scalaris* (Ophidia, Colubridae). Amphibia-Reptilia **7**: 181-186.

Cheylan, M. (1992): Couleuvre verte et jaune *Coluber viridiflavus*. In: Atlas de répartition des Batraciens et Reptiles de Corse, pp. 78-81. Delaugerre M., Cheylan M., Eds, Ecole Pratiques Hautes Etudes, Ajaccio Parc naturel régional de Corse.

Ciofi, C., Chelazzi, G. (1991): Radiotracking of *Coluber viridiflavus* using external transmitters. J. Herpetol. **25**: 37-40.

Ciofi, C., Chelazzi, G. (1994): Analysis of homing pattern in the colubrid snake *Coluber viridiflavus*. J. Herpetol. **28**: 477-484.

Corti, C., Capula, M., Luiselli, L., Razzetti, E., Sindaco, R. (2010): Fauna d'Italia, Reptilia. Edizioni Calderini de Il Sole 24 ORE, Milano.

Crawford, S. C. (1934): The habits and characteristics of nocturnal animals. Q. Rev. Biol. **9**: 201-214.

Delaugerre, M., Grita, F., Lo Cascio, P., Ouni, R. (2012): Lizards and Eleonora's Falcon (*Falco eleonorae* Gené, 1839), a Mediterranean micro-insular commensalism. Biodivers. J. **3**: 3-12.

Filippi, E., Capula, M., Luiselli, L. (2003): Dietary shifts in the Western Whip Snake *Coluber viridiflavus* Lacépède, 1789, of the small Mediterranean island of Ustica (Squamata: Serpentes: Colubridae). Herpetozoa **16**: 61-66.

Fornasiero, S., Bresciani, E., Dendi, F., Zuffi, M.A.L. (2007): Pheromone trailing in male European whip snake, *Hierophis viridiflavus*. Amphibia-Reptilia **28**: 555-559.

Gibbons, J.W., Semlitsch, R.D. (1987): Activity patterns. In: Snakes: Ecology and Evolutionary Biology, pp. 396-421. Seigel R.A , Collins J.T., Novak Y.Y, Eds, Mc Millan, New York.

Herrel, A., Huyghe, K., Vanhooydonck, B., Backeljau, T., Breugelmans, K., Grbac, I., Van Damme, R., Irschick, D.J. (2008): Rapid large-scale evolutionary divergence in morphology and performance associated with exploitation of a different dietary resource. P. Natl. Acad. Sci**.** USA **105**: 4792-4795.

Lambeck, K., Bard, E. (2000): Sea-level change along the French Mediterranean coast for the past 30,000 years. Earth Planet. Sc. Lett. **175**: 203-222.

Lanza, B., Brizzi, R. (1974): On two new Corsican microinsular subspecies of *Podarcis tiliguerta* (Gmelin, 1789) (Reptilia: Lacertidae). Natura **65**: 155-193.

Lelièvre, H., Blouin-Demers, G., Bonnet, X., Lourdais, O. (2010): Thermal benefits of artificial shelters in snakes: A radiotelemetric study of two sympatric colubrids. J Therm. Biol. **35**: 324-331.

Lelièvre, H., Blouin-Demers, G., Pinaud, D., Lisse, H., Bonnet, X., Lourdais, O. (2011): Contrasted thermal preferences translate into divergences in habitat use and realized performance in two sympatric snakes. J. Zool. **284**: 265-275.

Lomolino, M. V. (2005): Body size evolution in insular vertebrates: generality of the island rule. J. Biogeogr. **32**: 1683-1699.

Luiselli, L. (2006): Broad geographic, taxonomic and ecological patterns of interpopulation variation in the dietary habits of snakes. Web Ecol. **6**: 2-16.

Meiri, S. (2007): Size evolution in island lizards. Global Ecol. Biogeogr. **16**: 702-708.

Novosolov, M., Raia, P., Meiri, S. (2012): The island syndrome in lizards. Global Ecol. Biogeogr. **22**: 184-191.

Olesen, J. M., Valido, A. (2004): Lizards and birds as generalized pollinators and seed dispersers of island plants. In: Ecología insular/island ecology, pp: 229-249. Fernández-Palacios J.M., Morici C. Eds, AEET, Cabildo Insular de La Palma.

Pafilis, P., Meiri, S., Foufopoulos, J., Valakos, E. (2009): Intraspecific competition and high food availability are associated with insular gigantism in a lizard. Naturwissenschaften **96**: 1107-1113.

Pérez-Mellado, V., Corti, C. (1993). Dietary adaptations and herbivory in lacertid lizards of the genus *Podarcis* from western Mediterranean islands (Reptilia: Sauria). Bonn. Zool. Beitr. **44**: 193-220.

Rivière, V., Damery, C., Delaugerre, M., Aboucaya, A., Faggio, G., Passetti, A., Pavon, D., Piazza, C., Ponel, P. (2012): 43e parallèle, de Bagaud à la Pointe du Cap Corse: mieux appréhender le fonctionnement des écosystèmes microinsulaires et la place des espèces introduites et invasives. Edition PIM. http://www.initiative-pim.org/sites/default/files/fichier/documents/RAPPORT%20MISSION%20CORSE%202011%20vf_0.pdf

Salvador, A., Marco, A. (2012): Enciclopedia Virtual de los Vertebrados Españoles. Museo Nacional de Ciencias Naturales, Madrid. <www.vertebradosibericos.org> accessed 19/01/2013

Santos, X., Roig, J. M., Montori, A. (2010): Culebra verdiamarilla–*Hierophis viridiflavus* (Lacépède, 1789). In: Enciclopedia Virtual de los Vertebrados Españoles (Salvador, A., Marco, A.). Madrid: Museo Nacional de Ciencias Naturales. http://www.vertebradosibericos.org/reptiles/hievir.html

Scali, S., Mangiacotti, M., Bonardi, A. (2008): Living on the edge: habitat selection of *Hierophis viridiflavus*. Acta Herpetol. **3**: 85-97.

Shine, R. (1980): Ecology of eastern Australian whipsnakes of the genus *Demansia*. J. Herpetol.**14**: 381-389.

Sites Jr, J. W., Reeder, T. W., Wiens, J. J. (2011): Phylogenetic insights on evolutionary novelties in lizards and snakes: sex, birth, bodies, niches, and venom. Annu. Rev. Ecol. Evol. Syst. **42:** 227-244.

Traveset, A., Sáez, E. (1997): Pollination of *Euphorbia dendroides* by lizards and insects: spatio-temporal variation in patterns of flower visitation. Oecologia **111**: 241-248.

Van Damme, R. (1999): Evolution of herbivory in lacertid lizards: effects of insularity and body size. J. Herpetol. **33**: 663-674.

Vanni, S., Nistri, A. (2006): *Hierophis viridiflavus* (Lacépède, 1789). In: Atlante degli anfibi e dei rettili d'Italia/Atlas of Italian amphibians and reptiles, pp. 544-547. Sindaco R., Doria G., Razzetti E. and Bernini F., Eds, Polistampa, Firenze.

Vanni, S., Zuffi, M.A.L. (2010): *Hierophis viridiflavus* (Lacépède, 1789). In: Fauna d'Italia, Reptilia, pp 509-516. Corti, C., Capula, M., Luiselli, L., Razzetti, E., Sindaco, R., Eds, Edizioni Calderini de Il Sole 24 ORE, Milano.

Zuffi, M.A.L. (2001): Diet and morphometrics of *Coluber* (=*Hierophis*) *viridiflavus* on the island of Montecristo (Tyrrhenian Sea, Italy). Herpetol. J. **11**: 123-125.