The establishment of the crested tree lizard, *Calotes versicolor* (DAUDIN, 1802) (Squamata: Agamidae), in Seychelles

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Abstract.— There is evidence that the Asian agamid *Calotes versicolor* (DAUDIN, 1802), the crested tree lizard, is now established on Ste Anne Island in Seychelles, and it is reported to be dispersing away from its original point of introduction. Data collected outside Seychelles on its habitats, reproductive biology and feeding habits show that this species is adaptable, prolific and omnivorous, and it is considered to be an invasive alien species that competes with or feeds on native biota in some parts of the world, such as Singapore and Mauritius. The Ste Anne population needs to be studied and, if possible, eradicated, to prevent this potential ecological threat from reaching other islands in Seychelles, especially those that harbour significant populations of native animals.

Keywords.— *Calotes versicolor*, Seychelles, Ste Anne, invasive alien species.

INTRODUCTION

The crested tree lizard, *Calotes versicolor* (DAUDIN, 1802), is a strong candidate for the status of most widespread non-Gekkonid lizard in the world. GÜNTHER (1864) noted: "This is one of the most common lizards, extending from Afghanistan over the whole continent [sic] of India to China; it is very common in Ceylon [=Sri Lanka]…" Its present distribution stretches from Oman to the west (LOMAN 1997; SEUFER *et al.*. 1999) (the following in SAVY (1982) is presumably a reference to Oman: "… more recently the British Museum was sent a specimen from southern Arabia") right across southern and south-east Asia to Indo-China to the east (STUART 1999), the Maldives (HASEN DIDI 1993), Réunion (PERMALNAÏCK 1993), Mauritius (STAUB 1993), (including Rodrigues (BLANCHARD 2000)), Seychelles (MATYOT 2003) and Florida in the United States (ENGE & KRYSKO 2004). With growing evidence that *C. versicolor* is an invasive species with potentially harmful ecological impacts in the areas where it is introduced (DIONG *et al.*. 1994; MAUREMOOTOO *et al.* 2003), largely because of its omnivorous feeding habits, it is necessary to gather together the available, albeit limited, information on the status of its presence in Seychelles. At the same time the opportunity is taken to review the existing literature on the ecology of the species with a view to summarizing the available data as a basis for further research on its status as a potential threat. (Among the various common English names used for this species (garden lizard, bloodsucker, etc.) "crested tree lizard" is felt to be the most appropriate in the Seychelles context, to avoid confusion with other species found in gardens, so as not to perpetuate superstitious beliefs, etc.)

METHODS

Video footage of a specimen caught on Mahé in October 2003 filmed by the Seychelles Broadcasting Corporation (SBC) on November 6th 2003 (RACOMBO 2003) was viewed, and interviews were carried out with environment officers and others who have

been involved in sightings of specimens. Photographs of the Mahé specimen filmed by the SBC were sent to two authorities on the genus *Calotes*, HIDETOSHI OTA (Japan) and SCOTT MOODY (USA), who both confirmed it to be *C. versicolor*. (OTA, *pers. comm*. 2003; MOODY, *pers. comm*. 2003). A literature search was undertaken to find all references to *C. versicolor* in Seychelles, as well as references to the ecology of the species worldwide.

Presence in Seychelles

The first observation of *C. versicolor* in Seychelles dates back to the 27th of September 1982 at Barbarons on Mahé island when "a strange lizard … was found resting in the grass by a young man who handed it over to the Ministry of Agriculture" (Anon. 1982). The specimen measured 38.6 cm long, including the tail, and was therefore probably a fully-grown individual (DIONG *et al.*. 1994). It was sent to the Natural History Museum in London, where it was identified as *C. versicolor* (SAVY 1982). In the mid 1980s ("about 1985-1986") a Seychellois offered to sell two specimens that he said he had found on Mahé to a visiting American herpetologist, RONALD NUSSBAUM, but refused to provide information on where he had captured the lizards when the offer was turned down (NUSSBAUM, pers. comm., 2004). There were no further reports of *C. versicolor* in Seychelles until October 2003, when a specimen was discovered on a *Hibiscus* sp. bush near Anse aux Pins clinic on Mahé (JEANNE MORTIMER, *pers. comm*. 2003; RACOMBO 2003; MATYOT 2003). It was identified as *C. versicolor* by its dorso-nuchal crest, the two widely separated spines on either side of the head above the tympanum, and the absence of any fold or pit in front of the shoulder (OTA, *pers. comm*. 2003). This, the only recent Mahé record, was followed by further sightings, on a regular basis from November 2003 onwards, in the vicinity of the hotel on Ste Anne island, 5 km from Port Victoria on Mahé (LENA DESAUBIN, RODNEY FANCHETTE & MAURICE LOUSTAU-LALANNE, *pers. comm*. 2003; MATYOT 2003), providing evidence that *C. versicolor* is now firmly established on Ste Anne: in November 2003 there were both sexes there, including at least one male seen in breeding coloration (anterior part of the body, including the head, orange-red with a black patch on each side of the throat) and a gravid female that had been crushed by a vehicle, with the eggs that it had been carrying very much in evidence. On January 16th 2004 the Ministry of Environment and Natural Resources announced a bounty of fifty Seychelles rupees for every specimen of *C. versicolor* caught (Anon. 2004). Latest reports speak of crested tree lizards having been observed in parts of Ste Anne away from where the hotel is situated (RODNEY FANCHETTE, *pers. comm*. 2004).

It is not certain how *C. versicolor* was introduced to Seychelles. In view of the long gap of 17-18 years between the 1985-1986 and 2003 sightings, there may have been two separate introductions, an earlier one on Mahé that did not last and a more recent one on Ste Anne that has been successful. One connection between Ste Anne and Anse aux Pins, the locality for the only recent Mahé sighting, is that some of the expatriate hotel personnel working on Ste Anne is known to have accommodation quarters at Anse aux Pins. Unintentional transport by humans is a very strong possibility – it is certainly believed to have played a big role in the spread of *C. versicolor* elsewhere, e.g. the crested tree lizard is said to have been introduced to Réunion island in around 1865 as a stowaway in a shipment of sugarcane (*Saccharum officinarum*, Poaceae) cuttings from Java, Indonesia (PERMALNAÏCK 1993; STAUB 1993). In Florida, USA, however, *C. versicolor* escaped

from a reptile dealer in 1978 (ENGE &KRYSKO 2004).

Review of literature on ecology of C. versicolor

Since the 1970s *C. versicolor* has gained importance as a laboratory animal, and researchers in Asia in particular have been using it as a subject for a broad spectrum of biological studies. This has resulted in a considerable output of literature on anatomy (e.g. PARANJAPE 1974), morphometrics (e.g. TIWARI & SCHIAVINA 1990), endocrinology (e.g. GANESH & RAMAN 1995; SHANBHAG *et al.* 2000), embryology (e.g. MUTHUKKARUPPAN *et al.* 1970; JI *et al.* 2002) and cytology (e.g. OTA *et al.* 2000). However, there is relatively little published material on the ecology of *C. versicolor*. This is surprising in view of its recognized status as an invasive species that is extending its range and, in some colonized areas at least, is impacting negatively on native biodiversity (DIONG *et al.*. 1994; MAUREMOOTOO *et al.* 2003). The best general account of the species, based on original fieldwork in Singapore, is that of DIONG *et al.* (1994).

On the other hand, several of the laboratory-based studies referred to above have produced findings on the biology of *C. versicolor* that shed light on key aspects of its ecology.

Cytology.— OTA *et al.* (2000) have suggested the presence of cryptic taxonomic diversity in *C. versicolor*, i.e. that "*C. versicolor*" could in fact be a complex of different species, after the karyotype they worked out did not match those recorded by previous studies. It would be interesting to carry out a study of karyotypes from specimens caught in Seychelles and elsewhere in the western Indian Ocean to possibly elucidate the provenance of the Seychellois population.

Habitats.— Being a semi-arboreal, sun-loving lizard that spends a lot of time on tree-trunks and rocks, *C. versicolor* has a predilection for open scrubland, wasteland, gardens, parks and other "man-made habitats" in Asia (DIONG *et al.* 1994; ERDELEN 1984). STUART (1999) reports that it is found on low vegetation in open forest or disturbed areas near human habitation in Laos. In a study of diurnal lizards in the city of Karachi in Pakistan, it was the second most numerous species (KHAN & MAHMOUD 2003). In Réunion, Mauritius and Rodrigues it favours areas of "grassy savannah", such as that on the west coast of Réunion (BLANCHARD 2000) as well as cemeteries and along roadsides (PERMALNAÏCK *et al.* 1993). In Florida, USA specimens have been collected in an area of grasses and weeds in the vicinity of a canal running along a dirt road (ENGE & KRYSKO 2004). The species appears not to favour dense forest with closed canopies (PERMALNAÏCK *et al.* 1993; DIONG *et al.* 1994; PAWAR 1999). ERDELEN (1984) found it to be most abundant in the driest parts of Sri Lanka. It is reported to occur from sea level to an altitude of 600m (STUART 1999) or even 1,000 metres (DIONG *et al.* 1994). It has a sit-and-wait hunting strategy, usually watching for prey from a vantage point on a tree-trunk, but moving into the shade, including among high grasses, when it gets too hot; adult males stay in the open more often to exercise territoriality, while adult non-breeding females and, especially, juveniles tend to forage on the ground in grassy and shrubby vegetation (DIONG *et al.* 1994; SUNDERASAN & DANIELS 1994). In one study (SUNDARESAN & DANIELS 1994) an adult male was found on the same tree on 15 occasions. *C. versicolor* is reported to be able to swim in both fresh and sea water (PERMALNAÏCK *et al.* 1993). In Florida, USA

Table 1: Aspects of the reproductive biology of *Calotes versicolor*

	VARMA & GURAYA (1975) [India]	DIONG *et al.* (1994) [Singapore]	RADDER *et al.* (2002a, 2002b) [India]	RADDER & SHANBHAG (2004) [India]	JI *et al.* (2002a, 2002b) [China]	ENGE & KRYSKO (2004) [Florida, USA]
Breeding season	June - September		May - October	May - October	April - June	gravid female captured in August
Clutch size	10-32 (highest number for an Agamid)	to 22, depending on age & size of female	12-21 (mean 17)	11-29 (mean 19; clutches smaller in late breeding season)	3-14 (mean 9)	19 oviductal eggs in a dissected female
Optimum incubation conditions		moist soil in shade	soil or sand, 27±2°C with exposure to 35° C for 1-3 hours per day	moist soil at 27±2°C	27-30°C	
Incubation period		40-60 days, depending on temperature		70±5 days	60.5 days (27°C) & 51.4 days (30°C)	
Maturation period (from hatching to sexual maturity)		9-12 months				

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(ENGE & KRYSKO 2004) as well as in Mauritius (*pers. obs.*) *C. versicolor* roosts on vegetation at night, up to 9m from the ground, usually at the tips of twigs, shoots and inflorescences.

Reproductive biology.— Aspects of the reproductive biology of *C. versicolor*, a multiclutched seasonal breeder in India (SHANBHAG 2003), are summarized in Table 1. To BHAGYASHRI SHANBHAG and his colleagues at the Department of Zoology of Karnatak University in India we owe a series of studies that have revealed an array of reproductive strategies that help to explain the adaptability of the crested tree lizard (SHANBHAG 2003), among which are the following:

a) the variation of clutch and egg size depending upon the time of breeding: towards the end of the breeding season clutches are smaller and eggs larger; production of heavier hatchlings at the end of the breeding season may enhance their chance of survival in competition for food, shelter, etc with older offspring from earlier clutches;
b) the storage of viable sperm by the female for as long as six months, eliminating the need for repeated mating; and
c) the retention of eggs in the oviduct for six months or even more when conditions are not suitable for oviposition.

Feeding.— Records of prey and other food items of *C. versicolor*, most of them based on observations in India, are summarised in Table 2. It would seem that the crested tree lizard is predominantly insectivorous (according to DIONG *et al.* 1994, "analysis of stomach contents [in Singapore] reveals a diet comprising mainly ants, larval and adult insects, and other small invertebrates"), but it is clearly an opportunistic omnivore that can prey on small vertebrates and feed on plant material as well. One particularly interesting observation (KALITA 2000) is of a crested tree lizard charging and attempting to bite an Oriental magpie robin (*Copsychus saularis*) in a fight over a centipede (*Scolopendra* sp.).

Predators.— *C. versicolor* is in turn preyed upon by a number of carnivorous reptiles, birds and mammals. Published records of predators are summarised in Table 3.

Parasites.— The literature on the parasites of *C. versicolor* is extensive (e.g. DIONG *et al.* 1999; GOLDBERG *et al.* 2003; SATHYANARAYANA & PREMAVATHY 1994; SCHMASCHKE *et al.* 1997) The range of identified ecto- and endoparasites is shown in Table 4, but this is far from an exhaustive list. There may be interactions between parasites: for example, mites have been shown to transmit a species of *Schellackia* (Apicomplexa) to other lizards (BONORRIS & BALL 1955).

Discussion of status as an ecological threat

The continuing extension of the range of *C. versicolor* outside Asia, to the Middle East, the western Indian Ocean and Florida in the United States, is due to a combination of intentional and unintentional transport and introduction by humans. At the same time, the alteration of natural habitats through anthropogenic factors, including deforestation, must have created suitable habitats for the species where there were none before.

Food item	Locality	Source
Earthworms (Oligochaeta)	India	SHARMA 2002
Millipedes (Diplopoda), including *Proterosperhormage* sp.	India	AHMED 1984
Centipedes (Chilopoda), including (1) *Rhysida* sp. & (2) *Scolopenda* sp.	India	(1) AHMED 1984; (2) KALITA 2000
Dragonflies (Odonata)	India	MITRA 1996
Orthoptera, including grasshopper *Chrotogonus* sp. (Acridoidea: Pyrgomorphidae)	India	CHANDRA 1983; BHANOTAR & SRIVASTAVA 1985
Termites (Isoptera), including *Microtermes obesus* Holmgren 1913	India	PARIHAR 1978; MANAKADAN 1993
Wasps (Hymenoptera: Vespoidea)	India	BHATTI 1988
Ants (Hymenoptera: Formicidae)	Singapore	DIONG *et al.*. 1994
Frogs	India	DANIEL 1983
Small birds	India	DANIEL 1983
Eggs of weaver birds (Aves: Passeridae): Baya weaver (*Ploceus philippinus*), black-throated weaver (*P. benghalensis),* streaked weaver (*P. manyar*)	India	DHINDSA & TOOR 1983

Adult house sparrow (*Passer domesticus*) (Aves: Passeriformes: Passeridae)	India	PARALKAR 1995
Brook's gecko (*Hemidactylus brooki*) (Squamata: Gekkonidae)	India	SHARMA 1992b
Young Indian wolf snake (*Lycodon aulicus* (Squamata: Colubridae)	India	SHARMA 1999
Hatchlings of flying dragons (*Draco volans*) (Squamata: Agamidae)	Singapore	DIONG *et al.*. 1994
Hatchlings/juveniles of *C. versicolor* (i.e. cannibalism)	(1) India; (2) Singapore	SHARMA 1992a; (2) DIONG 1994
Plant material, including (1) unripe pods with soft seeds of Lima bean (*Phaseolus lunatus*, Papilionaceae); (2) buds & flowers of *Tabernaemontana* sp. (Apocynaceae); (3) germinating seeds of *Feronia limonia* (Rutaceae); (4) dry leaves of mango (*Mangifera indica*) (Anacardiaceae); (5) flowers of *Cassia marginata* (Caesalpiniaceae) and *Morinda tinctoria* (Rubiaceae); and (6) young shoots of cowpea (*Vigna sinensis*) (=*Vigna unguiculata*) (Papilionaceae) chewed but not swallowed, possibly as a source of water	India	BHATTI, BATTI & BATTI 1988; (1) DANIEL & SHULL 1963; (2) SEKAR 1988; (3) SHARMA 1994; (4) SHARMA 1998; (5) AENGALS 2000 (6) DEVASAHAYAN & DEVASAHAYAN 1989
Faeces of iguana (Squamata: Agamidae)	India	RAJARATHINAM & KALAIARASAN 1999

Table 2: Recorded food items of *C. versicolor*

Table 3: Recorded predators of *C. versicolor*

Predator	Locality	Source
Indian wolf snake (*Lycodon aulicum*) (Squamata: Colubridae)	Réunion	GUILLERMET 2004
Rat snake (*Ptyas mucosas*) (Squamata: Colubridae)	India	MUNDKUR 1986
Keeled grass skink (*Mabuya carinata*) (Squamata: Scincidae)	India	VYAS 1988
Pariah kite (*Milvus migrans*) (Aves: Accipitridae)	India	PITTIE 1998
Jungle crow (*Corvus macrorhynchus*) (Aves: Corvidae)	India	KALAIARASAN & RAJARATHINAM 1997
Mynahs (Aves: Sturnidae)	Singapore	DIONG *et al.* 1994
Jungle babbler *Turdoides striatus* (Aves: Sylviidae)	India	PARASHARYA & MATHEW 1994

Table 4: A selection of parasites recorded from *C. versicolor*

Parasite	Site of infection in host	Source
Tongue worm *Raillietiella gehyrae* (Pentastomida: Cephalobaenida)	Lungs	DUTTA & MANNA 1995
Scale mite *Pterygosoma neumanni* (Acarina: Pterygosomidae)	Beneath imbricating scales of body tegument & tympana	DIONG & HO 2001
Fluke *Paradistomum orientalis* (Trematoda: Dicrocoelidae)	Gall bladder	MADHAVI *et al.* 1998
Protozoan (Apicomplexa) *Isospora lacertae* (Coccidia: Eimeriidae)	Intestine? (Oocysts found in faeces)	SAUM *et al.*. 1997
Protozoan (Apicomplexa) *Schellackia calotesi* (Coccidia: Lankesterellidae)	Intestine? (Sporozoites found in blood & liver)	FINKELMAN & PAPERNA 1998
Flagellate protozoan *Proteromonas krishnamurtyi* (Slopalinida: Proteromonadidae)	Rectum	SARATCHANDRA & RAMESH BABU 1982

Surprisingly, although it is an adaptable, prolific and omnivorous species, its impact on native biodiversity does not appear to have been scrutinized very closely in the localities where it has become established. However, DIONG *et al.* (1994) have drawn attention to the fact that in Singapore it has "to some extent" displaced the native green crested lizard, *Bronchocela cristatella* (KUHL, 1820); and MAUREMOOTOO *et al.* (2003) include *C. versicolor* in their list of introduced vertebrates thought to have a significant impact on native biodiversity in Mauritius: they state that it competes with native geckos and consumes native invertebrates. VINSON (1968) speculated that *C. versicolor* may have been responsible for the disappearance or rarefaction of phasmids (Insecta: Phasmatodea) in both Mauritius and Réunion. Crested tree lizards have been observed in localities where phasmids have become less common in Réunion: this is the case for *Heterophasma*

multispinosa in the uplands of Saint Joseph and *Monandroptera acanthomera* at Mare Longue (NICOLAS CLIQUENNOIS, *pers. comm*. 2003). In the United States, there is apprehension that "*Calotes versicolor* is yet another exotic species that may compete with or prey upon Florida's native species" (ENGE & KRYSKO 2004).

In Seychelles, potentially suitable habitat for the crested tree lizard is found in coastal areas and perhaps even on some of the high-altitude "inselbergs" of the inner, granitic, islands as well as extensively in the outer, coralline, islands. While Ste Anne, its present focal point, is itself not a high-value island in terms of terrestrial fauna and flora, if *C. versicolor* were to disperse to other islands this could represent a serious new threat to native biodiversity, with prey records from India and elsewhere (Table 2) showing the wide range of groups of organisms that could be threatened. The smaller, rat-free islands with extensive seabird colonies and populations of endemic terrestrial birds, invertebrates, amphibians (Caecilidae on Frégate) and reptiles (GERLACH 1997) would seem particularly vulnerable. It is not clear to what extent the parasites harboured by *C. versicolor* are host-specific, i.e. whether some of them, at least, can infect native lizards like skinks (*Mabuya* spp.) and geckos (e.g. *Phelsuma* spp.) as well. It is likely that in Seychelles *C. versicolor* would be preyed upon, especially in the juvenile stage, by the endemic snakes *Boaedon geometricus* and *Lycognathopis seychellensis* and the endemic Seychelles kestrel *Falco araea* as well as domestic and feral cats (*Felis domesticus*); but it is doubtful that they would suppress the population of such a prolific and fast-maturing breeder.

Research is urgently required to elucidate the status and ecology of the established population of *C. versicolor* on Ste Anne island even if eradication efforts announced by the Ministry of Environment and Natural Resources are ongoing (Anon. 2004). Captured specimens could be sexed, measured, weighed and dissected for stomach contents and, possibly, parasites. Managing the spread of invasive alien species involves (1) prevention, preferably, to keep potential invaders from entering a new ecosystem; (2) early detection, if prevention is not successful, to locate the alien before it has the chance to become established and spread; (3) eradication, mostly possible when the alien is detected early; and (4) control as a long-term process to limit the population size and distribution of the alien if eradication is not possible (REASER 2003). In the Seychelles context, to manage the spread of the crested tree lizard would involve all of these going on at the same time on different islands within the archipelago.

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