Dietary habits of *Varanus salvator salvator* in Sri Lanka with a new record of predation on an introduced clown knifefish, *Chitala ornata*

DISSANAYAKA M. S. S. KARUNARATHNA[1*], THILINA D. SURASINGHE[2], MAHESH C. DE SILVA[3], MAJINTHA B. MADAWALA[4], DINESH E. GABADAGE[5] & WELATHANTHRIGE M. S. BOTEJUE[5]

[1]Nature Explorations and Education Team, No: B-1 / G-6, De Soysapura, Moratuwa 10400, Sri Lanka
[2]Department of Biology, Rhodes College, Memphis, TN 38112, USA
[3]Young Zoologists' Association, Department of National Zoological Gardens, Dehiwala, Sri Lanka
[4]South Australian Herpetology Group, South Australian Museum, North Terrace, Adelaide, SA 5000, Australia
[5]Biodiversity Conservation Society, 150/6 Stanley Thilakarathne Mawatha, Nugegoda 10250, Sri Lanka
[*]Corresponding author email: dmsameera@gmail.com

INTRODUCTION

Two species of monitor lizard (*Varanus*) occur in Sri Lanka: *V. salvator salvator* (water monitor) and *V. bengalensis* (land monitor). The nominotypic form *V. s. salvator* is endemic (Koch et al., 2007) and the largest species of lizard in Sri Lanka with the longest individual recorded being 321 cm in total length (Bennett, 1998). *V. s. salvator* are generally found in aquatic habitats including freshwater swamps, ditches, tanks, streams, reservoirs, ponds, rivers, mangroves and coastal marshes areas. They also live in urban areas (in Kandy Lake, a lake located in an urban center of Sri Lanka, they frequently forage around the city and flea markets), suburban storm-water discharge canals and man-made storage ponds (personal observations, Karunarathna et al., 2008a, b). Previous studies have indicated that *V. s. salvator* is an opportunistic generalist carnivore that scavenges and predates on a wide variety of prey including fish, amphibians, rodents, birds, reptiles, and large invertebrates such as crustaceans (e.g. Daniel, 2002; Somaweera & Somaweera, 2009). In this paper we present a short detailed review of the known dietary habitats of *V. s. salvator* in Sri Lanka, including new observations made by ourselves that includes a new record of a predation event on an introduced species of fish previously not recorded as a prey species of *V. s. salvator*.

METHODS

Our results are based on our field observations in various regions of Sri Lanka, observations made by other herpetologists, interviews conducted with local communities regarding their opportunistic observations and published peer-reviewed literature. Our field observations of the new prey type were made at a distance of 2-20 m from the focal individual between 0600 and 1700 hrs with 8×40 binoculars.

In this review we define non-natives as long-term resident species - i.e. domestic dogs and cats, as distinct from aliens, which are more recent introductions - see Hegan (2014) for an alternative definition.

RESULTS AND DISCUSSION

Our study indicates that prey selection of *V. s. salvator* is much broader than previously reported in the literature. We found a total of 102 food items that have been observed predated/consumed by *V. s. salvator* in Sri Lanka (Table 1). Among these, 86 (84.3%) were vertebrates, and 16 (15.7%) invertebrates. Vertebrate prey included four species of amphibian (3.9%), 18 species of reptile (17.7%) including highly toxic snakes, for example *Daboia russelii* and *Naja naja*, 11 species of birds (10.8%), 24 species of mammals (23.5%) and 29 fish species of fish (28.4%). Among these, 15 are considered introduced species in Sri Lanka (9 freshwater fish, 4 mammals, 1 bird and one land snail). In addition, we recorded predation on a captive population of *Aix galericulata* (Mandarin ducks) in the National Zoological Gardens of Sri Lanka. Our research confirms the importance of scavenging behaviour in *V. s. salvator* including foraging on discarded fish remains (10 species of marine fish) around fishing harbours and marine fish markets in the coastal areas. We also noted that *V. s. salvator* consumed household trash (personal observations).

Our field observations also indicate that (n>20 observations) water monitors when hunting are able to dive deep and actively hunt large fish (25-40 cm long). For instance, we observed lizards ingest about 2-3 large-sized introduced fish at a single feeding (e.g. *Piaractus mesopotamicus* [30 cm] and *Pangasianodon hypophthalmus* [30 cm]). We also documented predation on newborns and juveniles of domestic cat (Fig. 1a), domestic dog, and Indian hog deer (*Axis porcinus*). Further, both fully-grown and subadult lizards excavate below-ground nests of terrapins (*Melanochelys trijuga*) (Fig. 1b), *V. bengalensis*, rats, mice, burrowing frogs (*Uperodon systoma*), and birds (Fig. 1c), invasive fish including their benthic nests (Fig. 1d), and buried animal carcasses (e.g. domestic cats, domestic dogs and domestic buffalos). *V. s. salvator* is apparently able to detect prey items 20 – 70 cm deep in the ground, and dig continuously for at least two hours and are capable of breaking the carapace of terrapins (*M. trijuga*) using their jaws (personal observations;

Figure 1. Examples of predation by adult *V. s. salvator*: (a) attempting to predate a domestic cat *F. catus*; (b) consuming black terrapin (*M. strijuga*) eggs; (c) predating a little cormorant *Phalacrocorax niger* and (e) predating an invasive catfish *Hypostomus plecostomus* .

Deraniyagala, 1953). More recently, we observed *V. s. salvator* feeding on the remains of human meals e.g. cooked rice and other prepared food as has Karunarathna et al., (2012).

New record of predation. On 24th January 2015 in Kuda Waskaduwa old clay excavation site (altitude: 3 m; 6°37'30.85'' N and 79°57'17.26 E) in Kalutara district of Western Province, Sri Lanka a mature male water monitor (*V. s. salvator* ~80 cm SVL) was observed from a distance of ca. 5 m from 0915hrs (local standard time) until 0948hrs moving in an abandoned, "naturalized" clay pit. The pit was rain-fed, with dimensions 25 m wide, 40 m long, and from 0.5m (in the littoral zone) to 4m (in the center) deep. At 0920 hrs the monitor suddenly submerged and ~5 minutes later we noted that it was actively pursuing something. The monitor emerged from middle of the pool and hid in the littoral vegetation. After ~3 minutes it re-emerged from the littoral zone with a large live Clown knifefish (*Chitala ornata*). The fish was nearly 40 cm long from head to tail and although struggled to break free was consumed after 15 minutes.

Given these observations it is likely that *V. s. salvator*, an abundant, widely-distributed reptile in Sri Lanka, may play an important role in regulating the population size of invasive species (see Karunarathna et al., 2008a, b). There are 15 species of vertebrates and 5 invertebrates that are well-established invasive species in the lowland wet zone of Sri Lanka (Marambe et al., 2011) and our data indicate that *V. s. salvator* predates at least 8 of the invasive vertebrates (Table 1 & Fig. 1d). Future detailed investigations based on both field observations and experimental studies on the predator-prey interactions of *V. s. salvator*, especially in relation to invasive fauna, could potentially yield important information for our understanding of natural history, community ecology and conservation biology in Sri Lanka.

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Table 1. Current known prey items of *V. s. salvator*, in Sri Lanka

Prey taxa	Prey species	Prey condition at the time of ingestion	Location	Reference and remarks
Mammalia	*Axis axis*	Carcasses	Polonnaruwa, Udawalawe Lowland dry zone	L. Dayarathne and S. Weerathunga pers. com.
	Axis porcinus	Live juveniles	Baddegama Lowland wet zone	S. Akmeemana pers. com.
	Bandicota indica	Adults killed by people and carrion	Nugegoda Lowland wet zone	Current study
	Bubalus bubalis[1,3]	Offal scavenged from slaughter houses and other carcasses	Homagama, Beruwala, Udawalawe Lowland wet zone, lowland dry zone	Current study; S. Weerathunga pers. com.
	Canis aureus	Carcasses	Udawalawe Lowland dry zone	S. Weerathunga pers. com.
	Canis familiaris[1]	Live pups, road kill carcasses and buried carrion	Ganemulla, Galle, Panadura, Kesbewa, Kirulapone Lowland wet zone	Current study; S. Akmeemana pers. com.
	Capra hircus	Offal scavenged from slaughter houses	Aluthgama, Kandy Lowland wet zone, highland wet zone	Current study
	Elephas maximus	Carcasses	Polonnaruwa, Udawalawe Lowland dry zone	L. Dayarathne and S. Weerathunga pers. com.
	Fanambulus palmarum	Adult road kill carcasses	Piliyandala Lowland wet zone	Current study
	Felis catus[1]	Live juveniles, road kill carcass, buried carrions	Dehiwala,Galle, Hirana, Matugama, Nugegoda,Udawalawe Lowland wet zone, lowland dry zone	Current study; A. Nanayakkaraand S. Weerathunga pers. Com.
	Felis chaus	Live juveniles and dead carcasses	Udawalawe Lowland dry zone	S. Weerathunga pers. com.
	Hystrix indica	Adult carcasses that were killed by humans	Polonnaruwa Lowland dry zone	L. Dayarathne pers. com.
	Homo sapiens sapiens	Corpses or body parts floating on river	Kelaniya, Matara, Panadura, Kalutara Lowland wet zone	P. Mendis and P. Atapattu pers. com.
	Lepus nigricollis	Live juveniles	Udawalawe Lowland dry zone	S. Weerathunga pers. com.
	Macaca sinica	Carcasses	Matara Lowland wet zone	Current study

Prey taxa	Prey species	Prey condition at the time of ingestion	Location	Reference and remarks
	Moschiola meminna	Adult that had been killed by domestic dogs	Bandaragama Lowland wet zone	T. Pieris pers. com.
	Paradoxurus hermaphoditus	Adult road kill	Nugegoda Lowland wet zone	Current study
	Pteropus giganteus	Adults killed by electrocution	Homagama, Moratuwa Lowland wet zone	Current study
	Rattus rattus[1,3]	Adults and sub adults killed by people and as carrion	Maharagama Lowland wet zone	Current study
	Rusa unicolor	Dead adults and juvenile carcasses	Polonnaruwa, Giritale Lowland dry zone	Current study; T. Priyadarshana pers. com.
	Semnopithecus vetulus	Adults killed by electrocution	Avissawella Lowland wet zone	Current study
	Suncus sp.	Live adults and juveniles	Puttalam, Rajagiriya Lowland dry/intermediate zone, lowland wet zone	Karunarathna et al. 2012; K. Manamendra-Arachchi pers. com.
	Sus domesticus	Body parts scavenged from slaughter houses	Kuruwita, Moratuwa, Kandana Lowland wet zone	Current study
	Sus scrofa	Dead adults	Polonnaruwa Lowland dry zone	Current study
Aves	*Aix galericulata*[1]	Captive live adults	Dehiwala Lowland wet zone	S. Kiriwaththuduwa pers. com.
	Amaurornis phoenicurus	Live chicks	Ganemulla Lowland wet zone	Current study
	Ardea purpurea	Carcasses	Malambe Lowland wet zone	Current study
	Bubulcus ibis	Live adult	Udawalawe Lowland dry zone	S. Weerathunga pers. com.
	Corvus splendens	Carcass	Puttalam, Rajagiriya Lowland dry zone/wet zone	Karunarathna et al. 2012; Current study
	Gallus domesticus	Live juveniles, eggs and body parts scavenged from slaughter houses	Moratuwa, Homagama, Kandana Lowland wet zone	Current study
	Gallus lafayetii	Carcasses	Sinharaja Lowland wet zone	Current study
	Mesophoyx intermedia	Carcasses	Panadura Lowland wet zone	Current study
	Pavo cristatus	Carcasses, chicks and eggs	Thissamaharama, Puttalam Lowlan dry zone/arid zone	Karunarathna et al. 2012; Current study
	Phalacrocorax niger	Live juveniles and carcasses	Puttalam, Bellanwila-Attidiya, Kandy Lowland dry zone, lowland wet zone, highland wet zone	Karunarathna et al. 2012; Current study
	Vanellus indicus	Eggs	Boralesgamuwa Lowland wet zone	Current study
Reptilia	*Caretta caretta*	Live hatchlings and eggs	Weligama, Kahawa, Balapiyiya Lowland wet zone	Current study; T. Kapurusinghe pers. com.
	Chelonia mydas	Live hatchlings and eggs	Kosgoda, Rekawa, Seenigama Lowland wet zone	Current study; T. Kapurusinghe pers. com.
	Crocodylus palustris	Live hatchlings and eggs	Bibila, Thanamalwila Intermediate zone	Current study; C. Dissanayake pers. com.
	Crocodylus porosus	Live hatchlings and eggs	Beruwala, Borupana Lowland wet zone	Amarasinghe et al. 2015; Current study
	Daboia russelii	Live adults, sub adults and road kill carcass	Dambulla, Thissamaharama Lowland dry zone	Current study; S. Velaratne pers. com.
	Dermochelys coriacea	Live hatchlings and eggs	Hikkaduwa, Balapitiya, Rekawa Lowland wet zone	Current study; T. Kapurusinghe pers. com.
	Eretmochelys imbricata	Live hatchlings and eggs	Matara, Dikwella, Rekawa, Moratuwa Lowland wet zone	Current study; T. Kapurusinghe pers. com.
	Geochelone elegans	Buried eggs of captive tortoises	Angulana Lowland wet zone	C. Jayaweera pers. com.
	Lepidochelys olivacea	Live hatchlings and eggs	Kosgoda, Hikkaduwa, Wellawatta Lowland wet zone	Current study; T. Kapurusinghe pers. com.
	Lissemys ceylonensis	Live juveniles and adult road kill carcasses	Meegoda Lowland wet zone	Karunarathna et al. 2012; Current study

Prey taxa	Prey species	Prey condition at the time of ingestion	Location	Reference and remarks
	Melanochelys trijuga	Live juveniles, eggs and adult road kill carcasses	Puttalam, Ampara Lowland dry zone/intermediate zone	Deraniyagala, 1953; Karunarathnaet al. 2012; Current study
	Naja naja	Live sub adults and road kill carcasses	Puttalam, Kalutara Lowland wet zone, lowland dry zone//intermediate zone	Karunarathna et al. 2012; Current study
	Oligodon arnensis	Live sub adult	Horana Lowland wet zone	Current study
	Oligodon taeniolata	Live adult and road kill carcasses	Puttalam, Kegalle Lowland dry zone/intermediate zone, lowland wet zone	Karunarathna et al. 2012; S. Basnayake pers. com.
	Ptyas mucosa	Live sub adults, juveniles and adult road kill carcasses	Nugegoda, Puttalam, Nilgala lowland dry zone/intermediate zone, lowland wet zone	Karunarathna et al. 2012; Current study
	Varanus bengalensis	Road kill carcasses, juveniles and eggs	Dehiwala, Ambalangoda Lowland wet zone	Karunarathna et al. 2008b; V. Silva pers. com.
	Varanus salvator	Carcasses	Rathgama, Kandawala Lowland wet zone	Amarasinghe et al. 2009; Current study
	Xenochrophis piscator	Live adults, sub adults, juveniles and road kill carcasses	Maharagama, Ganemulla, Puttalam Lowland wet zone, lowland dry zone/intermediate zone	Karunarathna et al. 2012; Current study
Amphibia	*Duttaphrynus melanostictus*	Live adults, sub adults, juveniles and road kill carcasses	Jaela, Ratmalana, Panadura Lowland wet zone	Current study
	Hoplobatrachus crassus	Live adults and road kill carcasses	Anuradapura, Mahiyanganaya Lowland dry zone	Current study
	Pseudophilautus sp.	Contents of regurgitation	Kandy Highland wet zone	K. Ukuwela pers. com.
	Uperodon systoma	Live adults, sub adults and road kill carcasses	Hambegamuwa, Dambulla Lowland dry zone /intermediate zone	Current study
Pisces	*Aetobatus narinari*[2]	Discarded body parts from fishermen	Homagama, Boralesgamuwa Lowland wet zone	Current study
	Anabas testudineus	Live adults	Lahugala Lowland dry zone	Wickramasinghe et al. 2010
	Anguilla nebulosa	Dead adult	Gampaha Lowland wet zone	Current study
	Auxis thazard[2]	Discarded body parts from fishermen	Boralesgamuwa, Moratuwa Lowland wet zone	Current study
	Catla catla[1]	Discarded body parts from fishermen	Udawalawe Lowland dry zone	S. Weerathunga pers. com.
	Channa gachua	Live adults	Nugegoda Lowland wet zone	D. Geekiyanage pers. com.
	Channa striata	Individuals strangled in fishing nets	Udawalawe Lowland dry zone	S. Weerathunga pers. com.
	Chitala ornata[1,3]	Live adults	Waskaduwa Lowland wet zone	Current study
	Cirrhinus mrigala[1]	Discarded body parts from fishermen	Udawalawe Lowland dry zone	S. Weerathunga pers. com.
	Clarias brachysoma	Live adults	Nugegoda Lowland wet zone	Current study
	Cyprinus carpio[1,3]	Captive live adults and sub adults	Galle Lowland wet zone	S. Akmeemana pers. com.
	Euthynnus affinis[2]	Discarded body parts from fishermen	Angulana, Lunawa Lowland wet zone	Current study
	Heteropneustes fossilis	Live adults	Lahugala, Nugegoda Lowland dry zone, lowland wet zone	Wickramasinghe et al. 2010; Current study
	Hypostomus plecostomus[1,3]	Live adults and trash carcass	Bellanwila-Attidiya, Bolgoda Lowland wet zone	Karunarathna et al. 2008a; Current study
	Istiophorus platypterus[2]	Discarded body parts from fishermen	Ratmalana, Borupana Lowland wet zone	Current study
	Katsuwonus pelamis[2]	Discarded body parts from fishermen	Boralesgamuwa, Homagama Lowland wet zone	Current study
	Labeo rohita[1]	Discarded body parts from fishermen	Udawalawe Lowland dry zone	S. Weerathunga pers. com.

Prey taxa	Prey species	Prey condition at the time of ingestion	Location	Reference and remarks
	Oreochromis mossambicus[1,3]	Dead individuals and individuals asphyxiated in fishing nets	Dehiwala, Udawalawe Lowland wet zone, Lowland dry zone	Karunarathna et al. 2008b; Current study; S. Weerathunga pers. com.
	Oreochromis niloticus[1]	Dead individuals and individuals asphyxiated in fishing nets	Dehiwala, Udawalawe Lowland wet zone, Lowland dry zone	Karunarathna et al. 2008b; Current study; S. Weerathunga pers. com.
	Osphronemus goramy[1]	Discarded carcasses and other dead individuals	Dehiwala Lowland wet zone	Karunarathna et al. 2008b; Current study
	Pangasianodon hypophthalmus	Captive live sub adults	Moratuwa Lowland wet zone	Current study
	Piaractus mesopotamicus	Captive live adults and sub adults	Galle Lowland wet zone	S. Akmeemana pers. com.
	Prionace gluaca[2]	Discarded body parts from fishermen	Kuruwita Lowland wet zone	Current study
	Puntius sp.	Live adults	Lahugala, Bandanagala Lowland dry zone	Wickramasinghe et al. 2010; Current study
	Rastrelliger kanagurta[2]	Discarded body parts from fishermen	Lunawa, Moratuwa, Panadura Lowland wet zone	Current study
	Scomberomorus commersoni[2]	Discarded body parts from fishermen	Ratmalana, Angulana Lowland wet zone	Current study
	Selar crumenophtthalamus[2]	Discarded body parts from fishermen	Wellawatte, Ratmalana, Beruwala Lowland wet zone	Current study
	Systomus sp.	Live adults	Udawalawe Lowland dry zone	S. Weerathunga pers. com.
	Thunnus albacares[2]	Discarded body parts from fishermen	Boralesgamuwa, Maharagama Lowland wet zone	Current study
Arachnida	*Isometrus sp.*	Live hunting	Matugama Lowland wet zone	Current study; S. Akmeemana pers. com.
	Lychas sp.	Live hunting	Kanneliya Lowland wetzone	Current study
Chilopoda	*Solopendra sp.*	Live hunting and eggs	Baduraliya Lowland wet zone	Current study; S. Akmeemana pers. com.
	Rhysida sp	Live hunting	Kurunegala Lowland dry zone	Current study
Gastropoda	*Acavus phoenix*	Live adults	Kitulgala Lowland wet zone	Current study
	Acavus haemastoma	Live adults and juveniles	Balapitiya Lowland wet zone	Current study
	Cryptozona bistrialis	Live adults	Maduganga, Kalutara Lowland wet zone	Current study
	Lissachatina fulica[1,3]	Live adults and juveniles	Ambalangoda Lowland wet zone	Current study
	Oligospira polei	Live adults	Atweltota Lowland wet zone	Current study
Malacostraca	*Ceylonthelphusa sp.*	Live adults and juveniles	Ratnapura Lowland wet zone	Current study; M. Bahir pers. com.
	Macrobrachium rosenbergii	Live adults	Nilgala Intermediate zone	Current study
	Panulirus sp.	Discarded body parts from fishermen	Angulana, Moratuwa Lowland wet zone	Current study
	Penaeus semesulsctus	Discarded body parts from fishermen	Kandana, Jaela Lowland wet zone	Current study
	Perbrinckia sp.	Live adults and juveniles	Elpitiya Lowland wet zone	Current study; M. Bahir pers. com.
	Portunus pelagicus	Discarded body parts from fishermen	Thalapathpitiya, Aluthgama Lowland wet zone	Current study
	Scylla serrata	Discarded body parts from fishermen	Beruwala, Balapitiya Lowland wet zone	Current study

[1]non-native species, [2]Marine fish, [3]Invasive species (see Hegan, (2014).

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