The Water Monitor Lizard *Varanus salvator*:

Behavior, Ecology, and Human Dimensions in Banten, Indonesia

Linda Therese Uyeda

A dissertation

submitted in partial fulfillment of the

requirements for the degree of

Doctor of Philosophy

University of Washington

2015

Reading Committee:

Aaron Wirsing, Chair

Randall Kyes

Ivan Eastin

Program Authorized to Offer Degree:

School of Environmental and Forest Sciences

University of Washington

Abstract

The Water Monitor Lizard *Varanus salvator*:
Behavior, Ecology, and Human Dimensions in Banten, Indonesia

Linda Therese Uyeda

Chair of the Supervisory Committee:
Associate Professor Aaron J. Wirsing
School of Environmental and Forest Sciences

The water monitor lizard, *Varanus salvator*, is a large, ecologically flexible species commonly found in areas of human disturbance throughout its Southeast Asian range. The presence of anthropogenic resource subsidies may influence *V. salvator* behavior in such areas, potentially altering the social structure, ranging activity, and space use of this species. Overlapping human and *V. salvator* activity areas also create the potential for increased human-*V. salvator* conflict. We used behavioral observations and radio-telemetry to study *V. salvator* in an area of regular anthropogenic subsidy in Banten, Indonesia. We also conducted interviews with area residents to document local knowledge and to identify concerns regarding local herpetofauna. On Tinjil Island, Indonesia, we observed a higher incidence of intraspecific encounters among *V. salvator* in a human-subsidized area than in areas where animals foraged naturally. A greater number of agonistic interactions was also observed in the presence of food when compared to those in the absence of food. Our data suggest that on Tinjil Island a dominance hierarchy exists among *V. salvator* frequenting the area of anthropogenic subsidy. In addition, *V. salvator* activity areas appeared smaller in the dry season than in the wet season, when the island's natural water and prey resources were more abundant. Similarly, *V. salvator*

on the island showed increased use away from areas of anthropogenic subsidy in the wet season only. Through the interview process we learned that a local taboo prohibits the collection of *V. salvator* and *Python reticulatus* on Tinjil Island, but that the taboo is not observed in the nearby mainland villages, Muara Dua and Cisiih. In the villages, *V. salvator* is mainly considered a pest, but the meat of this species is also consumed for medicinal purposes. In our study *V. salvator* behavior in human-subsidized areas differed from that observed in wildland areas but varied temporally, indicating that anthropogenic subsidies may be more important for this population in the dry season when natural resources are less available. A location-specific taboo, official regulations, and anthropogenic subsidy serve to protect and maintain Tinjil Island's *V. salvator* population. However, in nearby Muara Dua and Cisiih, local use for medicinal purposes and concerns over livestock depredation could lead to increased harvest and persecution of this species.

Table of Contents

CHAPTER 1: Encounter rates, agonistic interactions, and social hierarchy among garbage-feeding water monitor lizards (*Varanus salvator bivittatus*) on Tinjil Island, Indonesia ………………. 8

In press as: Uyeda, L.T., E. Iskandar, R.C. Kyes and A.J. Wirsing. 2015. Encounter rates, agonistic interactions, and social hierarchy among garbage-feeding water monitor lizards (*Varanus salvator bivittatus*) on Tinjil Island, Indonesia. Herpetological Conservation and Biology.

CHAPTER 2: Seasonal Activity Areas and Space Use of the Water Monitor Lizard (*Varanus salvator*) in an area of anthropogenic resource subsidy ……………...…………………….. 38

Pending submission.

CHAPTER 3: Nocturnal Activity of *Varanus salvator* on Tinjil Island, Indonesia ………….. 78

Published as: Uyeda, L., E. Iskandar, A. Wirsing and R. Kyes. 2013. Nocturnal activity of *Varanus salvator* on Tinjil Island, Indonesia. Biawak 7:25–30.
©Copyright 2013

List of Figures

List of Tables

THE WATER MONITOR LIZARD *VARANUS SALVATOR*:

BEHAVIOR, ECOLOGY, AND HUMAN DIMENSIONS IN BANTEN, INDONESIA

INTRODUCTION

Human population growth and loss of wildlife habitat continue to affect humans and

wildlife, bringing them into closer contact with one another throughout the world (FAO 2006;

United Nations 2012). Potential consequences of greater human-wildlife interaction include

increased threat of zoonotic disease, economic losses related to depredation of livestock,

destroyed crops or property damage, and injury resulting from direct attacks. In addition,

wildlife in areas of human disturbance may be subject to anthropogenic hazards, harvest, and

pre-emptive or retaliatory killing.

Despite the risks of living in close proximity to human activity, some opportunistic

species are able to adapt to and even thrive in areas of anthropogenic disturbance, particularly in

areas of predictable anthropogenic resource subsidy (Lowry et al. 2012; Oro et al. 2013).

However, in many cases such wildlife are unwelcome, increasing concerns regarding human-

wildlife conflict. As human and wildlife activities increasingly intersect, anthropogenic effects

on animal behavior, prevention of human-wildlife conflict, and conservation of wildlife

populations at the human-wildlife interface have emerged as global issues (Treves and Karanth

2003; Timm et al. 2004; Distefano 2005; Millspaugh et al. 2015).

The water monitor lizard, *Varanus salvator*, is a large, carnivorous species which adapts

well to human-disturbed habitats throughout its broad Southeast Asian range (Gaulke et al. 1999,

Shine et. al. 1998; Uyeda 2009). A generalist known for ecological flexibility, *V. salvator*

subsists on a wide range of prey and scavenges broadly (Losos and Greene 1988; Gaulke 1991;

Traeholt 1993, 1994a/b). While *V. salvator*'s generalized diet increases the species' ability to thrive in human disturbed areas, behavioral changes in garbage-feeding populations may decrease *V. salvator*'s ecological impact as a top predator and scavenger, while creating increased potential for human-wildlife conflict.

V. *salvator* populations have also been subjected to heavy harvest for the global reptile leather trade. Indonesia is the world's primary exporter of *V. salvator* skins (Jenkins and Broad 1994; TRAFFIC and the IUCN/SSC Wildlife Trade Programme 2004; Engler and Parry-Jones 2007), reporting a total export volume of 6,201,615 wild-caught *V. salvator* skins from 2000-2010 (Koch et al. 2013). Despite *V. salvator*'s broad range and apparent resilience to collection (Shine et al. 1996), anecdotal reports indicate that the species has been extirpated in heavily harvested areas (e.g. KPSL 1988; De Lisle 1996), and concerns have been raised regarding the sustainability of such harvest levels (Bennett 1995; Auliya 2003, Shine et al. 1998). However, the issue is complicated in that commercial harvest of *V. salvator* is concentrated in a few key areas and is not widespread throughout Indonesia. In areas where *V. salvator* is not intensively harvested, the species can be ubiquitous, often associated with negative beliefs (Stanner 2010; Karunarathna et al. 2012), and with a bad reputation for preying on domestic chickens (Gaulke 1991; Uyeda et al. 2014).

V. *salvator* drawn to areas of human resource subsidy in such areas are vulnerable to opportunistic harvest or persecution, while also creating greater potential for livestock depredation. In the absence of systematic population surveys, increased concentration of *V. salvator* in areas of human activity may also create false impressions of healthy *V. salvator* populations. Unfortunately, official population data on *V. salvator* is largely lacking throughout

its range (Bennett et al. 2010), and there have been few detailed studies on the behavior of *V. salvator* in areas of anthropogenic subsidy.

In areas of anthropogenic subsidy, wildlife space use and behavior is determined by a combination of factors such as hierarchy status (Altmann and Muruthi 1988; Kolowski and Holekamp 2007), seasonal variability (Peirce and Van Daele 2006; El Alami and Chait 2012), and individual differences (Lowry et al. 2012). Meanwhile, humans control the amount of subsidy available to wildlife (e.g. garbage, accessible livestock), and human responses to wildlife encounters vary based on local belief systems (Lingard 2003; Riley 2010), as well as the perceived threat to resources and human safety (Whitaker and Shine 2000; Romanach et al. 2007; Campbell-Smith et al. 2010). Multidisciplinary approaches that address both human and wildlife perspectives are needed to produce effective location-specific assessments of ecological effects, human-wildlife conflicts, and conservation needs in human-subsidized areas.

The objective of our research was to utilize an interdisciplinary approach to study both *V. salvator* behavior and human dimensions in a location where humans and this species coexist. The research was conducted on Tinjil Island and in the village areas of Muarabinuangeun and Cisiih in the province of Banten, Indonesia, where *V. salvator* has access to regular anthropogenic subsidy. Tinjil Island is a largely undisturbed wildland with a small area of human activity that provides consistent resource provisioning to wildlife. These characteristics enabled us to study *V. salvator* behavior in areas where individuals had access to both natural resources and regular anthropogenic resource subsidy. A second and equally important aim of the research was to investigate human perspectives in areas where *V. salvator* and human activity intersects. In Muarabinuangeun and Cisiih many villagers live alongside *V. salvator* and own small livestock such as chickens. By interviewing individuals in both village areas and Tinjil

Island, we sought to identify sources of human-*V. salvator* conflict, and to reveal potential conservation approaches through greater understanding of local perspectives.

The first three chapters of this dissertation focus on the ecology and behavior of *V. salvator* on Tinjil Island. We evaluated intraspecific encounter and agonistic interaction rates in and out of the base camp area, and completed a sociometric matrix to assess the presence of a dominance hierarchy among Tinjil Island base camp's *V. salvator*. We carried out a radio-telemetric study on seasonal *V. salvator* activity areas and related *V. salvator* space use to the predictive variables forest edge/beach, trails, and areas of human activity on Tinjil Island. We also documented observations of nighttime foraging behavior in a garbage-feeding individual.

In chapters four and five we investigated the human perspectives of this system by conducting semi-structured interviews with individuals in both village areas and on Tinjil Island. Through these interviews we identified key concerns and attitudes regarding *V. salvator* among our study participants, while generating hypotheses for future research. Local knowledge on medicinal use of *V. salvator* meat was also noted.

In collecting data from both wildlife and human perspectives for this research our aim was to study the ecology of *V. salvator* while assessing both the likelihood of human-*V. salvator* conflict and the potential for conservation of this species in our study area. *V. salvator* captures and handling were carried out in accordance with the University of Washington Institutional Animal Care and Use Committee protocol #3143-04. The human dimensions component of our research received an exempt determination from the University of Washington Human Subjects Division, study #44076.

LITERATURE CITED

Altmann, J. and P. Muruthi. 1988. Differences in daily life between semiprovisioned and wild-feeding baboons. American Journal of Primatology 15:213-221.

Auliya, M. 2003. Taxonomy, Life History and Conservation of Giant Reptiles in West Kalimantan (Indonesian Borneo). Munster: Natur und Tier Verlag.

Bennett, D. 1995. The Water Monitor *Varanus salvator*. Reptilian 3:15–21.

Bennett, D., M. Gaulke, E.R. Pianka, R. Somaweera and S.S. Sweet. 2010. *Varanus salvator*. The IUCN Red List of Threatened Species. Version 2014.3. <www.iucnredlist.org>. Downloaded on 27 April 2015.

Campbell-Smith, G. H.V. Simanjorang, N. Leader-Williams, and M. Linkie. 2010. Local attitudes and perceptions toward crop-raiding by orangutans (*Pongo abelii*) and other nonhuman primates in northern Sumatra, Indonesia. American Journal of Primatology 72(10):866-876.

De Lisle, H.1996. The Natural History of Monitor Lizards. Krieger Publishing Company. Malabar, Florida, USA.

Distefano, E. 2005. Human-Wildlife Conflict worldwide: collection of case studies, analysis of management strategies and good practices. SARD. Initiative Report, FAO, Rome.

El Alami, A. and A. Chait. 2012. Seasonal variation in activity budget and diet of the endangered Barbary macaque (*Macaca sylvanus*) in the tourist valley of Ouzoud, central High Atlas, Morocco. Mammalia 76:245-250.

Engler, M., and R. Parry-Jones. 2007. Opportunity or Threat: The Role of the European Union in Global Wildlife Trade. Brussels, Belgium: TRAFFIC Europe.

Food and Agriculture Organization of the United Nations. 2006. Global Forest Resources Assessment 2005. FAO Forestry Paper.

Gaulke, M. 1991. On the Diet of the Water Monitor, *Varanus salvator*, in the Philippines. Mertensiella – Advances in Monitor Research 143-153.

Gaulke, M., Erdelen, W., and F. Abel. 1999. A Radio-Telemetric Study of the Water Monitor Lizard (*Varanus salvator*) in North Sumatra, Indonesia. Advances in Monitor Research II – Mertensiella 11:63-78.

Jenkins, M. and S. Broad. 1994. International Trade in Reptile Skins: A Review and Analysis of the Main Consumer Markets. 1983-91. Cambridge, U.K.: TRAFFIC International.

Karunarathna, D.M.S.S., A.A.T. Amarasinghe, M.B. Madawala and H.K.D. Kandambi. 2012. Population status of two Varanus species (Reptilia: Sauria:Varanidae) in Sri Lanka's Puttalam lagoon system, with notes on their diet and conservation status. Biawak 6:22-33.

Kelompok Program Studi Lingkungan (KPSL) 1998. Monitor Lizard Populations in Kalimantan. A report prepared by KPSL UNLAM and PSL UNTAN for CITES.

Koch, A., T. Ziegler, W. Böhme and M. Auliya. 2013. Pressing problems: Distribution, threats, and conservation status of the monitor lizards (Varanidae: Varanus spp.) of Southeast Asia and the Indo-Australian archipelago. Herpetological Conservation and Biology 8:1-62.

Kolowski, J.M. and K.E. Holekamp. 2007. Effects of an open refuse pit on space use patterns of Spotted Hyenas. African Journal of Ecology 46:341–349.

Lingard, M. N. Raharison, E. Rabakonandrianina, J.-A. Rakotoarisoa and T. Elmqvist. 2003. The role of local taboos in conservation and management of species: the radiated tortoise in southern Madagascar. Conservation and Society 1:223-246.

Losos, J.B. and H.W. Greene. 1988. Ecological and evolutionary implications of diet in monitor lizards. Biological Journal of the Linnean Society 35(4):379-407.

Lowry, H., A. Lill and B. Wong. 2013. Behavioural responses of wildlife to urban environments. Biological Reviews 88(3):537-549.

Millspaugh, J.J., C.D. Rittenhouse, R.A. Montgomery, W.S. Matthews and R. Slotow. 2015. Resource selection modeling reveals potential conflicts involving reintroduced lions in Tembe Elephant Park, South Africa. Journal of Zoology. doi: 10.1111/jzo.12224

Oro, D., M. Genovart, G. Tavecchia, M.S. Fowler and A. Martínez-Abraín. 2013. Ecological and evolutionary implications of food subsidies from humans. Ecology Letters 16:1501–1514.

Peirce, K. N. and L.J. Van Daele. 2006. Use of a garbage dump by brown bears in Dillingham, Alaska. Ursus 17(2):165-177.

Riley, E.P. 2010. The importance of human–macaque folklore for conservation in Lore Lindu National Park, Sulawesi, Indonesia. Oryx 44:235-240.

Romanach, S. S., P.A. Lindsey and R. Woodroffe. 2007. Determinants of attitudes towards predators in central Kenya and suggestions for increasing tolerance in livestock dominated landscapes. Oryx 41(2):185-195.

Shine, R., Ambariyanto, P. Harlow and Mumpuni. 1998. Ecological traits of commercially harvested water monitors, *Varanus salvator*, in northern Sumatra. Wildlife Research 25:437-447.

Shine, R., Harlow, P. S., and S. Keogh. 1996. Commercial Harvesting of Giant Lizards: The Biology of Water Monitors *Varanus salvator* in Southern Sumatra. Biological Conservation 77:125-134.

Timm, R.M., R.O. Baker, J.R. Bennett and C.C. Coolahan. 2004. Coyote attacks: an increasing suburban problem. Pp. 47–57 *In* Proceedings of the Twenty-First Vertebrate Pest Conference. Timm, R.M. and W.P. Gorenzel (Eds.). University of California, Davis, California, USA.

Traeholt, C. 1994a. Notes on the water monitor *Varanus salvator* as a scavenger. Malayan Nature Journal 47:345-353.

Traeholt, C. 1994b. The food and feeding behaviour of the water monitor, *Varanus salvator*, in Malaysia. Malayan Nature Journal 47:331-343.

Traeholt, C. 1993. Notes of the feeding behavior of the water monitor, *Varanus salvator*. Malayan Nature Journal 46:229-241.

TRAFFIC and the IUCN/SSC Wildlife Trade Programme. 2004. Taxa Identified as Possible Candidates for Inclusion in the Review of Significant Trade in Specimens of Appendix–II Species. Twentieth Meeting of the CITES Animals Committee Johannesburg (South Africa), 29 March – 2 April 2004.

Treves, A. and U. Karanth. 2003. Human-Carnivore Conflict and Perspectives on Carnivore Management Worldwide. Conservation Biology 17(6):1491-1499.

United Nations. 2012. World Urbanization Prospects, the 2011 Revision. United Nations, Department of Economic and Social Affairs Population Division, Population Estimates and Projections Section.
Internet resource, accessed April 18, 2012: http://esa.un.org/unpd/wup/index.html

Uyeda, L. 2009. Garbage appeal: relative abundance of water monitor lizards (*Varanus salvator*) correlates with presence of human food leftovers on Tinjil Island, Indonesia. Biawak 3(1):9-17.

Uyeda, L.T., E. Iskandar, A. Purbatrapsila, J. Pamungkas, A. Wirsing and R.C. Kyes. 2014. The role of traditional beliefs in conservation of herpetofauna in Banten, Indonesia. Oryx 1-6 doi:10.1017/S0030605314000623.

Whitaker, P. B. and R. Shine. 2000. Sources of mortality of large elapid snakes in an agricultural landscape. Journal of Herpetology 121-128.

CHAPTER 1

ENCOUNTER RATES, AGONISTIC INTERACTIONS, AND SOCIAL HIERARCHY
AMONG GARBAGE-FEEDING WATER MONITOR LIZARDS (*VARANUS SALVATOR
BIVITTATUS*) ON TINJIL ISLAND, INDONESIA

ABSTRACT

Predictable anthropogenic resource subsidies have the potential to influence the behavior

of wildlife populations. Concentrated, human-provided food resources in particular have been

associated with increases in encounter rates, agonistic interactions, and the development of

dominance hierarchies. While the effects of food subsidies on wildlife have been well

researched, few studies have focused on reptile populations. Through behavioral observations of

garbage-feeding, free-living Water Monitor Lizards (*Varanus salvator bivittatus*) on Tinjil

Island, Indonesia, we documented a higher incidence of intraspecific encounters in a garbage-

feeding area as compared to areas where animals foraged naturally. The number of agonistic

interactions observed was also higher in the presence of food compared with interactions

observed in the absence of food. Moreover, our data suggest the presence of a primarily size-

based dominance hierarchy among *V. salvator* frequenting the area of human-provided

resources. Although agonistic interactions were frequent among garbage-feeding individuals on

Tinjil Island, our observations indicate that in this population of *V. salvator*, intense fighting is

not essential for hierarchy maintenance.

INTRODUCTION

Anthropogenic resource subsidies have the potential to influence ecosystems by affecting wildlife behavior and abundance (Newsome et al. 2014). Human-provided food subsidies have been recognized as a primary concern (Oro et al. 2013), with documented effects ranging from increased abundance (Coyotes, *Canis latrans*, Fedriani et al. 2001; Common Ravens, *Corvus corax*, Boarman et al. 2006) altered space use (Spotted Hyenas, *Crocuta crocuta*, Kolowski and Holekamp 2007), increased interactions (Banded Mongoose, *Mungos mungo*, Gilchrist and Otali 2002) and increased incidence of aggression within wildlife populations (e.g. Herring Gulls, *Larus argentatus*, Pons 1992; Barbary Macaques, *Macaca sylvanus*, Alami et al. 2012). When food subsidies are concentrated, competition for feeding opportunities may even lead to the establishment of social hierarchies among conspecifics that would otherwise forage alone (e.g., Chuckwallas, *Sauromalus obsesus*, Berry 1974; wild lizard populations, Stamps 1977). Concentrated food subsidies that bring humans and wildlife into close contact, as in the case of refuse, may also increase the potential for conflict, especially when larger species that easily habituate to human presence are involved (e.g., Coyotes, Timm et al. 2004; Polar Bears, *Ursus maritimus*, Stirling and Parkinson 2006; Lemelin 2008; American Black Bears, *Ursus americanus*, Spencer et al. 2007). Previous research on the effects of garbage-feeding and other forms of anthropogenic resource subsidies has focused primarily on mammals and birds. Thus, there is a need for studies examining the implications of these subsidies for herpetofaunal populations. Here, we explored the impacts of garbage feeding on the behavior of the Water Monitor Lizard (*Varanus salvator bivittatus*).

Varanus salvator (Fig. 1.1) is a large (ca. 2 m total length) predator and scavenger. This species habituates well to areas of human disturbance and has been documented feeding on

human garbage (Traeholt 1994; Uyeda 2009). *Varanus salvator* is not considered territorial, and free-living *V. salvator* do not generally interact with each other at high frequencies (Traeholt 1997; Gaulke et al. 1999; Gaulke and Horn 2004). However, in captive varanid populations, high population densities and concentrated resources may facilitate the formation of social hierarchies (*V. salvator*, Daltry 1991; *Varanus varius*, Hoser 1994, 1998). Such dominance structures have also been noted in free-living varanid populations under similar conditions. For example, Cota (2011) noted a hierarchy among a high-density wild population of *V. salvator macromaculatus* at the Dusit Zoo (Thailand), while Auffenberg (1981) documented a hierarchical system among free-ranging *Varanus komodoensis*, noting that the most commonly observed agonistic interactions occurred around carrion. Gaulke (pers. comm.; 1989) also observed a hierarchy among wild, carrion-feeding *V. salvator marmoratus* (now *V. palawanensis*). Such varanid dominance hierarchies are largely based on size, with larger individuals dominating over smaller ones (Auffenberg 1981; Daltry 1991; Hoser 1994, 1998; Cota 2011).

Previous literature on agonistic behavior and social hierarchy in *V. salvator* has focused on either captive populations or free-living populations foraging primarily on naturally available resources. In contrast, our research was designed to investigate behavior in a population of garbage-feeding free-living *V. salvator*. Research was conducted on Tinjil Island, Indonesia, a largely undisturbed habitat with a small area of localized human activity. On Tinjil Island, we were able to observe the behavior of free-living individuals with consistent access to both anthropogenic resource subsidies and natural resources. We conducted behavioral sampling of *V. salvator* in garbage-feeding and non-garbage-feeding areas of Tinjil Island to compare encounter rates between areas with and without this resource, and to compare the ratio of

agonistic interactions associated with food to agonistic interactions in the absence of food in both areas. We also created a sociometric matrix to assess the presence of a dominance hierarchy, and related hierarchy data to morphometric measurements.

We predicted that, compared to the area where garbage feeding did not occur, we would observe (1) an increased encounter rate in the garbage-feeding area, (2) an increased agonistic interaction rate in the garbage-feeding area, and (3) a greater percentage of the agonistic interactions involving individuals engaged in foraging as compared to interactions occurring in the absence of food. In assessing the presence of a dominance hierarchy, we predicted that individuals engaging in regular agonistic interactions associated with garbage-feeding would have established a dominance hierarchy, and that any dominance hierarchy established among *V. salvator* would be largely based on size. Our aim was to increase understanding of *V. salvator* behavior in an area of concentrated anthropogenic resources while facilitating the prevention and mitigation of human-lizard conflict.

MATERIALS AND METHODS

Study site

We studied lizards on Tinjil Island, Indonesia, located at 6° 56' 97" S, 105° 48' 70" E, approximately 16 km off the south coast of Banten, Java, Indonesia. Tinjil Island is ca. 600 ha (6 km long and 1 km wide), with an average elevation of ca. 20 m. Tinjil Island has been managed by the Primate Research Center of Bogor Agricultural University (IPB) as a Natural Habitat Breeding Facility for Long-tailed Macaques (*Macaca fascicularis*) since 1987 (Kyes et al. 1997). As such, the island has limited accessibility to humans and all visitors to the island must obtain permission to conduct activity there. Although there are officially no permanent residents on

Tinjil Island, staff members provide a year-round human presence (5–8 people at any given time). *Varanus salvator* are found throughout Tinjil Island, and individuals are frequently seen around a small base camp area where most human activity on Tinjil Island is concentrated. Leftover food scraps and food waste are routinely discarded either 1–5 m away from a main base camp building in a cleared area, or in a large, ca. $1.5 \times 2 \times 1$ m cement garbage box, located approximately 3 m south of the building (Fig 1.2). *Varanus salvator* are not fed directly by humans in the base camp area but commonly gain access to forage in the garbage box via openings in the side and top and are regularly observed foraging in human-discarded food and garbage (Uyeda 2009; Uyeda et al. 2013). *Varanus salvator* and the Reticulated Python (*Malayopython reticulatus*) are the largest predators found on Tinjil Island. Long-tailed Macaques are the largest species of non-human mammal on the island, and generally avoid contact with *V. salvator*. The Saltwater Crocodile, *Crocodylus porosus*, the Small Asian Mongoose, *Herpestes javanicus*, and the Common Palm Civet, *Paradoxurus hermaphroditus*, species found on the mainland of Java, are not present on Tinjil Island. Unauthorized removal of flora and fauna from Tinjil Island is prohibited per official policy of IPB, and *V. salvator* on the island remain unharvested (see Uyeda et al. 2014).

Tinjil Island experiences two distinct seasons, a dry season and a wet season, with each season characterized by markedly different conditions. In the dry season there are no natural fresh-water sources on the island other than an occasional ephemeral puddle. In the wet season, frequent rains provide an abundance of water throughout the island; water pools in tree hollows, a swampy area develops in the center of the island, and puddles are omnipresent. Natural food resources (e.g., land crabs) are also more plentiful in the wet season. The peak of dry season is generally from June to August, while January to March represents the middle of the wet season.

Tinjil Island consists of lowland secondary Tropical Rainforest and coastal beach vegetation, with comparable flora and fauna throughout. Representative vegetation types include *Ficus* spp., *Gnetum gnemon* (Melinjo), and *Dracaena elliptica* (Jarwadi B. Hernowo et al., unpubl. report.; McNulty et al. 2008).

Data collection

Following anecdotal observations of agonistic behavior of the base camp population of *V. salvator* on the island in 2008 and 2011 (Linda Uyeda, pers. obs.), we undertook systematic documentation of *V. salvator* behavior from 5 July 2012 to 11 August 2012 (dry season) and 13 January 2013 to 27 March 2013 (wet season) to better understand the social behavior of this species in an area where garbage-feeding frequently occurred. During these periods, we collected behavioral data in conjunction with a larger study involving the use of radio-telemetric harnesses to determine activity and resource use of *V. salvator* in food-subsidized areas.

We captured *V. salvator* in the Tinjil Island base camp area primarily using baited wooden box traps, but we also captured lizards by hand. Following capture, we assigned an identifying number to each lizard and we applied a superficial mark with a non-toxic crayon that rubbed away in time or was shed off with the skin. We measured and weighed each individual, and we outfitted each with a backpack-style radio-telemetric harness. The harnesses used in this study were modified versions of a custom-designed LPR-3800 unit (Wildlife Materials, Murphysboro, Illinois, USA) used in a July 2011 pilot study (Uyeda et al. 2012). We removed all harnesses following completion of our research.

Throughout both study periods, a single observer used *ad libitum* sampling (ALS) and focal animal sampling (FAS) techniques (Altmann 1974) to collect behavioral data and to

complete a sociometric matrix. Prior to each behavioral follow, the observer located focal

animals by tracking lizards on foot using a TRX-48S receiver and 3-element yagi directional

antenna (Wildlife Materials, Murphysboro, Illinois, USA). *Varanus salvator* are generally

diurnal and we did not observe study animals to be active at night (with the exception of one

individual whose nocturnal activities were not included in this report; see Uyeda et al. 2013).

Thus, FAS was generally conducted between 0600 and 1800. The majority of the sampling

periods were 2-h time blocks, although we conducted two 12-h focal animal observations and

one 6-h observation in the 2013 season. We sampled focal animals across each of the six 2-h

time blocks in an effort to observe a representative sample of activity throughout the day.

Although we made attempts at FAS with all instrumented individuals, several animals had

clearly altered behavior in the presence of an observer, regardless of the distance of the observer.

Thus, we conducted FAS on only a subset of the instrumented animals, individuals that appeared

undisturbed by the presence of the observer, as evidenced by the willingness of individuals to

continue engaging in daily behaviors such as sleeping, foraging, and drinking while being

observed.

Encounter rates and agonistic interactions

        To compare the incidence of encounters in the area where garbage-feeding occurred (in

the base camp) to encounter rates in areas where such food resources were not available (outside

of the base camp), we documented all observed encounters between pairs of individuals, with

interactions characterized as In Camp, or Out of Camp. We defined In Camp as the cleared base

camp area plus a 3 m perimeter of brush surrounding the camp clearing, while Out of Camp

included any location beyond this perimeter. The observer documented all encounters, defined as

instances in which two *V. salvator* were within 3 m of one another, including all observed

agonistic interactions as well as instances in which no interaction was observed (noted as No

Response). We calculated encounter rates for each area as the total number of encounters / total

FAS time. In addition, the observer noted whether or not each encounter involved food or

foraging by one or both of the individuals. Because we could not accurately quantify agonistic

interactions observed through ALS by time, we did not include those observations in calculations

of interaction rate. However, we included additional interactions observed through ALS in the

base camp area in comparing the number of agonistic interactions associated with food to the

number of agonistic interactions that occurred in the absence of food. We used chi-square to

compare observed encounter rates and agonistic interaction rates in each area (In Camp and Out

of Camp). The expected frequencies were based on the assumption that the proportion of

observed encounters and agonistic interactions in each area were equal. We also used this test to

compare the number of agonistic interactions associated with food to the number of agonistic

interactions which occurred in the absence of food. Significance for all tests was set at $P \leq 0.05$.

Dominance hierarchy

We assessed the existence of a hierarchy among lizards competing for concentrated food

resources in the Tinjil Island base camp area by entering agonistic interactions observed between

dyadic pairs of known individuals into a sociometric matrix. Data were entered into the matrix

based on interaction outcomes (i.e., dominant and submissive) as a means to determine the

direction and degree of one-sidedness of each relationship. The observer noted agonistic

interactions, which were grouped into four categories based on type: (1) avoid; (2) displace; (3)

short pursuit; and (4) stand ground/concede. The avoid category referred to a clear avoidance

behavior (i.e., running away, veering off course to create a wide berth around a stationary dominant individual) demonstrated by the submissive individual, and did not involve any noticeable aggressive behavior from the dominant individual. Displace behaviors were defined as instances in which the dominant individual approached the submissive individual directly until the submissive individual gave way (typically running 1–2 m away), allowing the dominant individual to take over its previously occupied space (Fig. 1.3). Although individuals engaging in displace behaviors generally did not appear to be aggressive (i.e., did not engage in a Threat Walk posture), we considered interactions displace regardless of whether the approaching individual appeared to be in a relaxed or threatening posture. Short pursuit involved a dominant individual actively chasing a submissive individual a short distance (< 7 m). We observed three scenarios associated with the short pursuit: (1) the two individuals would encounter one another, at which point the individuals would approach closely and stand snout to snout, licking the snout of each other for several seconds before one of the two initiated a short pursuit; (2) the dominant individual initiated the pursuit, beginning chase as it approached a submissive individual (e.g., while the submissive individual was foraging in a desirable location), after which the dominant individual would return to take over activity (i.e., foraging) in the desirable location; or (3) a submissive individual slowly approached a dominant individual (e.g., while the dominant individual was foraging in a desirable location), at which point the dominant individual would chase the submissive one away a short distance before returning to resume its activity. We also occasionally observed tail slaps in conjunction with this third scenario; the dominant individual would continue foraging while tail slapping the approaching individual. Following 1–3 tail slaps, the approaching individual would either change direction and retreat (noted as stand ground/concede), or the dominant individual would then initiate a short pursuit before resuming

16

its foraging activity (noted as short pursuit). Stand ground/concede also included situations in which two individuals met snout to snout (usually at a foraging location), with one holding its ground and the other turning away after a few seconds.

We used data from the completed sociometric matrix to calculate Kendall's coefficient of linearity, K (Appleby 1983), an index used to describe the strength of a hierarchy among a group of individuals (Langbein and Puppe 2004). Specifically, K is a measure of the degree of linearity of a dominance hierarchy calculated by considering the actual number of circular triads (d) relative to the total number of possible triads. K is represented as a number between zero and one, with one corresponding to a completely linear hierarchy.

For even values of N,

$$K = 1 - \frac{24d}{N^3 - N}$$

for a group size of N, where d is the number of circular triads. Linearity of the hierarchy can be tested statistically by comparing the observed number of circular triads with the probability that such linearity would be observed by chance (Appleby 1983).

We calculated a dominance index (DI) for each individual based on the ratio of the number of individuals dominated by the individual relative to all individuals with which it interacted. DI is represented as a percentage of individuals dominated (Lamprecht 1986; Langbein and Puppe 2004):

$$\text{DI}_{\text{dom}} = \frac{\text{submissive individuals}}{\text{submissive individuals} + \text{dominant individuals}} \times 100$$

We then compared the size of the individuals involved in the linear hierarchy and dominance indices to measurements of weight and total length to qualitatively assess the role of size in the establishment of the hierarchy.

RESULTS

We captured 10 *V. salvator* in the base camp area of Tinjil Island. Of these, we instrumented eight with radio-telemetric harnesses. Two individuals were smaller sub-adults and were thus marked with crayon for identification, but we did not fit them with harnesses. Individual weights ranged from 4.5–21.5 kg. We measured seven of the 10 lizards in both the 2012 and 2013 seasons, and individual averaged total lengths (including three individuals with missing tail tips) ranged from 138.0–222.2 cm. We also recorded tail base circumference, maximum girth, snout-vent length, and thorax-abdomen length (Appendices I and II). We observed two individuals (53 and 23) with everted hemipenes and we thus considered them to be males. We did not determine the sex of the other individuals.

We conducted 98.4 h of focal animal sampling (FAS) across the 2012 and 2013 field seasons, including 18.6 observation hours in the garbage-feeding/base camp area and 79.8 observation hours conducted outside of the base camp. We observed five individuals for 36.1 h in the 2012 (dry) season, and three individuals for 62.3 h in the 2013 (wet) season. Individuals 04 and 44 were observed in both the 2012 and 2013 season. In 2012 these two individuals spent equal amounts of time in camp and out of camp (12.8 h in each area), but in 2013 the same individuals spent 22.5 of a total 25.5 observed hours outside of camp.

Encounter rates and agonistic interactions

Encounter rates were significantly higher in the garbage-feeding area (In Camp) than in the area outside of camp ($X^2 = 4.869$, df = 1, $P = 0.027$). Of 38 total encounters documented through FAS, we observed 32 encounters in the base camp area, while we observed only six outside of the base camp area, despite 79.8 of the 98.4 FAS hours having been conducted outside of base camp (Table 1.1). We observed 26 agonistic interactions through FAS in the garbage-feeding area compared to one interaction observed outside of the camp area. Overall interaction rates were low in both areas, with an average of 1.4 interactions per hour in camp and 0.01 interactions per hour outside of camp. There was not a significant difference in agonistic interaction rates between the two areas ($X^2 = 1.52$, df = 1, $P > 0.100$).

We included an additional 31 interactions observed through *ad libitum* sampling (ALS) in comparing the number of agonistic interactions associated with food to the number of agonistic interactions that occurred in the absence of food. The number of agonistic interactions that occurred in the presence of food was significantly higher than the number occurring in the absence of food ($X^2 = 36.48$, df = 1, $P < 0.001$). Only one encounter in the presence of food resulted in no response, while 52 encounters in the presence of food resulted in an agonistic interaction (Table 1.2). In the absence of food, 10 encounters resulted in no response, while six encounters resulted in an agonistic interaction. All but one of the 58 total agonistic interactions we observed through FAS and ALS across the 2012 and 2013 seasons occurred in the base camp area. Of the 57 total *V. salvator* interactions we observed in the base camp, 55 occurred in the dry season as compared to two agonistic interactions observed in the wet season.

Dominance hierarchy

Of the 58 observed agonistic interactions, short pursuit was the most commonly observed interaction (36.2%), followed closely by displace (29.3%), and avoid (22.4%). We only observed stand ground/concede on seven occasions (12.1%). Among known individuals, there did not appear to be a predictable pattern of similar interaction types among the categories recorded. For example, individual 04 was dominant over individual 44 fourteen times, consisting of four avoid, five displace, four short pursuit, and one stand ground/concede. We did not observe long pursuits, where an individual chased another for an extended ($\geq$ 7 m) distance, biting, ritual/bipedal combat, or wrestling during the course of the study.

Forty-two of the observed interactions occurred between dyads of known individuals (Fig. 1.4). Individual 07, the largest individual by weight and total length, was consistently dominant over all other individuals. Due to the high number of unknown dyads between known individuals (i.e., dyads for which we did not observe an agonistic interactions, even though it was possible for members to have done so), we assessed the linearity of the relationships between only four of the study individuals, 07, 04, 44, and 23. There were no circular dyads among these individuals. Thus, simple calculations yielded a Kendall's coefficient of linearity K of 1 (complete linearity). However, with small sample sizes such as this one (n = 4), the probability that such linearity would be observed by chance is 0.375. Therefore, this result cannot be considered statistically significant (Appleby 1983).

Similarly, calculations regarding Dominance Index (DI) and individual rank among these four individuals were straightforward. High ranks corresponded to larger overall size as indicated by weight and total length of the two top ranked individuals, 07 (DI = 100) and 04 (DI = 66.6), although 23 (DI = 0) ranked fourth to a slightly smaller but similarly sized 44 (DI =

33.3). Based on our observations, individuals 04 and 44 appeared to be residents of the base camp area, while 07 and 23 were less commonly seen in the base camp area.

DISCUSSION

Varanid lizards commonly engage in agonistic behavior at feeding places such as carcasses (Auffenberg 1981; Horn et al. 1994). When feeding behaviors occur at a concentrated, human-subsidized resource, regular agonistic interactions may also occur in areas of human activity. We documented increased encounter rates in such an area of anthropogenic resources at the base camp of Tinjil Island, Indonesia. On Tinjil Island, agonistic interactions among *V. salvator* were associated with the presence of food, and agonistic interactions among garbage-feeding *V. salvator* appear to have given rise to a dominance hierarchy largely based on size.

Encounter rates and agonistic interactions

Our data showed an increased encounter rate in the garbage-feeding area as well as a significantly higher proportion of agonistic interactions involving food as compared to those occurring in the absence of food. However, we did not document a significant increase in agonistic interaction rates at the garbage-feeding site despite a difference in observed agonistic interaction rates between the two areas (1.4 vs. 0.01 per hour). Agonistic behavior among *V. salvator* in proximity to food sources (e.g. carcasses) has been well documented (*V. s. salvator*, Vogel 1979 *in* Horn et al. 1994; *V. s. marmoratus*, Maren Gaulke, pers. comm.; Gaulke 1989), so increased agonistic interaction rates in the Tinjil Island garbage-feeding area would also be expected. Restricting the analysis to interactions observed through FAS for this comparison may have resulted in insufficient data, with a larger sample size potentially producing a significant

21

result. There is also a possibility that the presence of an observer may have led to a reduction of encounters between focal animals and those individuals who were less tolerant of human interaction. Although the presence of the observer was consistent in both study areas, a repellent effect could have been more pronounced in the areas outside of camp, as most individuals in the base camp appeared habituated to humans (Uyeda 2009). Due to these considerations, the potential for increased agonistic interaction among garbage-feeding *V. salvator* requires further attention.

Our data also suggest that there may be a seasonal shift in behavior on Tinjil Island. Namely, we observed 55 *V. salvator* interactions in the garbage-feeding area in the dry season whereas only two agonistic interactions were observed in the same area in the wet season. Such differences may be explained by increased availability of natural food resources in the wet season, which could have alleviated a dependence on human food resources. Seasonal changes in behavior related to food availability have been noted by Traeholt (1997), who documented larger wet season home ranges in *V. salvator* as compared to those in dry season, when the lizards fed on seasonally available concentrated food leftovers from tourists on Tulai Island in Malaysia. Similarly, despite human subsidized food resources being available year-round on Tinjil Island, individuals 04 and 44 appeared to spend more time outside of the garbage-feeding area in the wet season as opposed to the dry season. It is likely that water availability also affects the behavior of *V. salvator* on Tinjil Island across seasons, as this species prefers habitats in close proximity to fresh-water sources (Auffenberg 1981; Bennett 1995; Gaulke and Horn 2004). Anthropogenic activities in the base camp area provide a consistent source of fresh water, an additional concentrated resource that may be particularly important for *V. salvator* in the dry season. Despite the difference in number of interactions observed between seasons, we

conducted far fewer hours of FAS in the base camp area in the wet season and we observed only

two individuals in both wet and dry seasons. Thus, meaningful statistical comparisons of

seasonal encounter rates and agonistic encounter rates in the base camp area were not possible.

We recommend that future research efforts on Tinjil Island include comparisons of agonistic

behavior across seasons to further assess temporal differences.

Dominance hierarchy

Agonistic interactions observed between *V. salvator* on Tinjil Island demonstrated a

consistent directionality that strongly suggests the existence of a dominance hierarchy among

garbage-feeding individuals. Despite numerous unknown dyadic relationships within our data,

we documented a linear hierarchy based on size. The few differences we observed in expected

outcomes based on size may also be explained by additional factors. For example, resident

individuals have been known to dominate over transient individuals in varanid populations

(Auffenberg 1981; Earley et al. 2002). Such a trend may explain the higher ranking of the

resident lizard 44 of the base camp as compared to the slightly larger, but likely transient

individual 23.

Throughout the course of our study, we did not observe bipedal combat, biting, and

wrestling. The lack of extended or escalated interactions between individuals in our study is

consistent with the predictions of game theory in which familiar individuals refrain from

engaging in risky or energetically costly physical contact if a dominance relationship has already

been established (Earley et al. 2002). While the necessity for prolonged, high energy

expenditure contests may have been diminished by familiarity among individuals, interactions

between known individuals continued to occur regularly in the Tinjil Island garbage-feeding

area. For example, we observed 04 and 44, two individuals commonly seen around the base camp area, engaging in short pursuit four times throughout the study period, despite 04 dominating over 44 in 100% of their 14 observed interactions. Such non-contact interactions would be less energetically costly while still serving to resolve contests and maintain dominance relationships.

Our observations challenge the results of Heller et al. (1999), who observed agonistic behavior among *V. salvator* but did not see evidence of a social hierarchy, concluding that social structure establishment in this species may be "considered as an artefact developed after long periods of forced close contact between the same individuals". The interactions we observed among *V. salvator* on Tinjil Island were not forced, with regular contact between the same individuals coming about through competition for concentrated, human-provided food resources. Whereas our study was based on the natural behaviors of a free-living wild population of *V. salvator*, Heller et al. (1999) observed captivity stress among wild-caught *V. salvator* placed in enclosures for 3-day periods. It is likely that differences in methodology between the two studies resulted in differing conclusions.

Female *V. salvator* have been documented engaging in combat (Daltry 1991) and have also been known to be victorious over males (Horn et al. 1994). However, as we did not document the sex of every individual in our study, the role of gender in the establishment of the Tinjil Island base camp hierarchy could not be determined. Overall condition (Horn et al. 1994), individual differences in aggressiveness (Daltry 1991), and aggression related to mating behavior (Cota 2011) are also considerations that were not directly addressed by our research.

Future directions

On Tinjil Island, the establishment of size-based dominance hierarchies in garbage-feeding areas could result in increased presence of larger individuals in the base camp area. Although large individuals engaging in intraspecific aggressive behavior in areas of human activity may raise concerns about the potential for human-lizard conflict, the types of agonistic interactions observed among *V. salvator* frequenting the Tinjil Island base camp were of short duration and low intensity. Further, *V. salvator* on Tinjil Island were generally passive towards humans when encountered in the base camp area when food was not involved (Linda Uyeda pers. obs.). However, we not only observed bolder individuals approaching humans in the possession of food (e.g., fresh fish), but occasionally caught them attempting to enter the base camp kitchen, even when it was occupied by people. As most agonistic interactions between *V. salvator* on Tinjil Island occurred in the garbage-feeding area and in the immediate presence of food, efforts to mitigate human-lizard conflict should focus primarily on decreasing garbage-feeding in areas of human activity. Human food leftovers should be discarded far from the main areas of human activity, particularly during periods in which natural food resources for *V. salvator* are limited (i.e., the dry season). If unavoidably located in areas of human activity, human refuse receptacles should be lizard-proofed whenever possible to discourage garbage-feeding behavior in these areas.

Our research indicates that *V. salvator* on Tinjil Island are not deterred from garbage feeding in close proximity to human activity and in addition may favor human-provided food in the dry season when natural prey is less abundant. In addition to comparisons of agonistic behavior across seasons, future directions should include evaluating the temporal ecological effects of garbage feeding on natural prey populations. Uyeda (2009) reported that *V. salvator*

on Tinjil Island were more abundant in the base camp area than in areas of the island with less human activity. Although *V. salvator* populations artificially increased by anthropogenic subsidy could deplete prey populations, frequent garbage feeding could alternately decrease the use of natural food sources. Alterations to the composition of prey populations could result in trophic cascades, as has been noted in systems involving terrestrial mammalian predators (Newsome et al. 2014). Further research is crucial to better understanding the effects of anthropogenic resource subsidies on the behavior of large, predatory herpetofauna and the influence of behavioral changes on both ecosystems and human-wildlife relationships.

LITERATURE CITED

Alami, A.E., E.V. Lavieren, A. Rachida and A. Chait. 2012. Differences in activity budgets and diet between semiprovisioned and wild-feeding groups of the endangered Barbary macaque (*Macaca sylvanus*) in the Central High Atlas Mountains, Morocco. American Journal of Primatology 74:210–216.

Altmann, J. 1974. Observational study of behavior: sampling methods. Behavior 49:227–265.

Appleby, M.C. 1983. The probability of linearity in hierarchies. Animal Behaviour 31:600–608.

Auffenberg, W. 1981. The Behavioral Ecology of the Komodo Monitor. University Press of Florida, Gainesville, Florida, USA.

Bennett, D. 1995. The water monitor *Varanus salvator*. Reptilian 3:15–21.

Berry, K.H. 1974. The ecology and social behavior of the chuckwalla, *Sauromalus obesus obesus* Baird. University of California Publications in Zoology 101:1–60.

Boarman, W.I., M.A. Patten, R.J. Camp and S.J. Collis. 2006. Ecology of a population of subsidized predators: common ravens in the central Mojave Desert, California. Journal of Arid Environments 67:248–261.

Cota, M. 2011. Mating and intraspecific behavior of *Varanus salvator macromaculatus* in an urban population. Biawak 5:17–23.

Daltry, J. 1991. The social hierarchy of the water monitor, *Varanus salvator*. Hamadryad 16:10–20.

Earley, R.L., O. Attum and P. Eason. 2002. Varanid combat: perspectives from game theory. Amphibia Reptilia 23:469–485.

Fedriani, J.M., T.K. Fuller and R.M. Sauvajot. 2001. Does availability of anthropogenic food enhance densities of omnivorous mammals? An example with coyotes in southern California. Ecography 24:325–331.

Gaulke, M. 1989. Zur Biologie des Bindenwaranes, unter Berücksichtigung der paläogeographischen Verbreitung und der phylogenetischen Entwicklung der Varanidae. Ph.D. Dissertation. Courier Forschungsinstitut Senckenberg, Frankfurt am Main, Germany. 242 p.

Gaulke, M. and H. Horn. 2004. *Varanus salvator* (Nominate Form). Pp. 244–257 *In* Varanoid Lizards of the World. Pianka, E., and D. King (Eds.). Indiana University Press, Bloomington, Indiana, USA.

Gaulke, M., W. Erdelen and F. Abel. 1999. A radio-telemetric study of the water monitor lizard (*Varanus salvator*) in North Sumatra, Indonesia. Advances in Monitor Research II – Mertensiella 11:63–78.

Gilchrist, J.S. and E. Otali. 2002. The effects of refuse-feeding on home-range use, group size, and intergroup encounters in the banded mongoose. Canadian Journal of Zoology 80:1795–1802.

Heller, K.E., J. Groth and C. Traeholt. 1999. Behavioural responses to captivity stress in groups of wild-living water monitor lizards (*Varanus salvator*): an evolutionary approach. Malayan Nature Journal 53:307-313.

Horn, H.-G., M. Gaulke and W. Böhme. 1994. New data on ritualized combats in monitor lizards (*Sauria: Varanidae*), with remarks on their function and phylogenetic implications. Der Zoologische Garten 64:265–280.

Hoser, R. 1994. The Australian lace monitor (*Varanus varius*) in captivity. Varanews 4:3–5.

Hoser, R. 1998. Lace monitors (*Varanus varius*) in the wild and captivity in Australia, with reference to a collection of seven adults held in captivity for eight years. Monitor-Journal of the Victorian Herpetological Society 10:22–36.

Kolowski, J.M. and K.E. Holekamp. 2007. Effects of an open refuse pit on space use patterns of Spotted Hyenas. African Journal of Ecology 46:341–349.

Kyes, R.C., D. Sajuthi, W.R. Morton, O.A. Smith, R.P.A. Lelana, J. Pamungkas, D. Iskandriati, E. Iskandar, and C.M. Crockett. 1997. The Tinjil Island Natural Habitat Breeding Facility: a decade of operation. Jurnal Primatologi Indonesia 1:1–8.

Lamprecht, J. 1986. Social dominance and reproductive success in a Goose flock (*Anser indicus*). Behaviour 97:50–65.

Langbein, J. and B. Puppe. 2004. Analysing dominance relationships by sociometric methods—a plea for a more standardised and precise approach in farm animals. Applied Animal Behaviour Science 87:293–315.

Lemelin, R.H. 2008. Human-Polar Bear interactions in Churchill, Manitoba: the socio-ecological perspective. Pp. 91-108 *In* Marine and Tourism Management: Insights from the Natural and Social Sciences. Higham, J.E.S., and M. Lück (Eds.). CAB International, Wallingford, Oxfordshire, UK.

McNulty, J.A., R.R. Ha, R.C. Kyes and E. Iskandar. 2008. Forest structure at a primate natural habitat breeding facility after fifteen years of operation. Jurnal Primatologi Indonesia 5:2–8.

Newsome, T.M., J.A. Dellinger, C.R. Pavey, W.J. Ripple, C.R. Shores, A.J. Wirsing and C.R. Dickman. 2014. The ecological effects of providing resource subsidies to predators. Global Ecology and Biogeography 24:1-11.

Oro, D., M. Genovart, G. Tavecchia, M.S. Fowler and A. Martínez-Abraín. 2013. Ecological and evolutionary implications of food subsidies from humans. Ecology Letters 16:1501–1514.

Pons, J.-M. 1992. Effects of changes in the availability of human refuse on breeding parameters in a herring gull *Larus argentus* population in Brittany, France. Ardea 80:143–150.

Spencer, R.D., R.A. Beausoleil and D.A. Martorello. 2007. How agencies respond to human-black bear conflicts: a survey of wildlife agencies in North America. Ursus 18.2:217–229.

Stamps, J.A. 1977. Social behavior and spacing patterns in lizards. Pp. 265–334 *In* Biology of the Reptilia 7. Gans, C., and D.W. Tinkle (Eds.). New York Academic Press, New York, New York, USA.

Stirling, I. and C.L. Parkinson. 2006. Possible effects of climate warming on selected populations of polar bears (*Ursus maritimus*) in the Canadian Arctic. Arctic 59:261-275.

Timm, R.M., R.O. Baker, J.R. Bennett and C.C. Coolahan. 2004. Coyote attacks: an increasing suburban problem. Pp. 47–57 *In* Proceedings of the Twenty-First Vertebrate Pest Conference. Timm, R.M. and W.P. Gorenzel (Eds.). University of California, Davis, California, USA.

Traeholt, C. 1994. The food and feeding behaviour of the water monitor, *Varanus salvator*, in Malaysia. Malayan Nature Journal 47:331–343.

Traeholt, C. 1997. Ranging behaviour of the water monitor lizard *Varanus salvator*. Malayan Nature Journal 50:317–329.

Uyeda, L. 2009. Garbage appeal: relative abundance of water monitor lizards (*Varanus salvator*) correlates with presence of human food leftovers on Tinjil Island, Indonesia. Biawak 3:9–17.

Uyeda, L.T., E. Iskandar, R.C. Kyes and A.J. Wirsing. 2012. Proposed research on home ranges and resource use of the water monitor lizard, *Varanus salvator*. The Forestry Chronicle 88:542–546.

Uyeda, L., E. Iskandar, A. Wirsing and R. Kyes. 2013. Nocturnal activity of *Varanus salvator* on Tinjil Island, Indonesia. Biawak 7:25–30.

Uyeda, L.T., E. Iskandar, A. Purbatrapsila, J. Pamungkas, A. Wirsing and R.C. Kyes. 2014. The role of traditional beliefs in conservation of herpetofauna in Banten, Indonesia. Oryx 1-6 doi:10.1017/S0030605314000623.

Figure 1.1. The water monitor lizard (*Varanus salvator bivittatus*) on Tinjil Island, off the south coast of Java in Banten, Indonesia. (Photographed by Linda Uyeda).
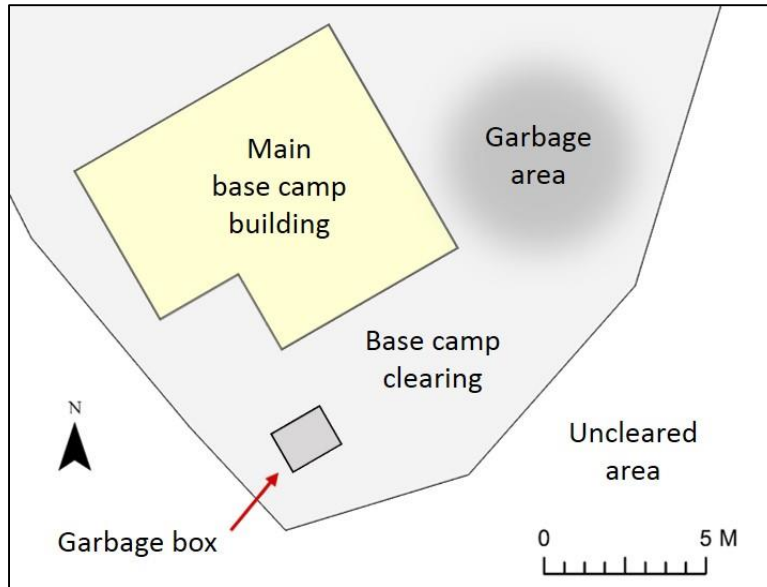
Figure 1.2. Top: overview of the main base camp building and garbage-feeding area frequented by water monitor lizards (*Varanus salvator bivittatus*) on Tinjil Island, Indonesia. Bottom: the garbage box outside of the main base camp building. The photographer of this photo (Linda Uyeda) was oriented in the position indicated by the red arrow labeling the garbage box in the top overview.

Figure 1.3. Displace behavior between two *Varanus salvator bivittatus* on Tinjil Island, Indonesia. Top: lizard 44 approached lizard 23 as it was consuming some human food leftovers outside the main base camp building. Bottom: lizard 23 ran away while lizard 44 took over foraging in the desired location. (Photographed by Linda Uyeda).

	Dominant									
	07	**93**	**15**	**63**	**04**	**53**	**23**	**44**	**02**	**01**
07	--									
93	1	--								
15	1		--		1					
63				--						
04	7				--					
53	1				1	--				
23	1				5		--	2		
44	3		2		14			--		
02									--	
01							1	2		--

(Submissive — row axis label)

Figure 1.4. Results of a sociometric matrix based on observations of agonistic interactions between known dyads of *Varanus salvator* on Tinjil Island, Indonesia. Matrix values represent the number of agonistic interactions recorded between pairs of individuals in each direction (e.g. individual 07 was observed to be dominant over individual 04 seven times, while individual 04 was not observed to be dominant over individual 07). Individuals are listed along the axes by weight from heaviest (07) to lightest (01).

Table 1.1. Encounter rates observed through focal animal sampling (FAS) of *Varanus salvator bivittatus* on Tinjil Island, Indonesia. All encounters (agonistic interactions and those that produced no response) versus hours of focal animal sampling (FAS), and encounter rate per hour. IC = in camp; OC = out of camp.

Year	Total encounters/hrs FAS-IC	Total encounters/hrs FAS-OC	Encounter/hr of FAS-IC	Encounter/hr of FAS-OC
2012	32/15.6	2/20.5	2.05	0.1
2013	0/3.0	4/59.3	0	0.07
Total	32/18.6	6/79.8	1.72	0.07

Table 1.2. Agonistic interactions and encounters resulting in no response among *Varanus salvator bivittatus* on Tinjil Island, Indonesia. Observed encounters were grouped according to whether they involved food and foraging, or were in the absence of food. Numbers in parentheses represent values inside/outside the base camp area.

Year	Total interactions	Interaction, food	Interaction, no food	Percentage of interactions involving food	no response, food	no response, no food
2012	55 (55/0)	49 (49/0)	6 (6/0)	89%	1 (1/0)	7 (5/2)
2013	3 (2/1)	3 (2/1)	0 (0/0)	100%	0 (0/0)	3 (0/3)
Total	58 (57/1)	52 (51/1)	6 (6/0)	89.6%	1 (1/0)	10 (5/5)

Appendix Ia. Morphometric measurements of *Varanus salvator bivittatus* on Tinjil Island, Indonesia. Weights were measured to the nearest 0.5 kg, lengths measured to the nearest 0.5 cm. All individuals except 93, 02, and 01 were measured in both the 2012 and 2013 season. Table values represent the mean and range (in parentheses) for each measurement. An asterisk (*) indicates that the individual had a missing tail tip. In each of the three cases it appeared very little of the tail had been lost. TOL = total length; SVL = snout-vent length; MG = maximum girth; TBC = tail base circumference; and TAL = thorax-abdomen length.

Individual	Weight	TOL	TBC	MG	SVL	TAL
07	21.5 (21.0–22.0)	222.2* (221.5–223.0)	34.5 (34.0–35.0)	66.5 (66.0–67.0)	95.5 (94.0–97.0)	40.5 (38.0–43.0)
93	20.5	211.5	33.5	65.0	92.0	43.0
15	18.5 (18.0–19.0)	213.0 (208.0–218.0)	32.0 (31.5–32)	60.0 (57.0–62.5)	92.0 (208.0–218.0)	41.75 (36.0–47.5)
63	17.5 (17.0–18.0)	206.5 (206.0–207.0)	31.0 (30.5–31.5)	61.7 (60.0–63.5)	93.2 (92.5–94.0)	43.7 (42.0–45.5)
04	17.7 (17.5–18.0)	215.0* (213.0–217.0)	31.7 (31.5–32.0)	62.0 (61.0–63.0)	94.5 (92.0–97.0)	44.5 (43.0–46.0)
53	16.7 (16.0–17.5)	215.7 (214.5–217.0)	29.0 (29.0–29.0)	62.7 (59.5–66.0)	96.2 (96.0–96.5)	44.0 (44.0–44.0)
23	16.2 (16.0–16.5)	214.5 (213.5–215.5)	31.0 (31.0–31.0)	61.5 (59.5–63.5)	93.5 (90.5–96.5)	40.0 (37.0–43.5)
44	15.0 (13.0–17.0)	208.2 (206.5–210.0)	28.7 (28.0–29.5)	59.5 (55.5–63.5)	96.2 (94.5–98.0)	43.5 (43.0–44.0)
02	7.0	159.0*	21.5	42.0	64.0	32.0
01	4.5	138.0	20.5	35.0	56.0	28.5

Appendix Ib. Key to morphometric measurements recorded of *Varanus salvator bivittatus* on Tinjil Island, Indonesia. Measurements were total length (TOL), snout-vent length (SVL), maximum girth (MG), tail base circumference (TBC), and thorax-abdomen length (TAL).
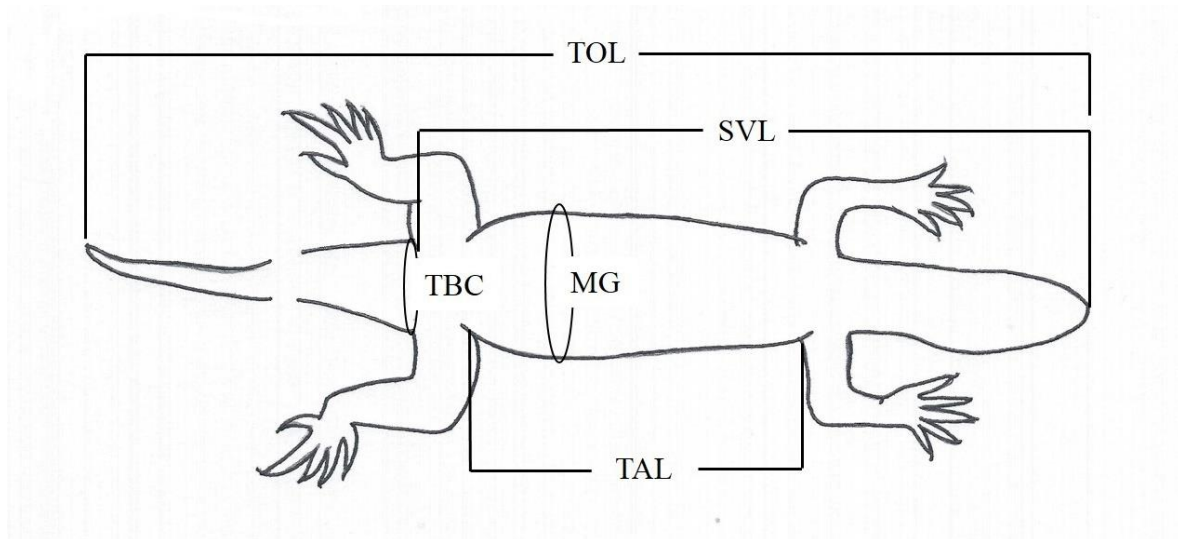
CHAPTER 2

SEASONAL ACTIVITY AREAS AND SPACE USE OF THE WATER MONITOR LIZARD
(*VARANUS SALVATOR*) IN AN AREA OF ANTHROPOGENIC RESOURCE SUBSIDY

ABSTRACT

Human-provided resources may draw wildlife to areas of anthropogenic activity,

increasing the potential for conflict while altering wildlife ecology. In areas where resource

availability varies seasonally, wildlife populations may exhibit seasonal shifts in activity and

resource use. Cross-season studies of wildlife behavior in areas of predictable anthropogenic

resource subsidy facilitate the identification of periods with increased potential for conflict while

ensuring that season-specific effects are not overlooked. Although altered behavior in areas of

anthropogenic subsidy has been well recognized, particularly in large carnivores, relatively few

studies have focused on temporal differences in activity, and herpetofaunal populations have

been largely underrepresented. Here, we report season-specific differences in activity and space

use of the water monitor lizard, *Varanus salvator*, a large predator and scavenger known for

garbage-feeding and preying on chickens throughout its Southeast Asia range. We collected dry

season and wet season radio-telemetric data on *V. salvator* on Tinjil Island, Indonesia in an area

of regular anthropogenic resource subsidy. Seasonal activity area estimates suggest that Tinjil

Island's *V. salvator* increase space use in the wet season, when natural resources are more

abundant. Similarly, through the use of resource utilization functions (RUF) we related *V.

salvator* space use and proximity to areas of anthropogenic activity (i.e. "camps"), documenting

increased probability of high use in areas away from camps in the wet season. We also observed

increased use of areas away from the island perimeter across both seasons. Our results indicate

that *V. salvator* do not always use anthropogenic resource subsidies when available and generally

use interior forested areas more than perimeter (beach) areas. Individual differences in behavior also occur. We propose that a combination of changing factors, including the ratio of available anthropogenic subsidies to natural resources, avoidance of human and intraspecific interactions, and dominance status appear to affect *V. salvator* activity and space use across seasons.

INTRODUCTION

As areas of human development and wildlife activity increasingly intersect, the effects of anthropogenic resource subsidy on wildlife behavior and ecology have become of greater concern (Oro et al. 2013; Newsome et al. 2014). Anthropogenic subsidies increase the potential for human-wildlife conflict by drawing unwanted wildlife into the human domain (Beckman and Berger 2003; Treves and Karanth 2003), while the presence of predictable resources can also affect wildlife ecology, altering behaviors such as foraging and space use (raccoons, *Procyon lotor*, Prange et al. 2004; Egyptian vultures, *Neophron percnopterus*, López-López et al. 2014). Such responses to anthropogenic subsidies are not always constant, however. Seasonal shifts in behavior occur naturally in many wildlife species (e.g. cougars, *Puma concolor*, Dickson and Beier 2002; eastern box turtles, *Terrapene carolina carolina*, Donaldson and Echternacht 2005), and temporal use of seasonally fluctuating anthropogenic resource subsidies has also been documented (e.g. Barbary macaques, *Macaca sylvanus*, El Alami and Chait 2012). However, studies on the effects of consistent anthropogenic subsidy on wildlife populations have generally not incorporated measures of temporal activity (Marczak et al. 2007). Thus, studies comparing season-specific wildlife use of anthropogenic subsidy are necessary to enable a more detailed understanding of ecological consequences while identifying periods with increased potential for human-wildlife conflict.

Larger predatory species are of particular concern because individuals frequenting areas of anthropogenic subsidy can also threaten livestock and human safety (Timm et al. 2004; Kolowski and Holekamp 2007). While responses of terrestrial mammals (e.g. Newsome et al. 2014; Millspaugh et al. 2015) and birds (Pons 1992; Kristen and Boarman 2007) have received considerable attention, studies of large reptiles in areas of anthropogenic resource subsidy (e.g. Jessop et al. 2012) are relatively few.   Here, we present a seasonal analysis of radio-telemetric data collected on water monitor lizards (*Varanus salvator*) on Tinjil Island, Indonesia.

Varanus salvator is a large (>2 m total length) generalist predator and scavenger known for its broad diet (Losos and Greene 1988; Gaulke 1991) and ability to adapt to human-disturbed areas (Gaulke et al. 1999; Shine et al. 1998). Although able to inhabit a wide range of habitat types throughout its broad range, as the name "water monitor lizard" suggests, *V. salvator* has an affinity for fresh or brackish water environments (Auffenberg 1981; Bennett 1995; Gaulke and Horn 2004). Despite numerous accounts of *V. salvator* in areas of regular anthropogenic food supplementation (e.g. Traeholt 1994a/b; Amarasinghe et al. 2009; Uyeda et al. 2013) detailed study of this species' behavior in areas of human subsidy are lacking. With the exception of Traeholt (1997a/b), who documented reduced *V. salvator* activity areas in seasons where turtle nesting and tourist visits resulted in increased food concentration, systematic study of seasonal space use in this species has been equally limited.

Although radio-telemetric studies of *V. salvator* have been conducted in the past, previous research has focused on activity in populations with seasonal access to anthropogenic food subsidy (Traeholt 1997a/b), and on *V. salvator* activity in a single season in a location where study of anthropogenic subsidy was not a main objective (Gaulke et al. 1999). In contrast, our research was designed to provide insight into the influence of year-round anthropogenic

resource subsidy on *V. salvator* space use. Current technology also facilitates more detailed

analyses, such as probabilistic measures of space use and the coupling of radio-telemetric data

with predictive resource variables to assess utilization of resources. We used the ESRI ArcMap

10.2.2 Geographic Information System (GIS) to assess *V. salvator* activity areas, and the

statistical computing environment R (R Core Team 2014) to create individual and population-

level resource utilization functions (RUF; Marzluff et al. 2004). To our knowledge, this is the

first study to use RUFs to relate *V. salvator* space use to available resources.

Our research was conducted on Tinjil Island, Indonesia, where human activity provides a

consistent resource subsidy for *V. salvator* in the form of discarded food scraps and fresh water

runoff in the base camp area. The island also experiences distinct wet and dry seasons, enabling

investigation of temporal changes in *V. salvator* behavior related to seasonal hydrology. We

collected radio-telemetric data on Tinjil Island's *V. salvator* to accomplish the following research

objectives: (1) calculate estimates of seasonal activity areas in an area of year-round

anthropogenic subsidy, and (2) investigate seasonal *V. salvator* space use in relation to resource

variables, particularly those related to anthropogenic resource subsidy (e.g. the island's base

camp). We hypothesized that *V. salvator* would have smaller activity spaces in the dry season,

when natural resources are limited and clumped resource subsidies may be more heavily utilized.

We also hypothesized that *V. salvator* space use would be more concentrated near areas of

anthropogenic subsidy during the dry season as opposed to wet season, when natural food and

water resources are more abundant.

METHODS

Study area

Our research took place on Tinjil Island, Indonesia, located approximately 16 km off the south coast of Banten Province, Java (Figs. 2.1, 2.2). Tinjil Island measures approximately 1 km North-South and 6 km East-West, with a total area of approximately 600 hectares. Since 1987, Tinjil Island has been designated as a Natural Habitat Breeding Facility for longtailed macaques, *Macaca fascicularis*, managed by the Primate Research Center of Bogor Agricultural University (IPB) (Kyes et al. 1997). All visitors to the island must obtain permission to conduct activity there. While island caretakers provide a continuous human presence (5–8 people at any given time), there are officially no permanent residents on Tinjil Island. Most human activity on Tinjil Island is concentrated around a main base camp area, and three smaller fisherman camps are also found along the northern edge of the island (Fig. 2.2). The camps are utilized for days or weeks at a time by fishermen who have been approved to reside on Tinjil Island while fishing in nearby waters. Cooking and fish cleaning are routinely carried out in both the base camp and fisherman camps, providing regular scavenging opportunities for *V. salvator* in the form of discarded food waste. In the base camp area, lizards are frequently seen scavenging in garbage piles or in a large, easily accessible (ca. 1.5 m x 2 m x 1 m) cement garbage receptacle located behind the main base camp building (Uyeda 2009; Uyeda et al. 2013). *V. salvator* have also been observed drinking from dripping base camp spigots and soaking in water runoff from human bathing facilities in the base camp area.

Tinjil Island experiences two distinct seasons, a dry season and a wet season. Natural fresh water resources are scarce during the dry season, while in the wet season frequent rains create puddles and pools of swampy water throughout the island. In the wet season, *V. salvator*

42

prey such as land crabs are also more abundant (L. Uyeda, pers. obs.; Appendix IId/e). The

island is typically at its driest from June-August and rains are generally at their peak from

January-March.

Tinjil Island consists of lowland secondary tropical rainforest and coastal beach

vegetation, with flora including *Ficus spp*., *Gnetum gnemon* (Melinjo), and *Dracaena elliptica*

(Hernowo et al. 1989; McNulty et al. 2008). A grid of transects, utilized by workers and

researchers, has been established across the island. *V. salvator* are also commonly observed

using these paths for traveling from one area to the next as well as for basking (L. Uyeda, pers.

obs.). Unlike populations living in other parts of its range, Tinjil Island's *V. salvator* are

protected by official policy of IPB, which does not allow harvesting the lizards from the island.

Data collection

Individual *V. salvator* were trapped in the Tinjil Island base camp area, fitted with radio-

telemetric harnesses, and tracked regularly to establish a series of individual locational data

points. Baited wooden box traps, measuring approximately 225cm length x 50cm height x 50cm

width, were the primary means of capture. Lizards were also captured by hand. Each lizard was

assigned an individual identifier and marked with a non-toxic wax crayon. These superficial

markings typically washed away within 1-2 weeks, depending on the activity level of the animal

and the weather. Each lizard was weighed and morphometric measurements were recorded (see

Chapter 1).

An external radio-transmitter was attached to each lizard by means of a custom-designed

LPR-3800 waterproof "backpack" harness (Wildlife Materials, Murphysboro, IL, USA) prior to

release at the point of capture. The harnesses used in this study were improved versions based

on LPR-3800 harnesses that had been field tested in 2011 (Uyeda et al. 2012). Each transmitter was assigned a unique signal, allowing for individual identification of instrumented lizards.

Once released, each animal was tracked on foot with a TRX-48S receiver and 3-element yagi directional antenna (Wildlife Materials, Murphysboro, IL, USA). A Garmin eTrex Vista HCx handheld GPS unit was used to record the position of each animal each time it was located via radio-telemetry. Data points (i.e. locational coordinates, or fixes) were collected from active animals immediately following their departure from the location where they were first observed. In the case of inactive individuals (e.g. basking or sleeping), data points were collected from as close to the individual as possible; animals buried in leaf litter, sleeping in hollow logs, or in the shelter of tree buttresses appeared undisturbed when approached within 1-2 m, while animals resting in more exposed areas generally tolerated human presence as close as 2-3 m. Behavior of each individual was closely observed to avoid inducing any visible reaction to the presence of the researcher. For example, if a lizard was observed inflating its gular area or raising its head, the researcher would immediately retreat, making note of the time and the individual's position. The researcher would later return to obtain GPS coordinates when the lizard was no longer present. Each individual was located within 24 hours of initial release to confirm both the individual's well being and that the equipment was functioning properly. These preliminary locational points were not utilized in the analysis, to avoid including behavior that may have resulted from reaction to capture.

Animals were tracked from 5 July 2012 to 16 August 2012 (dry season) and 13 January 2013 to 26 March 2013 (the following wet season). No tracking took place from 28 February 2013 to 10 March 2013 (11 days). With the exception of one individual whose nocturnal activity is not discussed here (see Uyeda et al. 2013), study animals were observed to be diurnal, and

tracking was conducted between 0500h and 1800h each day. Each individual was located up to

three times per day, with a minimum interval of two hours between consecutive fixes. Each

individual was located at different times of day throughout each study season to avoid

overrepresentation of locations (e.g. a favored morning basking site) that may have been

regularly utilized at only a particular time of day. At least four fixes per 2-hour time block (five

2-hour time blocks between 0600h and 1600h) were obtained per season for each of the animals

included in the RUF analysis. We removed all radio-telemetric harnesses upon completion of

the study. All *V. salvator* captures and handling were carried out in accordance with the

University of Washington Institutional Animal Care and Use Committee (IACUC) protocol

#3143-04.

Data analysis

        We estimated activity areas by first utilizing the ArcMap Minimum Bounding Geometry

Tool to create minimum convex polygons for each animal by season. The minimum convex

polygon method enabled comparison to data from previous literature on activity areas and home

ranges of *V. salvator* (Traeholt 1997b; Gaulke et al. 1999) and other varanid species (*V. griseus*,

Stanner and Mendelssohn 1987; *V. tristis*, Thompson et al. 1999; *V. varius*, Guarino 2002; *V.

komodoensis*, Ciofi et al. 2007; *V. indicus* and *V. mertensi*, Smith and Griffiths 2009). However,

the MCP method has recognized drawbacks. For example, the inclusion of peripheral long

excursions can result in inflated area values (Ciofi et al. 2007; Harless et al. 2010), and the MCP

also implies uniform use within the bounded area, which is not often the case.

        Unlike the MCP method, kernel density (KD) estimation takes into account the intensity

of use of a particular area, representing the probability of a particular individual occurring at a

specific location within the range encompassed by the recorded points at a given time. We used the Geospatial Modelling Environment (GME) Kernel Density Estimation tool (Beyer 2012) and ESRI ArcMap 10.2.2 to create fixed-kernel home range estimates for each set of location data.

There are several choices of selection method for determining the smoothing factor or bandwidth used to calculate the KD estimate, and the size and shape of the resulting home range estimates will vary slightly depending on the method selected (Kertson and Marzluff 2010). Although the least squares cross-validation (LSCV) bandwidth selection method has been used by Ciofi et al. (2007) in studying *Varanus komodoensis*, and is often recommended for wildlife home range analyses (Millspaugh et al. 2006), Kernohan et al. (2001) caution that LSCV does not yield optimal results in cases where many locations are at or near the same point, as was the case with Tinjil Island individuals with core areas around the base camp. Gitzen et al. (2006) have also noted this weakness of the LSCV method, supporting second generation bandwidth selection methods such as the plug-in as alternatives. The plug-in method of bandwidth selection is also indicated in cases where researchers aim to focus on areas of concentrated use rather than emphasize exploratory pathways (Walter et al. 2011). For these reasons, we used the plug-in option within GME to estimate bandwidths when creating KD estimates. We calculated 95% contours for each of the KD estimates by using the GME Isopleth tool (Beyer 2012) as a standard measure of activity area. 75% and 50% isopleths were also created to identify areas of core activity.

Both the MCP and KD methods resulted in multiple estimates that included areas beyond the perimeter of Tinjil Island. Although *V. salvator* can utilize saltwater (Gaulke and Horn 2004), only one Tinjil Island individual was ever observed swimming in the ocean, very close to shore, during the entire course of our study. However, study individuals made use of beach areas

located beyond the mapped perimeter of the island, particularly during low tide (L. Uyeda, pers. obs.). The furthest locational fix documented with radio-telemetry in either study season was approximately 30 m beyond the mapped Tinjil Island perimeter. Based on these observations, we created a 30 m buffer around the Tinjil Island perimeter using the ArcMap Buffer tool, clipping the area beyond the 30 m buffer from activity area estimates as needed to remove unsuitable habitat.

Varanids may engage in peripheral excursions, potentially resulting in overestimation of activity areas (e.g. *V. komodoensis*, Ciofi et al. 2007) During the wet season it appeared that lizard 04 engaged in at least one long distance (≥1.5 km) excursion. Although including the locational data points from these excursions significantly increased the area encompassed in our analysis of this individual, removal of these data points, which accounted for over half of the data on 04's wet season movements, would have resulted in an unacceptably small sample size for this individual. Thus, we included all data in the analysis of 04's individual activity, but excluded 04's wet season data from specific population-level analyses, as noted.

V. salvator KD estimates were converted to utilization distributions (UD) which represented space use as a continuous variable across each individual's activity area. UDs were combined with predictor variables to produce a Resource Utilization Function (RUF; Marzluff et al. 2004), which relates the intensity of use to mapped resources across each individual's range. To prepare data for RUF analysis, UDs were converted to percent volume polygons in GME, identifying 1-99 percentiles of use probabilities. In ArcMap polygons were converted to 1 m point grids, with each point assigned a value indicating the relative probability of use. Each point was then related to measures of resource availability selected to study the effects of anthropogenic factors on *V. salvator* space use. Based on observations of Tinjil Island's *V.*

salvator behavior, we chose distance to camps (fisherman camps and the base camp), distance to the island perimeter (i.e. distance to beach/forest edge), and distance to trail (transects) as predictor variables of space use. The camps, island perimeter, and trails were mapped while on Tinjil Island by traveling on foot, carrying a handheld Garmin eTrex Vista HCx GPS unit. The resulting GPS data were entered into ArcMap, and the ArcMap Near tool was utilized to calculate shortest distance (m) to nearest camp, distance to the island perimeter, and distance to nearest trail for each point within the established grid. Use and distance values for each point were joined into a single file and extracted from ArcMap for RUF analysis. RUFs were created by using the Ruf.fit package (Handcock 2012) in the statistical program R (R Core Team 2014), which uses multiple regression adjusted for spatial autocorrelation to calculate coefficient estimates for each predictor variable. We created RUFs for each individual per season, using the resulting unstandardized coefficients and associated standard errors to create 95% confidence intervals for each variable. Population level RUFs were estimated by averaging individual values for each coefficient within each season. We constructed 95% confidence intervals around population means using a precise standard error estimate that included inter-animal variation (Marzluff et al. 2004). Confidence intervals that did not include zero were considered significant and either positively or negatively correlated with *V. salvator* resource use as indicated by sign.

We included only data sets with ≥ 30 locational points, the recommended minimum for RUF analysis (Seaman et al. 1999; Kernohan et al. 2001) in our RUF analysis. We collected only 18 fixes for lizard 63 in the wet season, so this individual's wet season data were examined for activity area analysis but was not included in the RUF analysis. As previously noted, lizard 04's wet season activity resulted in a data set that encompassed a much larger area than other individuals in our study. Due to software computing requirements, we utilized a point grid cell

size of 30 to complete the analysis of this larger data set. To account for any bias stemming from lizard 04's wet season data, we conducted population level wet season RUFs both with and without this individual's data.

As noted by Johnston (2013), accurate RUF analysis also requires that data conform to assumptions of multiple regression, including homoscedasticity (Marzluff et al. 2004). Although past and recent RUF analyses have been conducted without mention of data transformation (e.g.; Kertson et al. 2011; Amelon et al. 2014), in his study of gray squirrels (*Sciurus griseus* and *S. carolinensis*) Johnston (2013) found highly skewed response data in examining residual plots of predicted values based on univariate RUFs. Johnston (2013) pointed out that a right-skewed pattern would be expected from response variables derived from utilization distributions, which generally consist of far more low-use than high-use cells. Johnston subsequently log-transformed the response variable for all study individuals, improving the distribution of residuals to better meet the assumption of homoscedasticity. Log transformations were also conducted by Prince (2013) in a RUF analysis of southeastern fox squirrels (*Sciurus niger niger*). We examined residual plots for univariate RUFs for each Tinjil Island individual per season and found that response data based on unclipped UDs (three individuals, 04, 44, and 23 in dry season only) were right-skewed. Accordingly, these data were log transformed for RUF analysis.

RESULTS

Eight *V. salvator* were captured in the Tinjil Island base camp area and equipped with radio-telemetric harnesses. Everted hemipenes were observed in one individual tracked in the dry season (23) and one individual in the wet season (53), so these two individuals were considered to be male. With the exception of lizards 23 and 53, sex was not determined,

although others (e.g. 07 and 04) were suspected to be male based on size (see Appendix Ia/b for

morphometric data) and observed interactions with conspecifics (Chapter 1; Uyeda et al. 2013).

More than 30 fixes were obtained for three individuals in both seasons, plus two individuals

tracked in the dry season (five total), and three individuals in the wet season (six total) (Table

2.1). Individuals included in the home range analyses were tracked for 19-72 days, with

locational fixes totaling 18-55 per season. In the wet season, numerous attempts (>50) were

made to locate lizard 23 at locations spanning the entire island, but no signal was obtained until

23 March 2013. Upon finally locating lizard 23 we captured this individual to ensure harness

removal prior to the end of the field season. Thus, we were unable to collect additional

locational fixes for this individual. Although it is possible that lizard 23's equipment had

temporarily stopped transmitting, based on the strong signal and undamaged condition of the

harness upon removal it is most likely that the lizard had been in a location (e.g. underground

burrow, dense forest in a remote area) where its signal could not be received.

Activity areas

V. salvator activity areas overlapped in both seasons (Fig. 2.3). Dry season 95% KD

activity areas estimates ranged from .55 to 7.88 ha, while wet season 95% KD ranged from 5.77

to 111.99 ha (Table 2.1). Dry season MCP averaged 4.06 ha (SD 3.69), while the mean 95% KD

estimate for dry season areas was 3.52 ha (SD 3.13). Wet season activity area averages for MCP

and 95% KD were approximately 8-10 times larger than dry season estimates, at 32.35 ha (SD

26.26) and 36.67 ha (SD 34.10) respectively. With the removal of individual 04's wet season

activity area, which was well over double the size of that of the next closest individual, mean wet

season estimates remained more than five times as large as those of the dry season at [MCP]

22.70 ha (SD 12.37) and [95% KD] 24.12 ha (SD 15.93). Of the three individuals tracked over

both seasons with ≥30 fixes, all had larger seasonal activity area estimates (both MCP and KD)

for the wet season as compared to the dry season (Table 2.1; Appendices IIa-IIc). Lizard 63 also

followed this trend, despite a wet season estimate based on only 18 data points versus 37 fixes in

the dry season (Table 2.1). With only three individuals sufficiently tracked across both study

periods, we had inadequate sample size to statistically analyze population level differences in

activity space across seasons.

Space use

The population-based RUF revealed positive correlation with distance from camp in the

wet season (95% CI [$9.04e^{-3}$, $3.94e^{-2}$], Table 2.2) indicating that Tinjil Island *V. salvators*'

highest use areas were away from camps during that season. The opposite pattern was observed

in the dry season, as high use was correlated to areas near to camps in three of five individuals

(04, 44, and 23, Table 2.3), although this correlation was not significant at the population level

(Table 2.2). Population level analysis also revealed a positive correlation between use and

perimeter in the wet season (95% CI [$2.19e^{-3}$, $1.34e^{-1}$], Table 2.2). High use away from

perimeter was consistent across seasons, and was significant in a population-based RUF

averaging use across both seasons (95% CI [$1.09e^{-2}$, $8.88e^{-2}$]). Individual analysis was

consistent with these results, as 5/5 (dry season) and 4/6 (wet season) individuals' use was

positively correlated with distance to perimeter (Table 2.3). Individual use of trails varied

between seasons. Two individuals in the dry season and one individual in the wet season

exhibited increased use with increasing distance to trail, while three individuals in wet season

showed the opposite association of increased use with decreasing distance to trail (Table 2.3).

51

The effect of distance to trail was not significant in the population-level analysis of this variable (Table 2.2). Individual differences in space use were also apparent among the three lizards that were tracked across both seasons. For example, lizard 04's use increased closer to camps in both seasons, lizard 44 increased its use of areas close to camps in the dry season but showed the opposite trend in wet season, and lizard 07 increased use as distance from camps increased in both seasons (Table 2.3). A population level wet season RUF excluding 04 remained significant for distance to camps (95% CI [$1.55e^{-2}$, $4.33e^{-2}$]) and distance to perimeter (95% CI [$1.24e^{-2}$, $1.55e^{-1}$]).

DISCUSSION

We investigated activity areas and space use of eight *V. salvator* across wet and dry seasons in an area with year-round access to both wildland resources and anthropogenic resource subsidy. As predicted, our analysis suggested a trend of smaller activity areas in the dry season, when natural food and water resources are limited and clumped anthropogenic subsidies in camp areas may be of greater importance. Although small sample sizes limited our ability to conduct population level comparisons of activity spaces across seasons, all four individuals with data from both seasons utilized markedly larger activity areas in the wet season as compared to the dry season. RUF analyses indicated a similar trend; *V. salvator* increased use of areas away from camps in the wet season, when natural resources are more abundant. High use in areas away from the island perimeter in both seasons indicates that *V. salvator* generally utilized forested areas more than beach and ocean areas.

Numerous studies show wildlife in areas of predictable human resource subsidy occupying smaller home ranges in comparison to wildland counterparts (e.g. crows and ravens,

Corvus brachyrhynchos and *C. corax*, Marzluff and Neatherlin 2006; black bears, *Ursus americanus*, Beckmann and Berger 2003; raccoons, *Procyon lotor*, Prange et al. 2004). It is also not uncommon for wildlife to utilize anthropogenic resource subsidies when available, shifting to other resources when subsidies are diminished (Pons 1992; El Alami and Chait 2012; Yirga et al. 2012). Based on these observations, we might expect smaller ranges and a lack of seasonally-altered space use in areas with predictable resources available year-round, as use of consistently located anthropogenic subsidies would make seasonal shifts in space use unnecessary. Such a result has been observed, for instance, in urban coyotes (*Canis latrans*, Grinder and Krausman 2001; Hidalgo-Mihart et al. 2004). In contrast, our dry and wet season estimates of Tinjil Island *V. salvator* appeared to follow the same trend as a seasonally subsidized island population researched by Traeholt (1997b, Appendix IIh); lizards may be active in smaller areas during dry season and larger areas in the wet season. Our RUF analyses also indicated that Tinjil Island's *V. salvator* increased use in areas away from camps in the wet season, despite the year-round availability of anthropogenic subsidies in these areas. It appears that Tinjil Island lizards used anthropogenic subsidies only when needed (i.e. in the dry season), rather than consistently utilizing these resources whenever available.

There are a number of potential explanations for the observed seasonal shifts in activity areas and space use. For example, prey availability, namely the ratio of subsidy resources to natural prey, has been identified as useful in predicting the effects of anthropogenic resource subsidy on wildlife populations (Marczak et al. 2007). On Tinjil Island, *V. salvator* may be more likely to frequent garbage feeding areas in the dry season, when prey items (e.g. crabs) are less abundant. *V. salvator* were observed actively hunting crabs in the wet season on numerous occasions (Appendix IId/e), but hunting was not observed in the dry season, when crab

availability was low (L. Uyeda, pers. obs.). Valeix et al. (2012) noted similar shifts in African

lions (*Panthera leo*); despite livestock being highly abundant year-round, lions switched to

livestock feeding only during seasons when wild prey migrated out of the resident area. It is also

possible that Tinjil Island's *V. salvator* prefer hunting live animals to scavenging on garbage.

Traeholt (1994a) reported that wild *V. salvator* preferred live prey to carrion, noting that *V.

salvator* not only tended to leave carrion and pursue live prey (rats), but could also be lured away

from carrion by dragging a knotted rope nearby.

Seasonal hydrology may also play a role in *V. salvator* activity and space use. Temporal

shifts in response to water resources have been discussed in a number of species. For example,

Dickson and Beier (2002) attributed smaller dry season ranges in cougars, *Puma concolor*, to

activity concentrated near water sources. On Tinjil Island, fresh water resources are extremely

limited in the dry season, with the only predictable sources (dripping spigots, water runoff from

human activities) located in the base camp area (Appendix IIf). During the wet season, fresh

water abounds on Tinjil Island, with water pooling in tree hollows (Appendix IIg) and flooding

common in the island's lower areas. Tinjil Island's *V. salvator* may concentrate use around base

camp in the dry season to take advantage of anthropogenic fresh water sources, while dispersing

out to individual activity areas in periods of greater natural water availability. Similar behavior

was observed in a population of eastern box turtles (*Terrapene carolina carolina*), which

coalesced towards a temporary pool in periods of high temperature and low precipitation, but

otherwise occupied separate home ranges in other parts of the year (Donaldson and Echternacht

2005).

The presence of humans is also a potential incentive for *V. salvator* to avoid camp areas

whenever possible. Opportunistic use of anthropogenic subsidy and avoidance of encounters

with humans is an unsurprisingly common practice across wildlife species in areas of human development (Grinder and Krausman 2001; Lowry et al. 2012). For example, African lions (*Panthera leo*) preyed on livestock when natural prey were scarce, but exhibited behaviors that reduced the probability of encounters with humans (e.g. avoiding cattle-posts during periods when humans were most active) and otherwise avoided human settlements when migratory prey were present (Valeix et al. 2012). Although base camp individuals generally appeared accustomed to human presence, we regularly observed Tinjil Island's *V. salvator* avoiding direct encounters with humans (e.g., slowly turning away upon noticing an approaching human; L. Uyeda, pers. obs.), suggesting that perhaps the island's lizards only tolerated close proximity to humans when necessary.

Use of camp areas not only increases the likelihood of encounters with humans, but with conspecifics as well. Indeed, observations on Tinjil Island documented that a higher incidence of intraspecific encounters occurred in the base camp as compared with wildland areas (Chapter 1). Tinjil Island's camps are small, and subsidies, although consistently available, are insufficient to allow ad libitum feeding by all individuals. Competition over such clumped, limited resources can lead to increased agonistic interactions and intraspecific aggression (Pons 1992; Alami et al. 2012). On Tinjil Island, a lack of natural resources in the dry season may necessitate use of camp subsidies despite the increased chance of intraspecific and human interactions.

Increased interactions in camp areas may in turn lead to dominance relationships influencing *V. salvator* ranging behavior and space use, resulting in individual differences. For example, lizard 07, the largest and most dominant individual (Chapter 1), was the only individual with high space use in areas away from camps in the dry season (Table 2.3). Although lizard 07 was victorious in 14/14 interactions with other lizards, all of which occurred in the base camp

area (Chapter 1), this individual was regularly tracked to a tree hollow in the nearby forest. In

contrast, use in three individuals ranked below lizard 07 (lizards 04, 44, and 23) was correlated

with proximity to camps in the dry season (Table 2.3). Because of the potential for lizard 07 to

gain priority access to resources at will, it is possible that this individual was able to live in the

forest away from unwanted encounters, traveling a short distance to base camp to access

subsidies only when needed. Less dominant individuals may have had to remain in closer

proximity to areas of subsidy in order to access such resources opportunistically.

Transient individuals may also show different patterns of space use if they travel great

distances to access camp area resources in the dry season. For example, in the dry season, lizard

23's use was correlated with areas close to camp (Table 2.3), although based on observations this

individual was suspected to be a transient rather than a resident of the base camp area (Chapter

1). Our inability to locate this individual throughout the entire wet season also suggests that it

may have occupied a much larger area away from camp when resources such as fresh water were

more abundant throughout the island.

Increased home range size and activity have been noted in varanid males searching for

females in the breeding season (*V. griseus*, Stanner and Mendelssohn 1987; *V. albigularis*,

Phillips 1995; *V. tristis*, Thompson et al. 1999; *V. varius*, Guarino 2002), suggesting that sex and

reproductive seasonality may also have an influence on *V. salvator* activity and space use.

Although *V. salvator* females have been shown to produce multiple clutches throughout the year,

(Shine et al. 1996; Shine et al. 1998; Gaulke et al. 1999), Shine et al. (1998) also noted

diminished reproductive activity among *V. salvator* females in drier months. Sex was not

determined in all study individuals, and the scope of our research did not include investigation of

Tinjil Island *V. salvator* reproductive chronology or activity. Thus, the exact role reproductive

behavior may play in the seasonal activity of our study population is unclear. We do propose, however, that if increased wet season activity areas and space use of the island's *V. salvator* were related solely to reproductive behavior, individual dry (non-reproductive) season activity areas would be expected to have little overlap, decreasing the potential for agonistic interactions between individuals. Similarly, areas of high use would be expected to be correlated with areas away from camps in both wet and dry seasons to facilitate year-round avoidance of human disturbance. We observed neither of these patterns in the course of our study.

Conclusions

Tinjil Island's *V. salvator* population tended to use areas away from human activity in the wet season, even though anthropogenic resources were available year-round in the island's camps. Despite a small sample size and lack of temporal replication, a seasonal shift in *V. salvator* activity was indicated both by observed activity areas, and through RUF analysis of space use. The results of this study also corroborate anecdotal evidence from previous behavioral observations on Tinjil Island's *V. salvator* that indicated individuals may have spent more time in base camp during the dry season as opposed to the wet season (Chapter 1).

Based on these results, human-*V. salvator* conflict should be low in areas where natural food and water resources are abundant, as *V. salvator* continues to utilize these resources even when anthropogenic subsidies are present. In other areas of this species range, however, additional factors will likely influence *V. salvator* behavior, increasing the potential for conflict. For example, as *V. salvator* has a reputation for preying on small livestock such as chickens (Auffenberg 1981; Gaulke 1991; Uyeda et al. 2014), behavior in areas where anthropogenic subsidies include live prey would likely differ from that observed on Tinjil Island, where

domestic livestock are not present. Tinjil Island's *V. salvator* also avoid humans by retreating to the island's wildland areas, an option that may not be readily available to *V. salvator* populations in more urban locales.

Reduction of wildlife access to anthropogenic food sources is often a key component of human-wildlife mitigation strategies, particularly in the case of garbage-feeding populations (Greenleaf et al. 2009; Bino et al. 2010). Such efforts have the potential to reduce conflict, either by decreasing the number of human-wildlife incidents (Greenleaf et al. 2009), or by directly reducing pest populations (Bino et al. 2010). While the reduction of pest species may be a welcome result of limiting anthropogenic resource subsidies, such actions should be considered carefully, as some wildlife populations have come to rely on anthropogenic subsidy. For example, consistently available food resources, including human-provided "vulture restaurants", were the main predictor of resource use in a population of endangered Egyptian vultures (*Neophron percnopterus*) in Spain (López-López et al. 2014). In some cases, vultures flew longer distances to access predictably located sources of food, highlighting the potential importance of anthropogenic subsidies to sustaining populations of this species.

Anecdotal evidence suggests that Tinjil Island's *V. salvator* may represent one of the only populations of large individuals remaining in our general study area (Uyeda et al. 2014). *V. salvator* is Tinjil Island's top predator, and the island's population is protected from harvest both by official regulation and by cultural taboo (Uyeda et al. 2014). However, if Tinjil Island's *V. salvator* rely on anthropogenic subsidies in the dry season as our results suggest, the island's population may be artificially high. Therefore, any future decreases in anthropogenic subsidy on Tinjil Island could negatively affect the resident *V. salvator* population.

Management practices based on greater understanding of seasonal activity have been successfully implemented in the prevention of human-wildlife conflict (Millspaugh et al. 2015) and the conservation of wildlife (e.g. protection of migratory marine species, Lascelles et al. 2014; limiting disturbance in breeding season, King County Department of Permitting and Environmental Review 2005). *V. salvator* has often been associated with anthropogenic resources (e.g. Amarasinghe et al. 2009; Cota 2011), and the management of these subsidies can be expected to affect *V. salvator* populations throughout its distribution. Our results further demonstrate the need to evaluate seasonal differences in resource use when considering management options for garbage-feeding wildlife populations, including large reptile species such as *V. salvator*. Additional study of seasonal *V. salvator* behavior in areas of anthropogenic resource subsidy will also aid in understanding the influence of natural resource availability, human interactions, dominance status, and reproductive behavior on activity and space use in this species.

LITERATURE CITED

Amarasinghe, A.A., G. Chathuranga and D.M.S. Suranjan Karunarathna. 2009. *Varanus salvator* (Laurenti, 1768) in Rathgama Lagoon in Galle District, Sri Lanka. Biawak 3(3):81-84.

Amelon, S.K., F.R. Thompson III, and J.J. Millspaugh. 2014. Resource utilization by foraging eastern red bats (*Lasiurus borealis*) in the Ozark region of Missouri. The Journal of Wildlife Management 78(3):483-493.

Auliya, M. 2003. Taxonomy, Life History and Conservation of Giant Reptiles in West Kalimantan (Indonesian Borneo). Munster: Natur und Tier Verlag. 432 pp.

Auffenberg, W. 1981. The behavioral ecology of the Komodo Monitor. University Press of Florida, Gainesville, Florida, USA. 406 pp.

Beckmann, J. and J. Berger. 2003. Using black bears to test ideal-free distribution models experimentally. Journal of Mammalogy 84(2):594-606.

Bennett, D. 1995. The Water Monitor *Varanus salvator*. Reptilian 3:15–21.

Beyer, H.L. 2012. Geospatial Modelling Environment, http://www.spatialecology.com/gme.

Bino, G., A. Dolev, D. Yosha, A. Guter, R. King, D. Saltz and S. Kark. 2010. Abrupt spatial and numerical responses of overabundant foxes to a reduction in anthropogenic resources. Journal of Applied Ecology 47(6):1262-1271.

Ciofi, C., J. Puswati, D. Winana, M.E. de Boer, G. Chelazzi and P. Sastrawan. 2007. Preliminary Analysis of Home Range Structure in the Komodo Monitor, *Varanus komodoensis*. Copeia 2:462-470.

Cota, M. 2011. Mating and intraspecific behavior of *Varanus salvator macromaculatus* in an urban population. Biawak 5:17–23.

De Lisle, H.1996. The Natural History of Monitor Lizards. Krieger Publishing Company. Malabar, Florida, USA. 201 pp.

Dickson, B.G. and P. Beier. 2002. Home-range and habitat selection by adult cougars in southern California. The Journal of Wildlife Management 66(4):1235-1245.

Donaldson, B.M. and A.C. Echternacht. 2005. Aquatic habitat use relative to home range and seasonal movement of eastern box turtles (*Terrapene carolina carolina: Emydidae*) in eastern Tennessee. Journal of Herpetology 39(2):278-284.

El Alami, A. and A. Chait. 2012. Seasonal variation in activity budget and diet of the endangered Barbary macaque (*Macaca sylvanus*) in the tourist valley of Ouzoud, central High Atlas, Morocco. Mammalia 76:245-250.

Gaulke, M. 1991. On the Diet of the Water Monitor, *Varanus salvator*, in the Philippines. Mertensiella – Advances in Monitor Research 143-153.

Gaulke, M., W. Erdelen and F. Abel. 1999. A Radio-Telemetric Study of the Water Monitor Lizard (*Varanus salvator*) in North Sumatra, Indonesia. Advances in Monitor Research II – Mertensiella 11:63-78.

Gaulke, M. and H. Horn. 2004. *Varanus salvator* (Nominate Form). Pp. 244-257 *In* Varanoid Lizards of the World. E. Pianka and D. King (Eds.). Indiana University Press, Bloomington, IN.

Gitzen, R.A., J.J. Millspaugh and B.J. Kernohan. 2006. Bandwidth Selection for Fixed-Kernel Analysis of Animal Utilization Distributions. The Journal of Wildlife Management 70: 1334–1344. doi: 10.2193/0022-541X(2006)70[1334:BSFFAO]2.0.CO;2

Greenleaf, S.S., S.M. Matthews, R.G. Wright, J.J. Beecham and H.M. Leithead. 2009. Food habits of American black bears as a metric for direct management of human-bear conflict in Yosemite Valley, Yosemite National Park, California. Ursus 20(2):94-101.

Grinder, M.A. and P.R. Krausman. 2001. Home range, habitat use, and nocturnal activity of coyotes in an urban environment. The Journal of Wildlife Management 65(4):887-898.

Guarino, F. 2002. Spatial Ecology of a Large Carnivorous Lizard, *Varanus varius* (Squamata:Varanidae). J. Zool. Lond. 258:449-457.

Handcock, M.S. 2012. Estimates of the Resource Utilization Function. Version 1.5-2. http://www.csde.washington.edu/~handcock/ruf.

Harless, M.L., A.D. Walde, D.K. Delaney, L.L. Pater and W.K. Hayes. 2010. Sampling considerations for improving home range estimates of desert tortoises: effects of estimator, sampling regime, and sex. Herpetological Conservation and Biology 5(3):374-387.

Hernowo, J.B., C. Wibowo, N. Santoso and N. Kosmaryandi. 1989. Ecological study of Tinjil Island, with special emphasize on Long-tailed Macaques, birds and vegetation. Department of Forest Resources Conservation, Faculty of Forestry, Bogor Agricultural University, Bogor, Indonesia.

Hidalgo-Mihart, M.G., L. Cantú-Salazar, C.A. López-González, E.C. Fernandez and A. González-Romero. 2004. Effect of a landfill on the home range and group size of coyotes (*Canis latrans*) in a tropical deciduous forest. Journal of Zoology 263(1):55-63.

Jessop, T.S., P. Smissen, F. Scheelings and T. Dempster. 2012. Demographic and phenotypic effects of human mediated trophic subsidy on a large Australian lizard (*Varanus varius*): meal ticket or last supper? PLoS one 7(4):e34069.

Johnston, A.N. 2013. Eastern gray squirrel ecology and interactions with western gray squirrels. PhD Dissertation. University of Washington, Seattle, Washington. 143 pp.

Kernohan, B., R. Gitzen and J. Millspaugh. 2001. Analysis of Animal Space Use and Movements. Pp 125-166 *In* Radio Tracking and Animal Populations. J. Millspaugh and J. Marzluff (Eds.). Academic Press San Diego, CA.

Kertson, B.N. and J.M. Marzluff. 2010. Improving studies of resource selection by a greater understanding of resource use. Environmental Conservation 38:18–27.

Kertson, B.N., R.D. Spencer, J.M. Marzluff, J. Hepinstall-Cymerman and C.E. Grue. 2011. Cougar space use and movements in the wildland–urban landscape of western Washington. Ecological Applications 21:2866-2881.

King County Department of Permitting and Environmental Review. 2005. King County Critical Areas Ordinance User's Manual, Part Two – Critical Areas: Wildlife Habitat Conservation Areas.
Accessed online 23 April 2015: http://www.kingcounty.gov/property/permits/codes/CAO.aspx

Kolowski, J.M. and K.E. Holekamp. 2007. Effects of an open refuse pit on space use patterns of Spotted Hyenas. African Journal of Ecology 46:341–349.

Kyes, R.C., D. Sajuthi, W.R. Morton, O.A. Smith, R.P.A. Lelana, J. Pamungkas, D. Iskandriati, E. Iskandar and C.M. Crockett. 1997. The Tinjil Island Natural Habitat Breeding Facility: a decade of operation. Jurnal Primatologi Indonesia 1:1–8.

Kristan III, W.B. and W.I. Boarman. 2007. Effects of anthropogenic developments on common raven nesting biology in the west Mojave Desert. Ecological Applications 17(6):1703-1713.

Lascelles, B., G. Notarbartolo Di Sciara, T. Agardy, A. Cuttelod, S. Eckert, L. Glowka, E. Hoyt, F. Llewellyn, M. Louzao, V. Ridoux and M.J. Tetley. 2014. Migratory marine species: their status, threats and conservation management needs. Aquatic Conservation: Marine and Freshwater Ecosystems 24(S2), 111-127.

López-López, P., C. García-Ripollés and V. Urios. 2014. Food predictability determines space use of endangered vultures: implications for management of supplementary feeding. Ecological Applications 24(5):938-949.

Losos, J.B. and H.W. Greene. 1988. Ecological and evolutionary implications of diet in monitor lizards. Biological Journal of the Linnean Society 35(4):379-407.

Lowry, H., A. Lill and B.B.M. Wong. 2012. Behavioural responses of wildlife to urban environments. Biological Reviews. doi: 10.1111/brv.12012.

Marczak, L.B., R.M. Thompson and J.S. Richardson. 2007. Meta-analysis: trophic level, habitat, and productivity shape the food web effects of resource subsidies. Ecology 88(1):140-148.

Marzluff, J. and E. Neatherlin. 2006. Corvid response to human settlements and campgrounds: Causes, consequences, and challenges for conservation. Biological Conservation 130:301-314.

Marzluff, J.M., J.J. Millspaugh, P. Hurvitz and M.S. Handcock. 2004. Relating resources to a probabilistic measure of space use: forest fragments and Steller's Jays. Ecology 85:1411–1427.

McNulty, J.A., R.R. Ha, R.C. Kyes and E. Iskandar. 2008. Forest structure at a primate natural habitat breeding facility after fifteen years of operation. Jurnal Primatologi Indonesia 5:2–8.

Millspaugh, J.J., R.M. Nielson, L. McDonald, J.M. Marzluff, R.A. Gitzen, C.D. Rittenhouse, M.W. Hubbard and S.L. Sheriff. 2006. Analysis of resource selection using utilization distributions. Journal of Wildlife Management 70(2):384-395.

Millspaugh, J.J., C.D. Rittenhouse, R.A. Montgomery, W.S. Matthews and R. Slotow. 2015. Resource selection modeling reveals potential conflicts involving reintroduced lions in Tembe Elephant Park, South Africa. Journal of Zoology. doi: 10.1111/jzo.12224

Newsome, T.M., J.A. Dellinger, C.R. Pavey, W.J. Ripple, C.R. Shores, A.J. Wirsing and C.R. Dickman. 2014. The ecological effects of providing resource subsidies to predators. Global Ecology and Biogeography 24:1-11. doi: 10.1111/geb.12236

Oro, D., M. Genovart, G. Tavecchia, M.S. Fowler and A. Martínez-Abraín. 2013. Ecological and evolutionary implications of food subsidies from humans. Ecology Letters 16:1501–1514.

Phillips, J. 1995. Movement Patterns and Density of *Varanus albigularis*. Journal of Herpetology 29(3):407-416.

Pons, J.-M. 1992. Effects of changes in the availability of human refuse on breeding parameters in a Herring Gull *Larus argentus* population in Brittany, France. Ardea 80:143–150.

Prange, S., S.D. Gehrt and E.P. Wiggers. 2004. Influences of anthropogenic resources on raccoon (*Procyon lotor*) movements and spatial distribution. Journal of Mammalogy 85(3):483-490.

Prince, A. 2013. Habitat selection, survival, and home range size of the southeastern fox squirrel. M.S. Thesis. North Carolina State University. Raleigh, North Carolina. 41pp.

R Core Team. 2014. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/.

Rittenhouse, C.D, Millspaugh, J.J., Hubbard, M.W., Sheriff, S.L. and W.D. Dijak. 2008. Resource selection by translocated three-toed box turtles in Missouri. The Journal of Wildlife Management 72(2):268-275.

Seaman, D.E., J.J. Millspaugh, B.J. Kernohan, G.C. Brundige, K.J. Raedeke and R.A. Gitzen. 1999. Effects of Sample Size on Kernel Home Range Estimates. The Journal of Wildlife Management 63(2):739-747.

Shine, R., P. Harlow, Ambariyanto, Boeadi, Mumpini and J.S. Keogh. 1998. Monitoring Monitors: A Biological Perspective on the Commercial Harvesting of Indonesian Reptiles. Conservation, Trade and Sustainable Use of Lizards and Snakes in Indonesia – Mertensiella 9:61-68.

Shine, R., P. Harlow and J.S. Keogh. 1996. Commercial Harvesting of Giant Lizards: The Biology of Water Monitors *Varanus salvator* in Southern Sumatra. Biological Conservation 77:125-134.

Smith, J.G. and A.D. Griffiths. Determinants of home range and activity in two semi-aquatic lizards. 2009. Journal of Zoology 279:349-357.

Stanner, M. and H. Mendelssohn. 1987. Sex ratio, population density and home range of the desert monitor (*Varanus griseus*) in the southern coastal plain of Israel. Amphibia-Reptilia 8:153-164.

Thompson, G.G., M. de Boer and E. Pianka. 1999. Activity areas and daily movements of an arboreal monitor lizard, *Varanus tristis* (Squamata: Varanidae) during the breeding season. Australian Journal of Ecology 24:117-122.

Timm, R.M., R.O. Baker, J.R. Bennett and C.C. Coolahan. 2004. Coyote attacks: an increasing suburban problem. Pp. 47–57 *In* Proceedings of the Twenty-First Vertebrate Pest Conference. Timm, R.M., and W.P. Gorenzel (Eds.). University of California, Davis, California, USA.

Traeholt, C. 1997a. Activity Patterns of Free-Living Water Monitor Lizards *Varanus salvator*. Malayan Nature Journal 50:301-315.

Traeholt, C. 1997b. Ranging Behaviour of the Water Monitor Lizard *Varanus salvator*. Malayan Nature Journal 50:317-329.

Traeholt, C. 1994a. Notes on the Water Monitor *Varanus salvator* as a Scavenger. Malayan Nature Journal 47:345-353.

Traeholt, C. 1994b. The Food and Feeding Behaviour of the Water Monitor, *Varanus salvator*, in Malaysia. Malayan Nature Journal 47:331-343.

Treves, A. and U. Karanth. 2003. Human-Carnivore Conflict and Perspectives on Carnivore Management Worldwide. Conservation Biology 17(6):1491-1499.

Uyeda, L. 2009. Garbage Appeal: Relative Abundance of Water Monitor Lizards (*Varanus salvator*) Correlates with Presence of Human Food Leftovers on Tinjil Island, Indonesia. Biawak 3(1):9-17.

Uyeda, L.T., E. Iskandar, R.C. Kyes and A.J. Wirsing. 2012. Proposed research on home ranges and resource use of the Water Monitor Lizard, *Varanus salvator*. The Forestry Chronicle 88:542–546.

Uyeda, L., E. Iskandar, A. Wirsing and R. Kyes. 2013. Nocturnal activity of *Varanus salvator* on Tinjil Island, Indonesia. Biawak 7:25–30.

Uyeda, L.T., E. Iskandar, A. Purbatrapsila, J. Pamungkas, A. Wirsing and R.C. Kyes. 2014. The role of traditional beliefs in conservation of herpetofauna in Banten, Indonesia. Oryx 1-6 doi:10.1017/S0030605314000623.

Valeix, M., G. Hemson, A.J. Loveridge, G. Mills and D.W. Macdonald. 2012. Behavioural adjustments of a large carnivore to access secondary prey in a human-dominated landscape. Journal of Applied Ecology 49:73–81.

Walter, W.D., J.W. Fischer, S. Baruch-Mordo and K.C. Vercauteren. 2011. What Is the Proper Method to Delineate Home Range of an Animal Using Today's Advanced GPS Telemetry Systems: The Initial Step. USDA National Wildlife Research Center - Staff Publications. Paper 1375.
http://digitalcommons.unl.edu/icwdm_usdanwrc/1375

Yirga, G., H.H. Delongh, H. Leirs, K. Gebrihiwot, J. Deckers and H. Bauer. 2012. Adaptability of large carnivores to changing anthropogenic food sources: diet change of Spotted Hyena (*Crocuta crocuta*) during Christian fasting period in northern Ethiopia. Journal of Animal Ecology 81:1052–1055.
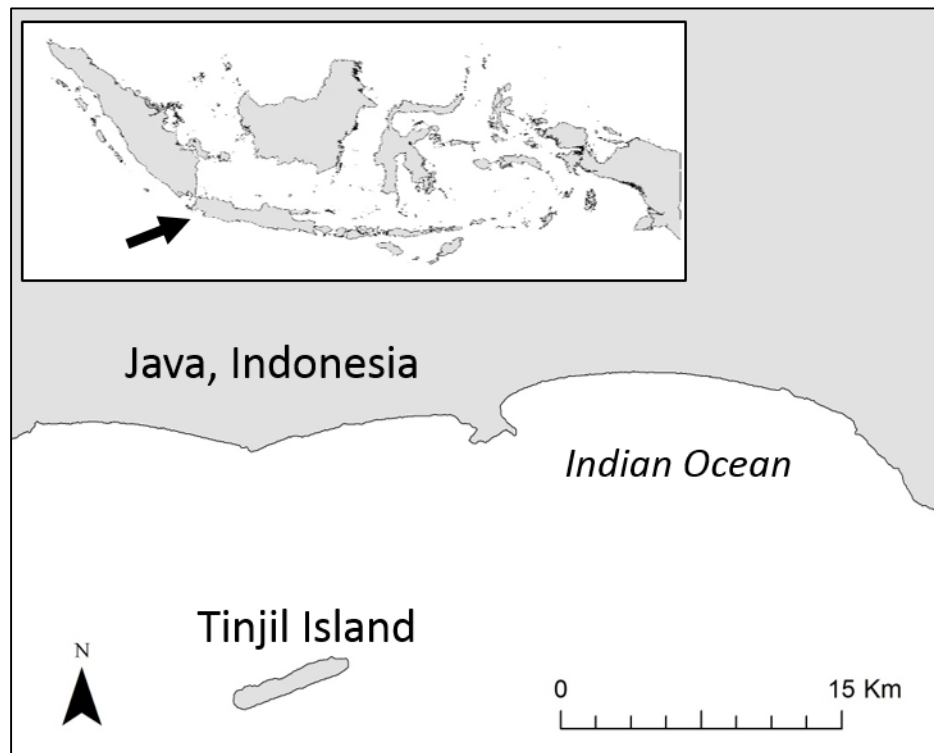
Figure 2.1. Location of Tinjil Island, off the south coast of Java, Indonesia. The arrow on the inset indicates the location of Tinjil Island in Indonesia.
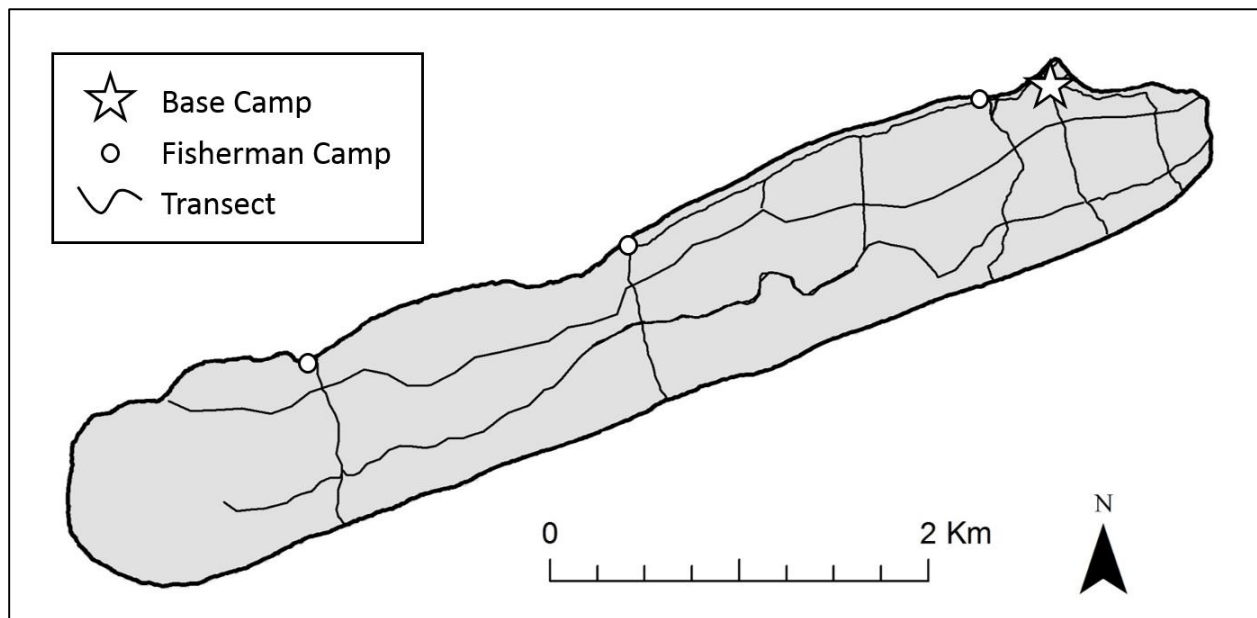
Figure 2.2. Tinjil Island, Indonesia including location of base camp, fisherman camps, and transects.
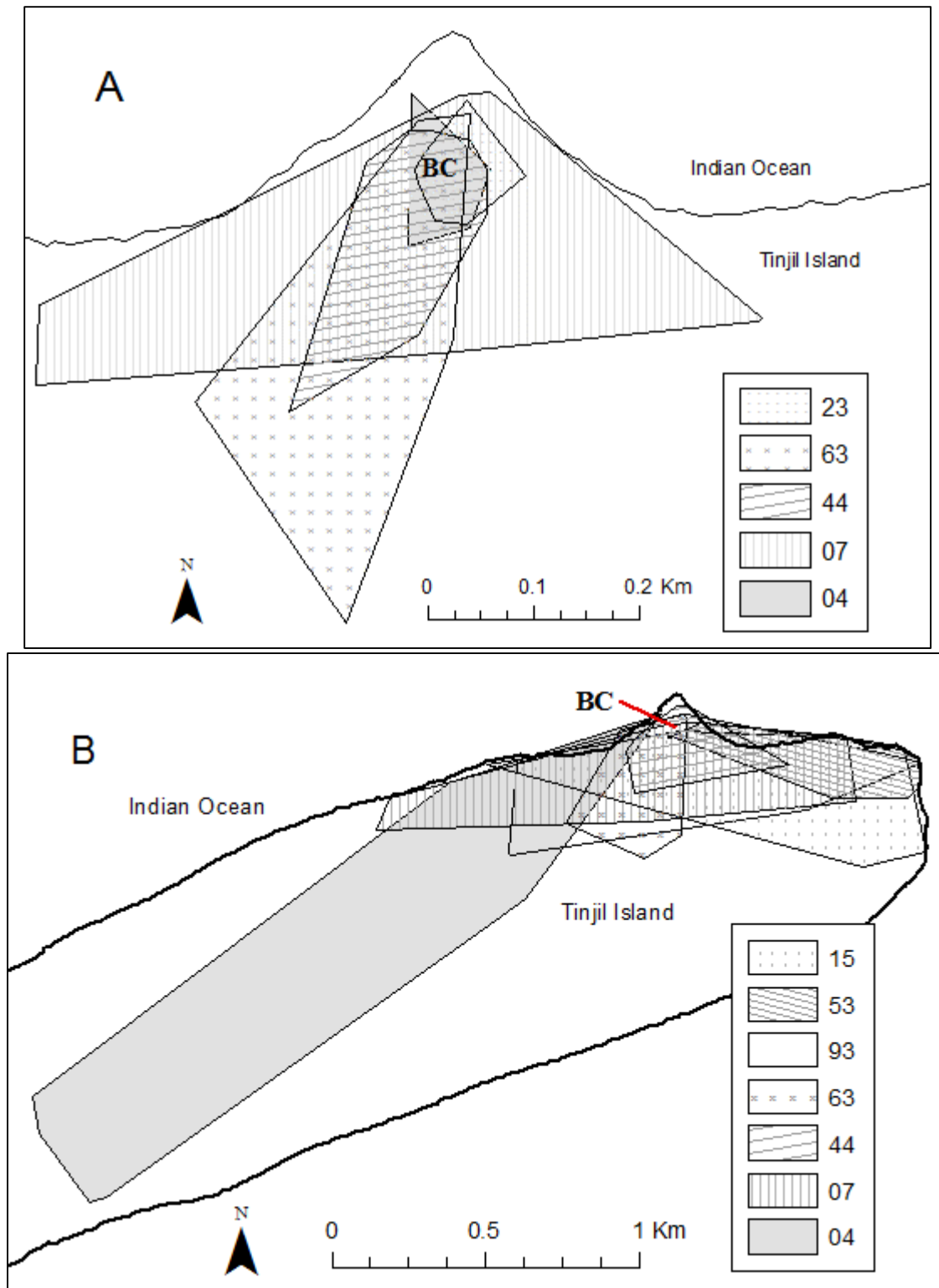
Figure 2.3. 100% convex polygon estimations of *V. salvator* activity areas on Tinjil Island, Indonesia based on radio-telemetry data. A. Dry season, individuals 23, 63, 44, 07, and 04. B. Wet season, individuals 15, 53, 93, 63, 44, 07, 04. BC = location of the base camp. Areas of each polygon are listed in Table 2.1.

Table 2.1. Seasonal and combined activity areas (ha) for *Varanus salvator* on Tinjil Island, Indonesia, using minimum convex polygon (MCP) and kernel density (KD) estimation.

| Animal ID	Dry season activity area					Wet season activity area					Combined activity area				
	MCP	KD			#	MCP	KD			#	MCP	KD			#
	100%	95%	75%	50%	locations	100%	95%	75%	50%	locations	100%	95%	75%	50%	locations
07	10.25	7.88*	3.01	1.13	44	34.69*	32.26*	13.15*	5.48*	49	36.32*	23.92*	8.80*	2.78*	93
04	0.69	0.55	0.20	0.09	53	90.24*	111.99*	54.29*	21.66*	40	95.33*	49.06*	14.59*	3.81*	93
44	2.50	1.76	0.74	0.35	55	8.23*	5.77*	2.66	1.32	49	9.32*	4.03	1.58	0.65	104
63	6.17	6.71	2.87	1.27	37	12.00	11.23*	4.59	1.60	18	12.41	10.20*	3.87	1.68	55
15	–	–	–	–	9	35.78*	39.34*	28.31	13.60	41	37.75*	35.27*	19.31*	10.18*	50
23	0.69	0.72	0.32	0.11	37	–	–	–	–	2	–	–	–	–	–
93	–	–	–	–	–	34.55*	46.62*	29.50	13.46	34	–	–	–	–	–
53	–	–	–	–	3	10.94*	9.47*	4.65	1.90	55	–	–	–	–	–
Mean	4.06	3.52	1.43	0.59		32.35	36.67	19.59	8.43		38.35	21.80	7.21	2.23	
SD	3.69	3.13	1.25	0.51		26.26	34.10	17.54	7.33		34.52	17.31	5.00	1.18	

* estimated activity area was clipped for greater accuracy, as described in the methods.

Table 2.2. Population level RUF (dry season = 5 individuals, wet season = 6 individuals) of unstandardized coefficients and 95% confidence intervals for *Varanus salvator* on Tinjil Island, Indonesia. Standard errors were calculated using a precise estimation of variance that included inter-animal variation (Marzluff et al. 2004). An asterisk indicates that the variable is considered significant for the population at α 0.05. The number of individual lizards with significant positive or negative use associated with each variable is also indicated (see Table 2.3 for individual results).

	Dry season				Wet season			
			# of lizards				# of lizards	
	$\bar{x}$	95% CI	+	-	$\bar{x}$	95% CI	+	-
Distance to Camps	-0.001	$-1.88e^{-2} - 1.61e^{-2}$	1	3	0.024	$9.05e^{-3} - 3.95e^{-2}$ *	5	1
Distance to Perimeter	0.028	$-3.75e^{-3} - 5.99e^{-2}$	5	0	0.068	$2.19e^{-3} - 0.13$*	4	2
Distance to Trails	0.003	$-8.56e^{-3} - 1.46e^{-2}$	2	0	-0.028	$-0.12 - 6.66e^{-2}$	1	3

Table 2.3. Resource utilization function (RUF) unstandardized coefficients for individual *Varanus salvator* on Tinjil Island, Indonesia. Dist_Cmp = distance to nearest camp; Dist_Per = distance to island perimeter; Dist_Tr = distance to nearest trail

Animal ID	Dry Season						Wet Season					
	Dist_Cmp	SE	Dist_Per	SE	Dist_Tr	SE	Dist_Cmp	SE	Dist_Per	SE	Dist_Tr	SE
07	$2.94e^{-2}$ *	$3.45e^{-3}$	$8.94e^{-2}$ *	$3.92e^{-3}$	$-1.47e^{-2}$	$1.05e^{-2}$	$2.23e^{-2}$ *	$1.99e^{-3}$	$1.15e^{-1}$ *	$5.44e^{-3}$	$7.02e^{-3}$	$8.32e^{-3}$
04	$-2.33e^{-2}$ *	$1.86e^{-3}$	$9.54e^{-3}$ *	$9.98e^{-4}$	$2.17e^{-2}$ *	$3.14e^{-3}$	$-1.50e^{-3}$*	$3.50e^{-5}$	$-1.04e^{-2}$ *	$8.30e^{-5}$	$-3.54e^{-3}$ *	$1.10 e^{-4}$
44	$-7.40e^{-3}$ *	$8.10e^{-4}$	$4.62e^{-3}$ *	$7.79e^{-4}$	$-3.71e^{-3}$	$2.28e^{-3}$	$4.85e^{-2}$ *	$1.81e^{-3}$	$1.38e^{-1}$ *	$4.67e^{-3}$	$-3.54e^{-2}$ *	$1.30e^{-2}$
63	$5.44e^{-3}$	$4.25e^{-3}$	$3.28e^{-2}$ *	$3.97e^{-3}$	$4.56e^{-3}$	$7.62e^{-3}$	–	–	–	–	–	–
23	$-1.09e^{-2}$ *	$1.36e^{-3}$	$3.83e^{-3}$ *	$9.80e^{-4}$	$7.34 e^{-3}$ *	$2.65e^{-3}$	–	–	–	–	–	–
15	–	–	–	–	–	–	$3.75e^{-2}$ *	$1.09e^{-3}$	$1.02e^{-1}$ *	$6.13e^{-3}$	$1.97e^{-2}$	$1.18e^{-2}$
93	–	–	–	–	–	–	$6.53e^{-3}$ *	$9.09e^{-4}$	$1.22e^{-1}$ *	$1.73e^{-3}$	$9.72e^{-2}$ *	$5.67e^{-3}$
53	–	–	–	–	–	–	$3.23e^{-2}$ *	$1.03e^{-3}$	$-5.99 e^{-2}$ *	$2.65e^{-3}$	$-2.51e^{-1}$ *	$9.96e^{-3}$

* Indicates that the individual's use is significantly associated with attribute.

Appendix IIa – IIc.
Individual dry (A) and wet season (B) kernel density estimations (unclipped) of *Varanus salvator* activity areas based on radio-telemetry data collected on Tinjil Island, Indonesia. 95%, 75%, and 50% isopleths are shown. A 100% convex polygon for the same data is outlined in grey.

Appendix IIa. Lizard 07 activity area estimations: A, dry season; B, wet season.
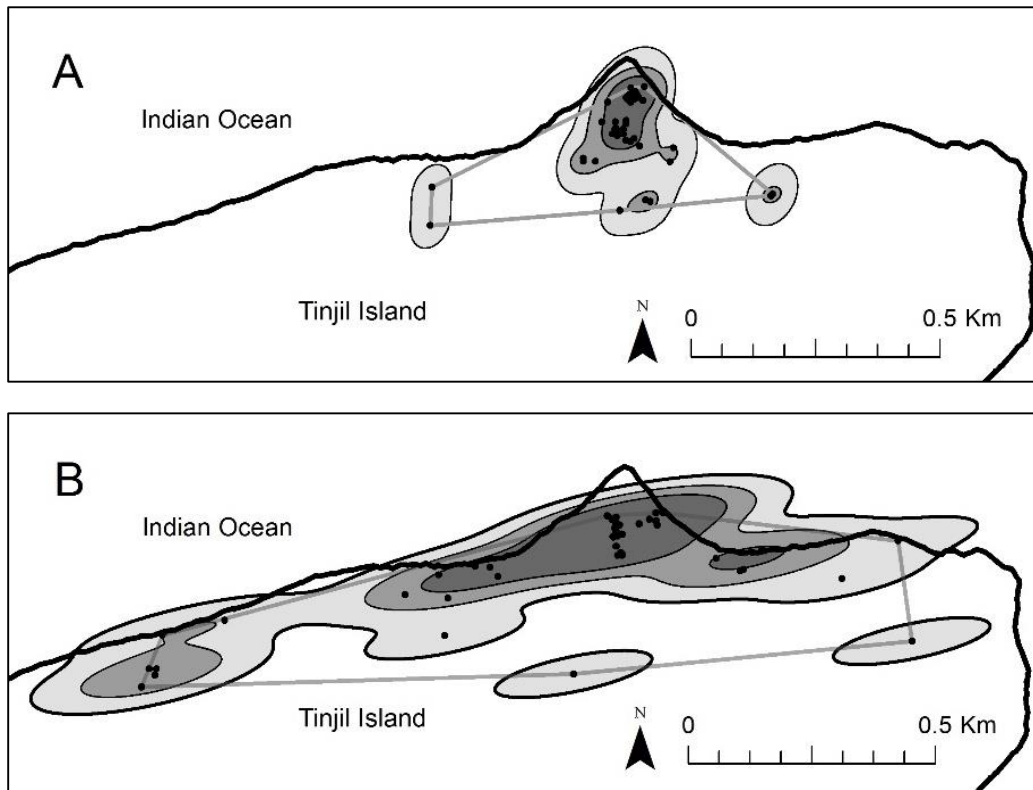
Appendix IIb. Lizard 04 activity area estimations: A, dry season; B, wet season.
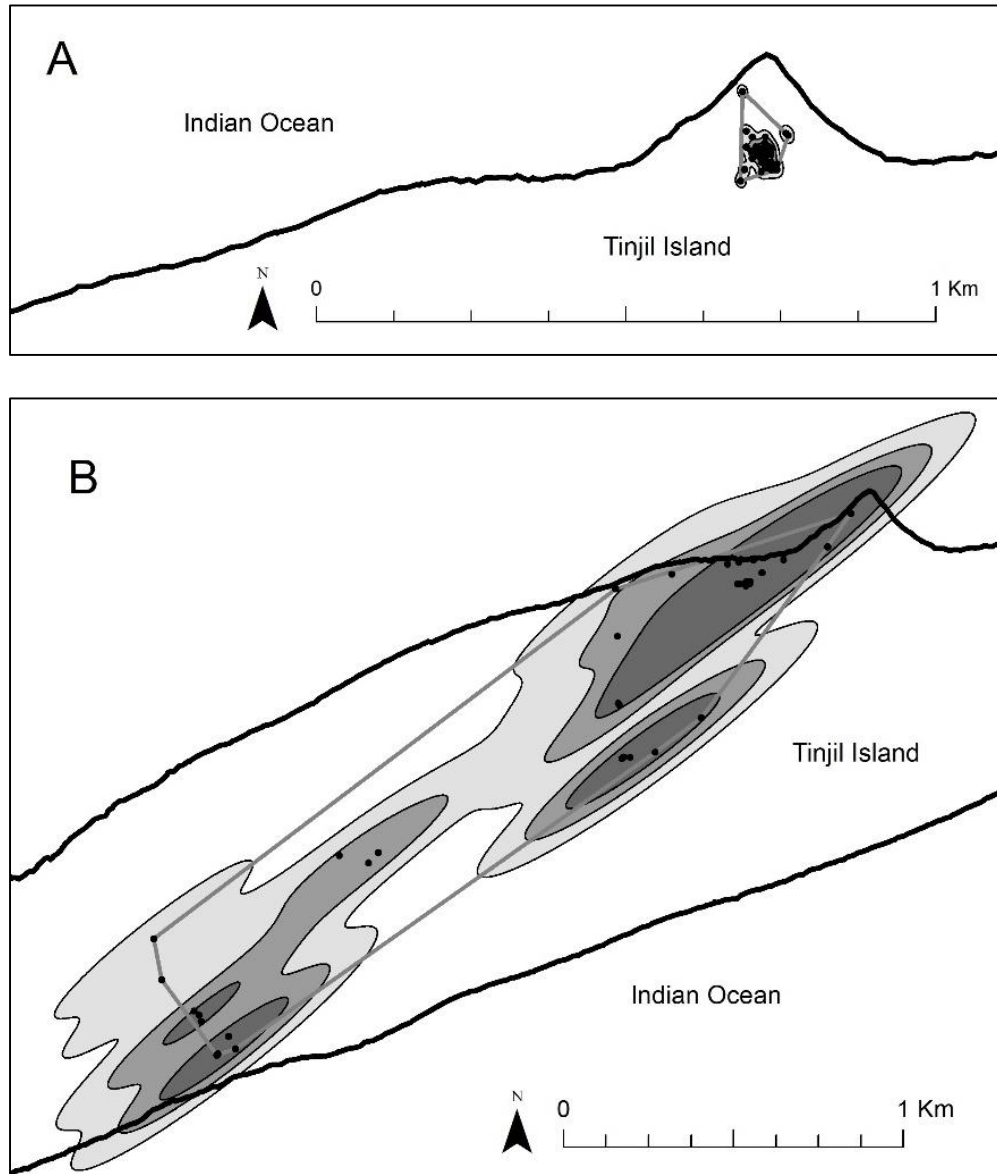
Appendix IIc. Lizard 44 activity area estimations: A, dry season; B, wet season.
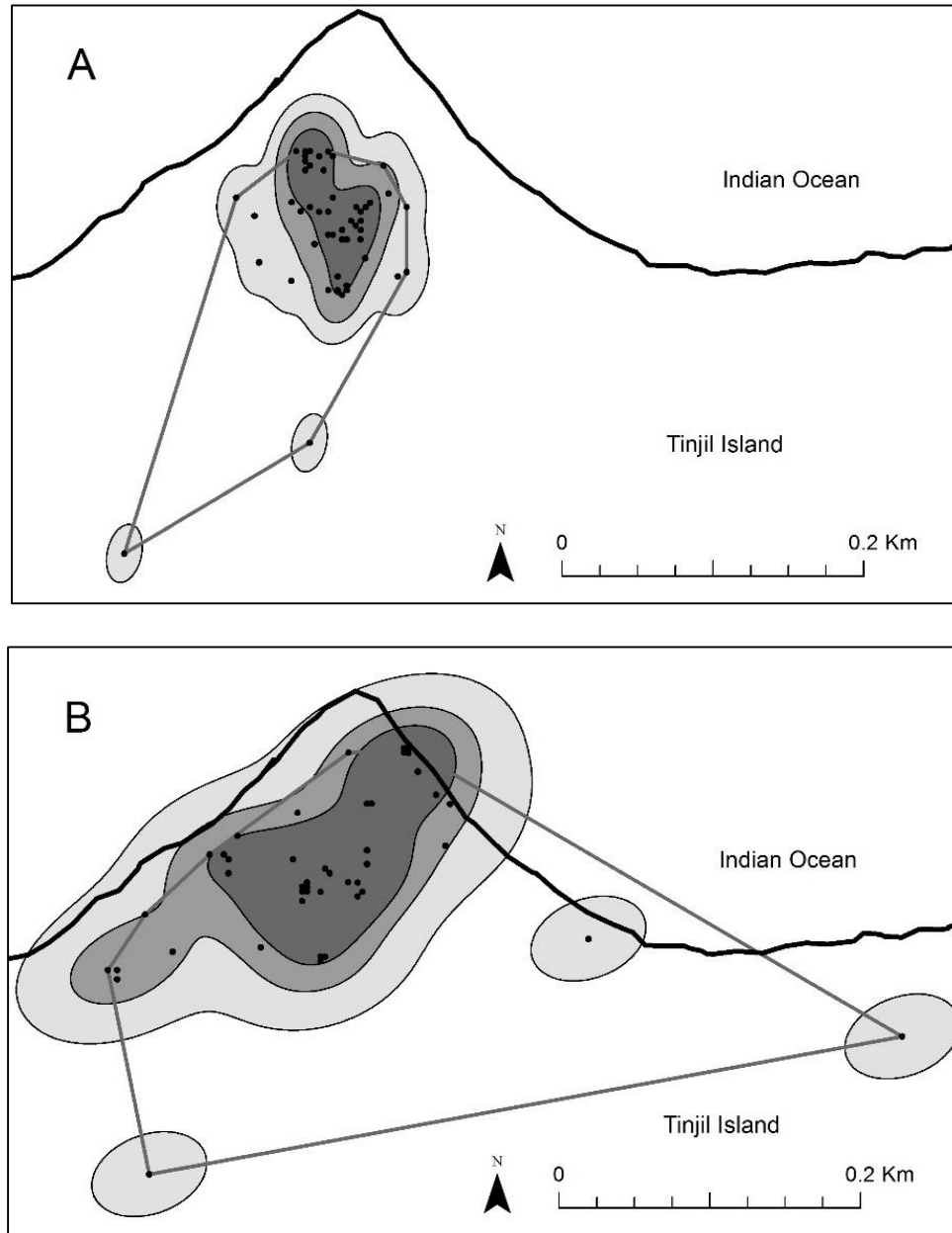
Appendix IId/e. *Varanus salvator* and land crabs on Tinjil Island, Indonesia

Appendix IId. Lizard 53 with a crab in its mouth, 16 February 2013 (wet season). On this day lizard 53 was observed hunting, successfully catching and consuming five crabs over a period of 80 minutes.

Appendix IIe. Land crabs after a period of heavy rainfall, in the forest on Tinjil Island.

Appendix IIf. *Varanus salvator* (lizard 44) drinking from a bucket containing water from a dripping spigot at Tinjil Island's base camp on 29 July 2012 (dry season). RUF analysis of this individual showed high use in areas near camps in the dry season. The opposite correlation of higher use in areas with increasing distance from camps was observed in the wet season (Table 2.3).

Appendix IIg. *Varanus salvator* (lizard 93) soaking in a pool of water on top of a large fallen tree deep in the forest on Tinjil Island, 14 February 2013 (wet season). This individual was correlated with areas away from camps in the wet season based on RUF analysis (Table 2.3), but was not tracked in the dry season.

All Photographs © Linda Uyeda

Appendix IIh. Home range and activity area estimates (in ha) of *Varanus salvator* according to different studies.
MCP = minimum convex polygon, KD = kernel density

Study	Location	Season	Population	Weight (kg)	Area estimate (ha)	# of days	# of locations	Method of estimation
Traeholt 1997b	500 ha island, South China Sea	dry	4 males	3.2 - 13.5	1.7 - 4.1	≥ 20	--	MCP (radio-telemetric follow)
Traeholt 1997b	"	dry	4 males	3.2 - 13.5	1.4 - 2.6	≥ 20	--	Hand-drawn (radio-telemetric follow)
Traeholt 1997b	"	wet	2 males	11.2 - 12.8	13.6 - 14.4	≥ 20	--	MCP (radio-telemetric follow)
Traeholt 1997b	"	wet	2 males	11.2 - 12.8	12.7 - 12.9	≥ 20	--	Hand-drawn (radio-telemetric follow)
Traeholt 1997b	2400 ha oil palm plantation, mainland Malaysia	dry	3 males, 1 female	2.8 - 12.4	18.4 - 82.5	≥ 20	--	MCP (radio-telemetric follow)
Traeholt 1997b	"	dry	"	2.8 - 12.4	12.1 - 33.3	≥ 20	--	Hand-drawn (radio-telemetric follow)
Traeholt 1997b	"	wet	"	2.9 - 11.9	17.5 - 76.3	≥ 20	--	MCP (radio-telemetric follow)
Traeholt 1997b	"	wet	"	2.9 - 11.9	12.0 - 31.7	≥ 20	--	Hand-drawn (radio-telemetric follow)
Gaulke et al. 1999	oil palm estate, mainland Sumatra	wet	2 males	3.5 - 7.2	1.5 - 1.7	7 - 21	10 -14	MCP (radio-telemetry)
Auliya 2003	440 ha island, Sibau River	--	3 males	4.5 - 10.5	11.6 - 127	95 - 119	3 - 4	MCP (mark-recapture trap locations)
Uyeda (this study)	600 ha island, Indian Ocean	dry	1 male, 4 unknown	15.0 - 21.5	.69 - 10.25	24 - 40	37 - 55	MCP (radio-telemetry)
Uyeda (this study)	"	dry	"	15.0 - 21.5	.55 - 7.9	24 - 40	37 - 55	95% KD (radio-telemetry)
Uyeda (this study)	"	wet	1 male, 5 unknown	15.0 - 21.5	8.2 - 90.2	35 - 62	34 - 55	MCP (radio-telemetry)
Uyeda (this study)	"	wet	"	15.0 - 21.5	5.8 - 112.0	35 - 62	34 - 55	95% KD (radio-telemetry)

CHAPTER 3

NOCTURNAL ACTIVITY OF *VARANUS SALVATOR* ON TINJIL ISLAND, INDONESIA

ABSTRACT

Nocturnal activity has rarely been reported in *Varanus salvator*. This report documents observations of nocturnal activity in *Varanus salvator* on Tinjil Island, Indonesia, where such behavior may provide a competitive advantage over conspecifics in foraging for human food leftovers. Pre-dawn scavenging of a *V. salvator* carcass by a conspecific is also noted.

INTRODUCTION

The water monitor lizard, *Varanus salvator*, is generally considered to be diurnal (Gaulke and Horn, 2004), though nocturnal activity has been observed on occasion. For example, Biswas and Kar (1981) noted nocturnal nesting behavior in *V. salvator*, and Gaulke (pers. comm.; 1989) documented nocturnal feeding behavior by two *V. salvator marmoratus* (now *V. palawanensis*) on the carcass of a wild pig. Here, 16 observations of nocturnal activity by a single *V. salvator* on Tinjil Island, Indonesia are reported. An observation of a second *V. salvator* attempting to scavenge on the carcass of a conspecific in the early morning (prior to daylight) is also noted.

METHODS

Varanus salvator were observed from 5 July 2012 to 11 August 2012 on Tinjil Island, Indonesia as part of an ongoing study of the island's population and their behavior, range, and resource use. Tinjil Island, located approximately 16 km off the south coast of Java, Indonesia, is about 600 ha in size and consists primarily of lowland tropical rainforest and coastal/beach vegetation. Since 1987 the island has been designated as a natural habitat breeding facility for long-tailed macaques (*Macaca fascicularis*) (Kyes et al. 1997). Although there are officially no permanent residents on Tinjil Island, a continuous human presence of staff and researchers (about 5-8 people at any given time) reside in a small base camp area. Food preparation is carried out primarily in a main base camp building, and food scraps (e.g., egg shells, fish skeletons) are regularly discarded in a clearing anywhere from 1 to 5 m from the east side of the main base camp building. Food scraps and other garbage are also routinely disposed of in a large, ca. 1.5 x 2 x 1 m cement garbage box, located approximately 3 m south of the main base camp building. The garbage box has large openings in the side and top, through which *V. salvator* commonly enter to forage (Uyeda, pers. obs.). *Varanus salvator* living in the base camp area are habituated to people and seem unconcerned about the presence of humans when walking and foraging around base camp (Uyeda, pers. obs.).

In addition to the base camp, there are also three small fishermen camps spaced along the north side of the island. The fishermen utilizing these camps are not permanent residents, but stay on Tinjil Island regularly when fishing in nearby waters. The fishermen camps are small (3-5 fishermen per camp), equipped with basic huts and no modern facilities. Cooking and fish cleaning also occur at the fishermen camps.

Throughout the study period, behavioral observations were carried out using a combination of ad libitum sampling (behaviors of one or more animals were recorded) and focal individual follows (behaviors of a single focal animal were recorded). Focal individuals were followed for two-hour time blocks between 0600 and 1800 h. During these daytime ad libitum and focal sampling periods, recorded behaviors included sleeping, walking, foraging, etc.

Although initial observations were carried out between 0600 and 1800 h, sampling periods were extended to begin at 0500 h on 9 July 2012 after pre-dawn activity was observed on 8 July 2012. Sampling periods were further extended on 30 July 2012 to include the hours between 0300 h and 0500 h following observations of nocturnal activity on 28 and 30 July 2012. These early morning observations were carried out daily from 30 July 2012 to 11 August 2012, with the exceptions of 5 August 2012, 7 August 2012, and 10 August 2012 (Table 3.1).

The study population consisted of seven *V. salvator* that had been fitted with LPR-3800 radio-telemetric harnesses (Wildlife Materials, Murphysboro, IL, USA) and marked with crayon as part of a broader study on Tinjil Island's population. Although these study animals were outfitted with telemetry equipment, it was extremely difficult to track animals through the forest in the dark without creating a noisy disturbance and without the excessive use of artificial light. For this reason, nocturnal observations were carried out in the immediate base camp area (a cleared perimeter surrounding the main camp building approximately 10 m in width), where they could be accomplished quietly and with minimal effect on the monitors' behavior. No *V. salvator* were observed sleeping in the cleared perimeter surrounding the base camp building during the early morning sampling periods and only active behaviors such as walking and foraging were recorded during these times. As *V. salvator* activity (e.g., walking, foraging) could be easily heard from inside the main base camp building (Uyeda, pers. obs.), it was also

possible for researchers to become aware of nocturnal behavior without actively observing the area. Additional instances of nocturnal behavior were opportunistically recorded as they were discovered.

On 5 July 2012 an adult *V. salvator* was captured, fitted with an LPR-3800 radio-telemetric harness (Wildlife Materials, Murphysboro, IL, USA), and marked with crayon. The animal was assigned the identifier "04" and was released at the point of capture. Monitor 04 was a suspected male based on size (17 kg, 217 cm in total length–minus tail tip) and numerous observed agonistic interactions with other individuals.

REPEATED NOCTURNAL ACTIVITY AND FORAGING BEHAVIOR IN A SOLITARY INDIVIDUAL

On 8 July 2012, monitor 04 was observed walking in the dark at 0525 h in the immediate base camp area. At 0530 h on 12 July 2012, monitor 04 was again observed walking in the dark in the base camp area. No other *V. salvator* were observed engaging in nocturnal behavior until 28 July 2012, when monitor 04 was again seen active in the base camp area.

21 July 2012 marked the first day of the month-long religious fasting associated with the observance of Ramadan. All researchers and staff present on Tinjil Island at that time began observing the fast, and meal times were adjusted to include the traditional pre-dawn meal (that occurs during the fasting period) at approximately 0300 h each morning. Cooking for the pre-dawn meal generally began around 0200 h, and perimeter lights for the main base camp building were turned on for approximately an hour between 0230 h and 0330 h. An additional early morning dumping of food scraps (around 0330 h) also occurred on most days during this fasting period.

At 0341 h on 28 July 2012 monitor 04 was seen walking around the main base camp building. Although it was dark outside, perimeter lights to the building had been turned on, illuminating the immediate base camp area. Monitor 04 was seen again at 0343 h on 30 July 2012 walking around the main base camp area. Following the 30 July 2012 sighting of monitor 04, sampling periods were extended to include additional hours corresponding to the pre-dawn meal associated with the Ramadan fast. In total, monitor 04 was observed engaging in nocturnal activity in the base camp area on 14 occasions from 28 July 2012 – 11 August 2012 (Table 3.1). Among these 14 nocturnal observations, activity was recorded as early as 0128 h (1 August 2012) with the majority of activity observed between the hours of 0300 and 0530 h (Table 3.1). On seven occasions, monitor 04 was seen active while the perimeter lights were on, but on seven occasions monitor 04 was active in the absence of artificial light (Table 3.1). Of the seven dates monitor 04 was observed without supplemental perimeter lights, three (1 August 2012 and 2 August 2012) occurred when the moon was near full/full, and the other four (6 August 2012 – 9 August 2012) occurred as the moon approached its third quarter.

Each of the 14 occurrences of nocturnal activity involved monitor 04 alone as it was engaged in foraging/eating and/or walking to one or both base camp garbage dumping areas (approximately 15 m apart). On three occasions monitor 04 was observed actively foraging/eating for longer than 1 hr; foraging was carried out across both base camp garbage scrap dumping areas, and monitor 04 was observed consuming food scraps (fish and crab remains, bits of chicken, etc.) Although monitor 04 often slept along the forest edge, very close to base camp (as confirmed visually and by radio-telemetry), the nocturnal activity did not seem to closely correspond to any obvious cues such as the commencement of cooking, turning on of the perimeter lights, or the dumping of food scraps. On only two occasions did monitor 04 arrive

82

at the base camp clearing within one hour of food scraps having been discarded (Table 3.1). Monitor 04 was also observed on occasion walking to each of the garbage areas in the dark and leaving the area presumably after finding that no new food had been dumped. On 31 July 2012 and 1 August 2012 monitor 04 was observed returning to camp a second time after food scraps were dumped (Table 3.1). However, an observer might wait more than two hours after food scraps were dumped before witnessing the emergence of monitor 04 from the forest edge. When active in the base camp clearing, monitor 04 was observed rummaging through newly discarded food scraps whenever available. Discarded food did not always include meat, consisting of rice, vegetables, fruit rinds, etc., and was not always consumed.

Based on information obtained via radio-telemetry, monitor 04 was likely not active in the forest prior to the observed nocturnal activity around base camp; at the beginning of each observation period monitor 04 was often tracked to just inside the forest edge, with the position confirmed multiple times and the animal inactive up until emergence from the forest to forage at base camp.

EARLY MORNING ACTIVITY: ATTEMPTING TO EAT A CARCASS

On 30 July 2012 an unknown adult *V. salvator* was encountered at 0520 h while engaged in foraging in the dark at the forest edge ca. 3 m from the base camp clearing. The individual's behavior was characterized by lateral head movements and frequent tongue flicks focused on a particular area on the ground. After approximately 3 min of this behavior, the monitor scraped at the leaf litter with its forefeet, unearthing an old, desiccated *V. salvator* carcass. The monitor then dragged the carcass approximately 2 m and propped it against a fallen branch. The monitor

used its forefeet to hold the carcass down while maneuvering around to tear at the carcass with its mouth. The carcass appeared quite tough and devoid of flesh.

The monitor attempted to rip at the carcass with its mouth from numerous angles but seemed to be unsuccessful. After about 5 min of this behavior, the monitor left the carcass and walked directly towards the observer while tongue flicking, approaching within 0.5 m. The monitor then retreated farther into the forest, at which time the observation was concluded. This observation was carried out in the dark; however, a headlamp and flash photography were utilized sparingly by a single observer, ca. 3 m away from the monitor. The monitor did not appear to have been disturbed noticeably by the presence of the observer or the accompanying light sources.

DISCUSSION

Throughout the course of the study period, only two individuals were seen engaging in nocturnal behavior. Other than the unknown monitor attempting to feed on a *V. salvator* carcass in the early morning, all occurrences of nocturnal behavior were observed in a single individual, monitor 04. On numerous nighttime occasions, monitor 04 was seen foraging on recently discarded food scraps alone and free from any competition. During daylight hours, monitor 04 was frequently observed "patrolling" the base camp area, walking back and forth between garbage dumping areas and chasing smaller and even similarly sized monitor lizards away. In all agonistic interactions observed in the base camp area between monitor 04 and other individuals, monitor 04 was the clear "winner", with the exception of those encounters between monitor 04 and the largest individual recorded in the area, monitor 07 (22 kg, 221.5 cm in total length– minus tail tip). As monitor 07 was an infrequent presence in the base camp area, monitor 04 was

generally able to access all dumped garbage at will despite the presence of other monitors, though with some effort. Thus, it can be concluded that monitor 04 did not engage in nocturnal foraging out of necessity, but perhaps as a strategy to increase food consumption without having to expend additional energy on the defense of food resources. Previous research has documented associations between nocturnal activity in varanids and feeding: in addition to Gaulke's (1989) observation of nocturnal feeding activity in two *V. salvator marmoratus* (now *V. palawanensis*), Yong et al. (2008) documented nocturnal foraging in *V. dumerilii*, Trembath (2000) noted nocturnal foraging in *V. gouldii*, and Cota et al. (2008) documented nocturnal activity in *V. dumerilii* in an area where crabs, a favorite prey item, were abundant.

High nighttime temperatures have also been suggested as a partial explanation for unusual occurrences of nocturnal behavior in *V. panoptes* (Shannon 2008) and *V. dumerilii* (Cota et al. 2008). *Varanus salvator*, however, is generally active at body temperatures of 30-32 °C (Traeholt 1995) and has demonstrated an apparent tolerance for ambient temperature fluctuations. For example, Traeholt (1995) noted that *V. salvator* in a Malaysian study population were easily able to raise their body temperatures above the ambient temperature even during the cooler rainy season. Nocturnal behavior in Tinjil Island's population occurred at ambient temperatures as low as 24.6 °C, suggesting that nocturnal activity in *V. salvator* is not restricted to high nighttime temperatures.

Though monitor 04 was observed engaging in early morning nocturnal activity before the start of Ramadan, fourteen of the sixteen recorded occurrences fell within the month of religious fasting. Monitor 04's behavior may represent a shift in foraging activity in response to a change in human activity associated with the fast. A logical test of this hypothesis would be to compare the incidence of monitor 04's nocturnal activity between periods including the month of

85

Ramadan, to those typifying times when Tinjil Island's inhabitants are not participating in a nightly 0300 h meal. Interestingly, throughout the study period monitor 04 was not observed engaging in regular nocturnal activity between 1800 h and 0100 h despite the fact that food scraps were often dumped after an evening meal around 1800 h. As research on Tinjil Island's *V. salvator* population is ongoing, future observations of monitor 04 in subsequent field seasons will serve as opportunities to shed further light on this individual's nocturnal behavior. Additional observations in the Tinjil Island study area may also reveal new instances of individuals engaged in nocturnal activity. Further systematic study of nocturnal activity in varanids is needed to explore the prevalence and potential fitness benefits of such behavior.

LITERATURE CITED

Biswas, S. and S. Kar. 1981. Some observations on nesting habits and biology and *Varanus salvator* (Laurenti) of Bhitarkanika Sanctuary, Orissa. Journal of the Bombay Natural History Society 78: 303-308.

Cota, M., T. Chan-Ard, S. Mekchai and S. Laoteaw. 2008. Geographical distribution, instinctive feeding behavior and report of nocturnal activity of *Varanus dumerilii* in Thailand. Biawak 2(4): 152-158.

Gaulke, M. 1989. PhD dissertation: Zur Biologie des Bindenwaranes, unter Berücksichtigung der paläogeographischen Verbreitung und der phylogenetischen Entwicklung der Varanidae. Courier Forschungsinstitut Senckenberg, Frankfurt a. M.

Gaulke, M. and H.-G. Horn. 2004. *Varanus salvator* (Nominate Form). Pp. 244-257 *In* Pianka, E.R., D.R. King and R.A. King (Eds.). Varanoid Lizards of the World. Indiana University Press, Bloomington.

Kyes, R.C., D. Sajuthi, W.R. Morton, O.A. Smith, R.P.A. Lelana, J. Pamungkas, D. Iskandriati, E. Iskandar and C.M. Crockett. 1997. The Tinjil Island Natural Habitat Breeding Facility: A decade of operation. Jurnal Primatologi Indonesia. 1(1): 1–8.

Shannon, R. 2008. Observations on three species of Varanus in Ilfracombe, Queensland. Biawak 2(2): 80-86.

Traeholt, C. 1995. A radio-telemetric study of the thermoregulation of free living water monitor lizards, *Varanus s. salvator*. Journal of Comparative Physiology B 165: 125-131.

Trembath, D. 2000. Nocturnal activity by Gould's monitor (*Varanus gouldii*) at Town Common Environmental Park, Townsville Queensland. Herpetofauna (Sydney) 30: 52.

Yong, D.L., S.D. Fam and J.J. Ng. 2008. Rediscovery of Dumeril's monitor, *Varanus dumerilii* (Varanidae) in Singapore. Nature in Singapore 1: 21-22.

Figure 3.1. Monitor 04 foraging in the dark on Tinjil Island, Indonesia at 0420 h, 1 August 2012.

Fig 3.2. Monitor 04 foraging in the dark at Tinjil Island base camp at 0425 h, 1 August 2012.

Figure 3.3. Monitor 04 foraging in a bucket outside the Tinjil Island base camp kitchen in the dark, 0515 h, 2 August 2012.

Figure 3.4. *Varanus salvator* addressing the carcass of a conspecific near Tinjil Island base camp, pre-dawn (ca. 0523 h), 30 July 2012.

Fig. 3.5. *Varanus salvator* attempting to feed on the carcass of a conspecific near Tinjil Island base camp, pre-dawn (ca. 0525 h), 30 July 2012.

Fig. 3.6. *Varanus salvator* pulling on the arm of a *V. salvator* carcass near Tinjil Island base camp, pre-dawn (ca. 0525 h), 30 July 2012.

All Photographs © Linda Uyeda

Table 3.1. Nocturnal observations of *V. salvator*, monitor 04, at Tinjil Island base camp

Date (2012)	Time observed	Lights	< 1 h after food discarded	Observed consuming food?
8-Jul	0525 h	Off	?	Yes
12-Jul	0530 h	Off	?	No
28-Jul	0341 h	On	?	No
29-Jul	No Data	--	--	--
30-Jul	0343 h	On	?	No
31-Jul	0259 h	On	?	No
31-Jul	0317 h	On	Yes	No
1-Aug	0128 h	Off	No	No
1-Aug	0413 h	Off	Yes	Yes
2-Aug	0505 h	Off	?	Yes
3-Aug	0252 h	On	?	No
4-Aug	0330 h	On	?	Yes
5-Aug	No data	--	--	--
6-Aug	0527 h	Off	No	Yes
7-Aug	*	*	--	--
7-Aug	0514 h	Off	No	No
8-Aug	0455 h	Off	No	Yes
9-Aug	0450 h	Off	No	Yes
10-Aug	*	*	--	--
11-Aug	0334 h	On	No	Yes

* Staff members reported seeing monitor 04 at approximately 0300 h (lights on), but animal was not formally observed

CHAPTER 4

THE ROLE OF TRADITIONAL BELIEFS IN CONSERVATION OF HERPETOFAUNA
IN BANTEN, INDONESIA

ABSTRACT

Social taboos have been increasingly recognized for their role in determining human behaviour. Such informal institutions may also, in some instances, guide practices that serve as effective conservation measures. Here we present a case in Banten, Indonesia, where a local taboo has discouraged the collection of two herpetofaunal species, the water monitor lizard *Varanus salvator* and the reticulated python *Python reticulatus*, on Tinjil Island, an undeveloped island off the coast of Java. The taboo is not observed in the nearby mainland villages of Muara Dua and Cisiih, where the two species may be harvested for skin or meat, and where the water monitor may also be killed as a pest. Water monitors and reticulated pythons figure prominently in the international reptile leather trade, with skins produced from Indonesia's wild populations representing the highest percentage of total global exports of both lizard and snake skins. The site-specific taboo documented here provides a strong deterrent to collection of these species in a location where they could be subject to illicit harvest as populations in nearby mainland areas decrease. Preliminary evidence also suggests that belief in forest guardian spirits may extend protection to other wildlife species on Tinjil Island.

INTRODUCTION

The importance of traditional beliefs and social norms in the context of conservation has been recognized and documented (Colding and Folke 1997; Jones et al. 2008; Riley 2010). Colding and Folke (2001) refer to such social institutions as invisible systems of resource management in which informal, culture-based norms effectively guide human behaviour. As in Colding and Folke (2001) we define taboos in a broad sense as a subset of these informal institutions, serving as prohibitions that are enforced by social custom rather than by government or official regulation. Taboos may serve to protect wildlife that otherwise might be exploited or persecuted, effectively aiding the conservation of potentially vulnerable populations. Identification of taboos and an understanding of local concerns can help to direct conservation efforts by facilitating the integration of local belief systems with formal management strategies.

In Indonesia, local cultures maintain traditional belief systems that may have an indirect influence on attitudes and behaviour towards animals (Wadley and Colfer 2004; Wessing 2006). Although there may be regional commonalities in spiritual beliefs (Wessing 2006), the country's c. 200 ethnic groups and >500 spoken languages (Ministry of Tourism and Creative Economy, Republic of Indonesia 2013) also necessitate that social institutions be investigated at a finer scale to ensure greater understanding of local differences. Here we document a social taboo that serves to support official regulations in preventing collection of the water monitor lizard *Varanus salvator* and the reticulated python Python reticulatus on Tinjil Island, off the coast of Java. We also report interview data from the nearby mainland villages of Muara Dua and Cisiih on local knowledge and attitudes regarding these species. We aim to contribute specific knowledge on local perspectives and to discuss the role of traditional beliefs in conservation of wildlife populations in Indonesia.

93

STUDY AREA

Tinjil Island (c. 600 ha; Fig. 4.1) has served as a natural habitat breeding facility for long-tailed macaques *Macaca fascicularis* since 1987 (Kyes 1993; Pamungkas et al. 1994) and is managed by the Primate Research Center of Bogor Agricultural University. Unauthorized access to the island is prohibited by official regulation of the Indonesian state-owned forestry company Perum Perhutani (UU PK No. 35 Tahun 1967 Juncto Pasal 5 ayat butir C dan Pasal 6 Peraturan Pemerintah No. 36 Tahun 1986). According to the official policy of Bogor Agricultural University, unauthorized removal of flora and fauna from the island is also prohibited. Tinjil Island remains undeveloped, with no permanent residents. Staff members are rotated on and off the island, with only 5–8 individuals residing in a small base camp at any given time. A select group of fishermen (c. 8–12) have also been authorized to use three small camps on the island. Muara Dua, in Banten province on the island of Java, is c. 16 km from Tinjil Island and is the closest mainland village to the island. It is 45 km from the village of Cisiih, also in Banten province. The majority of staff and fishermen associated with Tinjil Island have established permanent residences in the area known as Muarabinuangeun, consisting of Muara Dua village and its neighbouring village of Binuangeun.

Water monitors and reticulated pythons are the only known large (>2 m in length) reptile species on Tinjil Island. Water monitors are found throughout the island and are considered common in all three study locations, whereas reticulated pythons are encountered less frequently. These species are exploited consistently throughout South-east Asia to supply the international reptile leather trade (Luxmoore and Groombridge 1990; Shine et al. 1998; Auliya 2006). Indonesia is the primary exporter of skins of both species (Jenkins and Broad 1994; TRAFFIC and the IUCN/SSC Wildlife Trade Programme 2004; Engler and Parry-Jones 2007; Kasterine et

94

al. 2012), and both species are listed on Appendix II of CITES (CITES 2014), with export quotas established annually (UNEP 2013a,b).

METHODS

We conducted individual and group (2–3 participants) interviews during 19 January–4 September 2013 as part of a broader interdisciplinary study investigating the behaviour and resource use of water monitors (Uyeda et al. 2012, 2013), and local attitudes and knowledge regarding this species. Interviewees were asked about their perceptions and knowledge of local herpetofauna, with an initial focus on water monitors. Interviews were semi-structured but casual, and questions were open-ended to encourage participants to express their perspectives and attitudes freely. Participants comprised adult residents of Muara Dua or Cisiih and individuals authorized to carry out activity on Tinjil Island. On Tinjil Island 15 individuals (13 men and two women) participated in 12 interviews; participants included individuals from each of the three fisherman camps as well as staff members from the base camp area. As most participants on Tinjil Island were permanent residents in the area of Muarabinuangeun, they were asked about both their permanent place of residence and Tinjil Island. We used a combination of convenience sampling (i.e. interviewing people who were easily accessible) and snowball sampling (i.e. identifying new participants based on the recommendation of current participants; Auerbach and Silverstein 2003) to identify participants in the villages of Muara Dua and Cisiih. In these villages 40 individuals (21 men and 19 women) participated in 23 interviews (12 in Muara Dua and 11 in Cisiih). The mean duration of interviews was 30 minutes, and interviews were conducted in Bahasa Indonesia.

RESULTS

Social taboo on Tinjil Island

Throughout the course of the interviews a social taboo against the collection of water monitors and reticulated pythons on Tinjil Island emerged. We documented several versions of the taboo that were consistent in theme. In the first story a fisherman took a water monitor from Tinjil Island, killed it, and skinned it, intending to sell the skin. That night, the fisherman became possessed to the point of madness, running around wildly. An orang pintar (wise man) was sought for advice and he told the fisherman that the lizard wished to be returned to the island. The fisherman followed the advice of the orang pintar and brought the head of the lizard back to the exact location where the animal had been captured. Subsequently, the fisherman was healed.

Other versions of the taboo involved a fisherman encountering an exceptionally large reticulated python on Tinjil Island. The fisherman caught the snake with the intention of taking it to sell in the village. The snake's spirit entered the fisherman and spoke to him, requesting to be released. The fisherman became possessed and remained cursed until he returned the snake to the island.

We were unaware of these stories prior to beginning our research, and therefore initially we did not question Tinjil Island participants specifically about the existence of taboos. After learning of the taboo we began probing subsequent participants regarding their knowledge of any taboos related to wildlife. Each of the five male individuals on Tinjil Island questioned about taboos relayed a version of one or both of the taboo stories. Although neither of the women interviewed on Tinjil Island had knowledge of the taboo, both expressed a general belief in the presence of spirits on the island. All interviewees in Muara Dua and Cisiih were asked about

their knowledge of wildlife taboos, with two former long-time staff members of Tinjil Island living in Muara Dua providing similar accounts of the taboo. None of the participants indicated knowledge of taboos prohibiting the harvest of any wildlife species in the villages of Muara Dua or Cisiih. Individuals with experience on Tinjil Island expressed that whereas they were afraid to harvest water monitors or reticulated pythons from the island, a person harming or even killing these species in the mainland villages would suffer no negative repercussions.

Individuals who were aware of the taboo had spent 3–24 years working on Tinjil Island, with younger workers having acquired knowledge of the taboo from their older coworkers. One less experienced fisherman reported what he had been told by others:

> According to the elders the island is *angker* (haunted). If there is a snake, don't try to take it because it belongs to the *orang sini* (guardian spirit of the island). Other people said that snakes and monitor lizards belong to the *orang sini*. All of the elders know this, so I'm not brave enough to kill or to take one indiscriminately. People here fear being cursed.

Of the stories associated with the taboo, at least one was reported to have occurred in the recent past; several interviewees had heard of a fisherman becoming possessed when he had attempted to remove a snake from Tinjil Island c. 10 years previously. It was also noted that Tinjil Island had been haunted (*angker*) since long ago and that the neighbouring island, Pulau Deli, was also known to be haunted.

Interviewees who were familiar with the stories indicated that the taboo was a strong deterrent, discouraging attempts to take either of the species off the island despite the potential for financial gain. The following quotations illustrate such sentiments:

> I'm scared to take a snake or a monitor lizard. I often get requests from Muarabinuangeun …for skin, to make shoes, to make wallets, and the meat can also be eaten. It's not allowed, but if you put it into a bag, you could do it. Nobody would know. We're just scared because of what happened to the fisherman.

> It's a warning for other fishermen. Now fishermen wouldn't dare to take even a single monitor lizard from here, even though there are requests for the meat. Honestly, the monitor

97

lizards here are big, bigger than 10 kg. They could be sold for 3,000–4,000 rupiah per kilo. But the fishermen are afraid now. They are afraid of what happened.

Interviewees specified that the taboo applied only to water monitors and reticulated pythons, although none could explain why other wildlife species were not included in the taboo. There was some evidence that belief in the taboo also conferred some degree of protection to other wildlife species. For example, although venomous snakes were generally viewed as a threat to human safety and had reportedly been killed on Tinjil Island, more than one individual expressed a reluctance to disturb any being on the island for any reason. A worker who had instinctively killed a venomous snake after it had bitten him had been extremely fearful of spiritual repercussions, although there were none. He explained:

> Because of what happened with the fisherman and the snake, I'm afraid of it happening with all animals. If I see a snake, better to go around it. If I were to hit it, I'm afraid something bad would happen.

Attitudes and local knowledge

Several interviewees reported that independent collectors in the area of Muarabinuangeun continue to harvest water monitors and reticulated pythons for skin and to fulfil orders for water monitor meat. Although the meat is not eaten regularly as a protein source in the study area, local knowledge supported occasional consumption as a cure for skin ailments (Uyeda et al. 2014).

The majority of local people interviewed in Muara Dua and Cisiih reported keeping small livestock such as chickens, for personal consumption, and many participants reported having chased or killed a water monitor to protect chickens or ducks from predation. A number of people in both Muara Dua and Cisiih referred to water monitors as jahat, a word used to

characterize unacceptable behaviour, with others calling the lizard a hama (pest). Although generally disliked, water monitors were not considered dangerous to humans.

There are no domestic livestock kept on Tinjil Island, and interviewees indicated that water monitors were left undisturbed, even when encountered at close proximity. In the island's camp areas the lizards were reportedly habituated to people, as supported by our previous observations (Uyeda 2009; Uyeda et al. 2013). In contrast, inhabitants of Muara Dua and Cisiih reported that water monitors were likely to flee upon encountering humans.

Snakes were encountered only rarely in the villages, with the reticulated python and the Malayan pit viper *Calloselasma rhodostoma* being the most commonly encountered species. On Tinjil Island the Javanese pit viper *Trimeresurus puniceus* was the venomous snake observed most frequently, although it was not encountered often. Interviewees indicated that venomous species were generally killed on sight in the mainland villages because of the threat they posed to human safety. The non-venomous reticulated python was rarely seen as a threat to humans, chickens or other livestock but was sometimes killed opportunistically for its skin or meat.

Participants reported a general decrease in populations of water monitors and reticulated pythons in Cisiih and Muarabinuangeun. Several participants noted that Tinjil Island was the only place where large water monitors were still seen, and they were reported to be larger and more numerous on the island than in Muara Dua, where it was speculated that observed population trends may be attributable to harvesting of the animals for skin and meat:

Pythons, I rarely see them; they're already gone around here. People have taken them.

In the past, there were many [monitor lizards], but now there aren't any big ones. They're hunted by people, the big ones.

Based on our personal observations as well as reports from interview participants, water monitors on Tinjil Island appear to have lower quality (scarred, peeling) skin than in Muara Dua or Cisiih and are thus considered less suitable for collection to supply the reptile leather trade.

DISCUSSION

Interviews indicated that a local taboo guides behaviour in discouraging harvesting of water monitors and reticulated pythons on Tinjil Island. The location-specific nature of the taboo suggests it originated in beliefs associated with characteristics of the island. In traditional Javanese culture it is generally believed that spirits exist in most natural places and both inhabit and protect these areas (Wessing 2006). Forests are perceived as forbidding places, home to fearsome forest guardians that may be angered by humans entering their territories or removing things without permission. The forest guardians are reputed to be powerful spirits that punish offenders by causing them to become disoriented or by subjecting them to illness or death (Wessing 2006). The folklore documented here suggests that interview participants believed in the power of such forest guardians on Tinjil Island. As forest guardians are associated with isolated, wild forest rather than human-disturbed areas (Wessing 2006), it is unsurprising that a taboo exists on Tinjil Island, which is secluded and largely untouched by humans. Similarly, we would expect to find less regard for a taboo involving forest guardians in the mainland villages, which are more developed.

The water monitor lizard is categorized as Least Concern on the IUCN Red List (Bennett et al. 2010), having demonstrated a certain degree of resilience to substantial harvesting pressure (Shine et al, 1998). However, Indonesia reported a total export volume of 6,201,615 wild-caught water monitor skins during 2000–2010 (Koch et al. 2013), and the impact of such collection on wild populations cannot be dismissed as insignificant. Although populations of reticulated

pythons also seem able to withstand high volumes of harvest (Shine et al. 1999), the species has

not been evaluated for the Red List, and anecdotal reports suggest that harvested populations

have been depleted in some areas (Groombridge and Luxmoore 1991).

Despite official regulations protecting Tinjil Island's wildlife, and the poor quality of

water monitor skins originating from the island, incentives for illicit harvest remain. The

population status of monitor lizards and reticulated pythons in Muara Dua have not been

evaluated formally but anecdotal reports from interview participants indicated that populations of

both species have decreased there as a result of collection, whereas they remain more abundant

on Tinjil Island. Interview responses also suggested that larger water monitors are more

desirable to collectors than smaller individuals, and that their meat is still in demand. As

populations of water monitors in Muarabinuangeun decrease, collectors may consider risking

official sanctions to access larger specimens on Tinjil Island. Moreover, unlike in Cisiih and

Muara Dua, water monitors on Tinjil Island are naïve to hunting and are less likely to avoid

humans, and therefore they are vulnerable to collection. Reticulated python populations on the

island could also be subject to collection pressure in the future as populations in nearby villages

are depleted.

There is evidence to suggest that despite the species-specific nature of the taboo, belief in

forest guardian spirits on Tinjil Island may influence behaviour towards all wildlife, and

therefore any decline in such beliefs could also have negative consequences for other species. A

variety of factors could contribute to the decline of local taboos, including an influx of people to

the area who are unaware of or who do not believe in the taboo (Thalmann et al. 1993; Lingard et

al. 2003), economic incentives resulting in deliberate disregard for the taboo (Jones et al. 2008),

degradation of natural, wild lands, and a decline in belief if offenders do not appear to suffer any negative consequences.

In the case presented here, modern-day stories of fishermen becoming possessed after capturing water monitors and reticulated pythons on Tinjil Island have reinforced a taboo that appears to be based on a long-standing traditional belief in forest guardians. Individuals in the island's base and fisherman camps, and former Tinjil Island workers living in Muara Dua, were familiar with the folklore and expressed a strong belief in the taboo, which had been passed down to younger generations as they began their association with the island. However, the lack of knowledge about Tinjil Island among local people in mainland villages is a potential limitation to the conservation value of the taboo. Those who had no previous experience on the island appeared to be unaware of the taboo associated with the collection of herpetofauna there, and this ignorance could embolden individuals to harvest wildlife from Tinjil Island in the future. Increasing awareness of the taboo among people on the mainland may aid in pre-empting such efforts, and further investigation into the prevalence and scope of beliefs associated with forest guardians in this area could identify additional protection afforded to local wildlife species.

The value of sacred forests or groves to conservation has been noted in Indonesia (Wessing 1999; Wadley and Colfer 2004) and elsewhere (e.g. Bhagwat and Rutte 2006; Khan et al. 2008). However, not all sacred areas ensure protection for wildlife. For example, Wadley and Colfer (2004) documented hunting effort among the Iban community in West Kalimantan, where a number of bird and mammal species were captured regularly in a sacred forest. Hunting in the sacred forest was considered acceptable among the Iban, whereas the felling of trees was strictly regulated in accordance with the belief that illness would befall those who did not obey.

Such examples highlight the need for location-specific and species-specific understanding of traditional belief systems in assessing their potential application to conservation efforts.

This need is particularly great in Indonesia, which faces considerable logistical challenges in the conservation of its flora and fauna across >17,000 islands (Ministry of Environment Indonesia 2009). These islands are not only home to a variety of endemic species but may also support the undisturbed, wild habitats associated with sacred forests and guardian spirits. As behaviours associated with the belief in forest spirits may prove critical to the protection of Indonesia's biodiversity, continued investigation of taboos throughout the Indonesian archipelago will aid in the consideration of such traditional values in the conservation of wildlife.

ACKNOWLEDGEMENTS

LITERATURE CITED

Auerbach, C. F. and L.B. Silverstein. 2003. Qualitative Data: An Introduction to Coding and Analysis. NYU Press, New York, USA.

Auliya, M. 2006. Taxonomy, Life History and Conservation of Giant Reptiles in West Kalimantan (Indonesian Borneo). Natur und Tier Verlag, Münster, Germany.

Bennett, D., M. Gaulke, E.R. Pianka, R. Somaweera and S.S. Sweet. 2010. *Varanus salvator*. In IUCN Red List of Threatened Species v. 2013.2.
Internet resource, accessed March 2014: http://www.iucnredlist.org/details/178214/0

Bhagwat, S.A. and C. Rutte. 2006. Sacred groves: potential for biodiversity management. Frontiers in Ecology and the Environment 4:519–524.

CITES. 2014. Convention on International Trade in Endangered Species of Wild Fauna and Flora. Appendices I, II and III.
Internet resource, accessed 21 August 2014: http://cites.org/eng/app/appendices.php

Colding, J. and C. Folke. 1997. The relations among threatened species, their protection, and taboos. Conservation Ecology 1:6.

Colding, J. and C. Folke. 2001. Social taboos: "invisible" systems of local resource management and biological conservation. Ecological Applications 11:584–600.

Engler, M. and R. Parry-Jones. 2007. Opportunity or Threat: The Role of the European Union in Global Wildlife Trade. TRAFFIC Europe, Brussels, Belgium.

Groombridge, B. and R. Luxmoore. 1991. Pythons in South-East Asia: A Review of Distribution, Status and Trade in Three Selected Species. A report to the CITES Secretariat. Lausanne, Switzerland.

Jenkins, M. and S. Broad. 1994. International Trade in Reptile Skins: A Review and Analysis of the Main Consumer Markets, 1983–91. TRAFFIC International, Cambridge, UK.

Jones, J.P.G., M.M. Andriamarovololona and N. Hockley. 2008. The importance of taboos and social norms to conservation in Madagascar. Conservation Biology 22:976–986.

Kasterine, A., R. Arbeid, O. Caillabet and D. Natusch. 2012. The Trade in South-East Asian Python Skins. International Trade Centre (ITC), Geneva, Switzerland.

Khan, M.L., A.D. Khumbongmayum and R.S. Tripathi. 2008. The sacred groves and their significance in conserving biodiversity: an overview. International Journal of Ecology and Environmental Sciences 34:277–291.

Koch, A., T. Ziegler, W. Bohme, E. Arida and M. Auliya. 2013. Pressing problems: distribution, threats, and conservation status of the monitor lizards (Varanidae: Varanus spp.) of Southeast Asia and the Indo-Australian archipelago. Herpetological Conservation and Biology 8:1–62.

Kyes, R.C. 1993. Survey of the long-tailed macaques introduced onto Tinjil Island, Indonesia. American Journal of Primatology 31:77–83.

Lingard, M., N. Raharison, E. Rabakonandrianina, J.-A. Rakotoarisoa and T. Elmqvist. 2003. The role of local taboos in conservation and management of species: the radiated tortoise in southern Madagascar. Conservation & Society 1:223–246.

Luxmoore, R. and B. Groombridge. 1990. Asian Monitor Lizards: A Review of Distribution, Status, Exploitation and Trade in Four Selected Species. World Conservation Monitoring Centre, Cambridge, UK.

Ministry of Environment Indonesia. 2009. Fourth National Report: The Convention on Biological Diversity. Biodiversity Conservation Unit, Ministry of Environment, Jakarta, Indonesia.

Ministry of Tourism and Creative Economy, Republic of Indonesia. 2013. Discover Indonesia. Internet resource, accessed 12 September 2014: http://www.indonesia.travel/en/discover-indonesia

Pamungkas, J., D. Sajuthi, P.A. Lelana, D. Iskandriati, B. Joeniman, R.C. Kyes, G.H. Knitter and R.A. Watanabe. 1994. Tinjil Island, a natural habitat breeding facility of simian retrovirus-free *Macaca fascicularis*. American Journal of Primatology 34:81–84.

Riley, E.P. 2010. The importance of human–macaque folklore for conservation in Lore Lindu National Park, Sulawesi, Indonesia. Oryx 44:235–240.

Shine, R., Ambariyanto, P.S. Harlow, and Mumpuni. 1999. Reticulated pythons in Sumatra: biology, harvesting and sustainability. Biological Conservation 87:349–357.

Shine, R., P. Harlow, Ambariyanto, Boeadi, Mumpuni and J.S. Keogh. 1998. Monitoring monitors: a biological perspective on the commercial harvesting of Indonesian reptiles. Mertensiella 9:61–68.

Thalmann, U., T. Geissmann, A. Simona and T. Mutschler. 1993. The indris of Anjanaharibe-Sud, northeastern Madagascar. International Journal of Primatology 14:357–381.

TRAFFIC and the IUCN/SSC Wildlife Trade Programme. 2004. Taxa identified as possible candidates for inclusion in the review of Significant Trade in Specimens of Appendix–II Species. In Twentieth Meeting of the CITES Animals Committee Johannesburg (South Africa), 29 March–2 April 2004.

UNEP (United Nations Environment Programme). 2013a *Python reticulatus*. Internet resource, accessed March 2014: http://www.speciesplus.net/#/taxon_concepts/5959/

UNEP (United Nations Environment Programme). 2013b. *Varanus salvator*. Internet resource, accessed March 2014: http://www.speciesplus.net/#/taxon_concepts/5763/

Uyeda, L. 2009. Garbage appeal: relative abundance of water monitor lizards (*Varanus salvator*) correlates with presence of human food leftovers on Tinjil Island, Indonesia. Biawak 3(1):9-17.

Uyeda, L.T., E. Iskandar, R.C. Kyes and A.J. Wirsing. 2012. Proposed research on home ranges and resource use of the Water Monitor Lizard, *Varanus salvator*. The Forestry Chronicle 88:542–546.

Uyeda, L.T., E. Iskandar, A. Purbatrapsila, J. Pamungkas, A. Wirsing and R. Kyes. 2014. Water monitor lizard (*Varanus salvator*) satay: a treatment for skin ailments in Muarabinuangeun and Cisiih, Indonesia. Biawak 8:35–38.

Uyeda, L., E. Iskandar, A. Wirsing and R. Kyes. 2013. Nocturnal activity of *Varanus salvator* on Tinjil Island, Indonesia. Biawak 7(1): 25-30.

Wadley, R.L. and C.J.P. Colfer. 2004. Sacred forest, hunting, and conservation in West Kalimantan, Indonesia. Human Ecology 32:313–338.

Wessing, R. 1999. The sacred grove: founders and the owners of the forest in West Java, Indonesia. Pp 59-74 *In* L'homme et la forêt tropicale. S. Bahuchet, D. Bley, H. Pagezy and N. Vernazza-Licht (Eds.). Travaux de la Societe d'Ecologie Humaine, Marseille, FR.

Wessing, R. 2006. A community of spirits: people, ancestors, and nature spirits in Java. Crossroads: An Interdisciplinary Journal of Southeast Asian Studies 18:11–111.
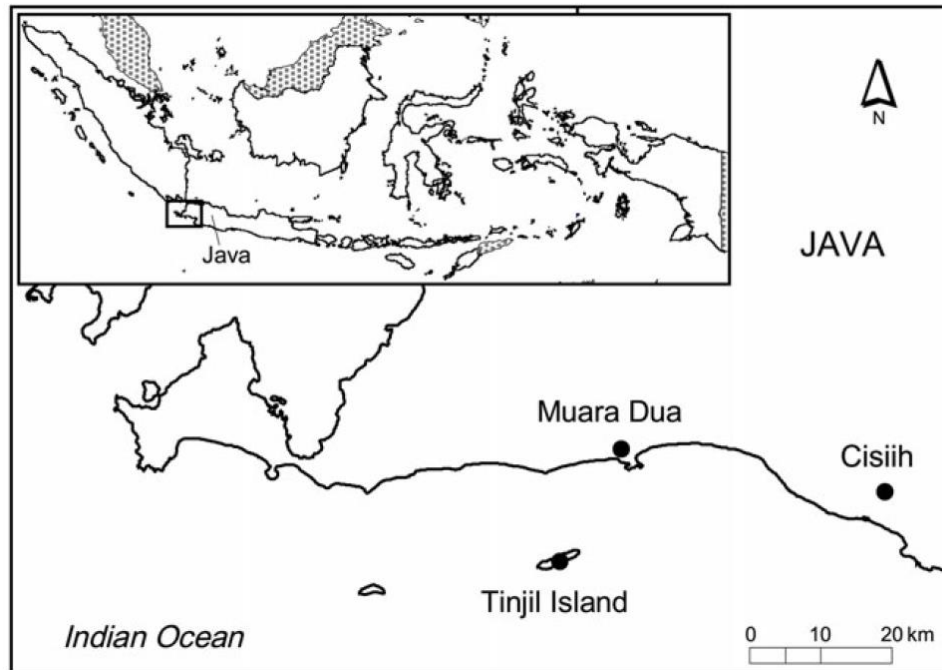
Figure 4.1. Location of Tinjil Island and the villages of Muara Dua and Cisiih. The rectangle on the inset shows the location of the main map in Indonesia.

CHAPTER 5

WATER MONITOR LIZARD (*VARANUS SALVATOR*) SATAY: A TREATMENT FOR SKIN AILMENTS IN MUARABINUANGEUN AND CISIIH, INDONESIA

ABSTRACT

Varanus salvator meat is consumed as a protein source in certain areas throughout its Southeast Asian range, while in others it is shunned because of religious or traditional beliefs, or simply avoided due to taste preferences. Here we document the use of *Varanus salvator* for medicinal purposes in Muarabinuangeun and Cisiih, part of Pandeglang District in the Province of Banten, Indonesia, where villagers report consuming grilled *V. salvator* meat as a cure for various skin ailments.

The meat of *Varanus salvator*, a large-bodied species of monitor lizard found in southern and Southeast Asia (Gaulke and Horn 2004; Bennett et al. 2010; Koch et al. 2013), is not often consumed as a source of protein in Indonesia (Luxmoore and Groombridge 1990). However, there are a few local ethnic groups that will eat *V. salvator*, such as the Bataks in North Sumatra, the Dayaks in Kalimantan (Luxmoore and Groombridge 1990), and the Minahasa people of North Sulawesi who consider *V. salvator* to be a favored delicacy (De Lisle 2007). This note documents the consumption of *V. salvator* meat in two village areas on the southwest coast of Java, Indonesia, where some consider it to be an effective remedy for common skin ailments such as *Pityriasis versicolor* and eczema.

Varanus salvator is a species common to both Muarabinuangeun and Cisiih, two village areas located approximately 45 km apart in Banten province, Indonesia. Residents of Muarabinuangeun and Cisiih were interviewed as part of a larger interdisciplinary study investigating local perceptions and attitudes towards *V. salvator* as well as the behavior and resource use of this species (Uyeda et al. 2012, 2013). Through the use of open-ended interviews, participants were asked about experiences and knowledge related to *V. salvator*. Each interview consisted of 1-3 participants, with a total of 55 participants over the course of 35 interviews. Interviews were conducted in Bahasa Indonesia, digitally recorded, and later transcribed and translated into English.

Interviews revealed local knowledge regarding the consumption of *V. salvator* meat as a cure for skin ailments associated with itching. Fourteen participants mentioned specific knowledge regarding the medicinal use of *V. salvator* meat, with four of these detailing personal experiences in utilizing *V. salvator* meat for its curative properties (Table 5.1). Participants mentioned the use of *V. salvator* meat to treat *Pityriasis versicolor* (*panu* in Bahasa Indonesia), a yeast overgrowth on the skin common in many tropical areas (Erchiga and Hay 2010), *Tinea corporis* (*kurap* in Bahasa Indonesia), a fungal infection commonly known as ringworm, and eczema (*eksim* in Bahasa Indonesia), a term often used synonymously with atopic dermatitis (Burgess et al. 2009), a disease associated with itching and redness of the skin. Several participants did not specify a particular skin ailment treated with *V. salvator* meat, using instead either the Indonesian phrase *gatal-gatal*, which translates to a general "itching", or *penyakit kulit*, translating to "skin disease". One participant referred to "ulcerations" or "sores" (*koreng*) that could be alleviated by the consumption of *V. salvator* meat. A single preparation method was reported; *V. salvator* meat was prepared as a satay (the meat grilled on a skewer) or grilled, and

then eaten. Participants indicated that consuming a one-time "dose", consisting of only a small amount of meat, was enough to achieve the curative effect. Each of the individuals who had personal experience with the consumption of *V. salvator* for a skin ailment indicated that eating the *V. salvator* meat resulted in a noticeable improvement in the skin condition within a short period of time (Table 5.1).

Interviewees further explained that *V. salvator* meat was only effective for the treatment of certain types of skin ailments, indicating that direct injuries or scars would not be positively affected by the consumption of *V. salvator* meat. However, one individual reported that oil extracted from *V. salvator* could be applied topically to effectively reduce the prominence of scars. Two interviewees mentioned that *V. salvator* meat could be eaten to combat the symptoms of asthma, although none of the study participants reported personal experience in consuming *V. salvator* for this purpose.

Muarabinuangeun and Cisiih are located in predominantly Muslim areas, where *V. salvator* is generally not consumed as a regular dietary item or source of protein due to religious beliefs. Individuals who had eaten *V. salvator* meat as a skin cure specified that they would not have eaten the meat other than for medical purposes, although it was not clear if this was for religious reasons or simply due to a dislike for *V. salvator* meat. Throughout the course of the study, only two individuals indicated that they had occasionally eaten *V. salvator* meat as a protein source rather than as a medical treatment.

Throughout Asia, varanid body parts or extracts have been utilized in treating a variety of ailments. For example, varanid gall bladders are said to cure heart problems, impotency, and liver failure (Bennett 1995) and gall bladders from *V. salvator* have been noted in the Asian medicine trade (Luxmoore and Groombridge 1990). The fat and oil of *V. bengalensis* have been

utilized by tribes in Pakistan as a salve for skin infections and for relief of rheumatic pain (Hashmi et al. 2013). In India, *V. bengalensis* meat is believed to aid lung muscles in recovering from lack of oxygen, and powdered *V. bengalensis* meat is used in energy tonics for the relief of asthma (Subramanean and Reddy 2012). Khatiwada and Ghimire (2009) reported that the meat of *V. flavescens* is consumed for medicinal purposes in Nepal, where individuals also believe it to be an effective treatment for asthma (in addition to other conditions such as tuberculosis and leprosy).

The number of interviewees who mentioned *V. salvator* satay as a known cure for skin ailments, and the presence of individuals who had engaged in the consumption of *V. salvator* meat as medicine despite the predominant religious practices suggest that belief in the efficacy of this treatment is strongly supported by traditional knowledge in our study areas. Reports of varanid meat consumption to treat asthma should also be noted as eczema and asthma are characterized by similar allergic mechanisms (e.g., Cookson, 2004), with recent literature identifying possible links between eczema and the development of asthma (e.g., Burgess et al. 2009; von Kobyletzki et al. 2012). To our knowledge, the effectiveness of varanid products in medicinal applications has not been systematically or empirically tested. Future research directions might include investigating the prevalence of medicinal *V. salvator* consumption throughout the species' range, as well as laboratory analysis to evaluate the potential curative properties of *V. salvator* meat.

ACKNOWLEDGEMENTS

LITERATURE CITED

Bennett, D. 1995. A Little Book of Monitor Lizards. Viper Press, Aberdeen. 208 pp.

Bennett, D., M. Gaulke, E.R. Pianka, R. Somaweera and S.S. Sweet. 2010. *Varanus salvator*. In IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2.
Internet resource, accessed 10 January 2014: www.iucnredlist.org

Burgess, J.A., A.J. Lowe, M.C. Matheson, G. Varigos, M.J. Abramson and S.C. Dharmage. 2009. Does eczema lead to asthma? Journal of Asthma 46(5):429-436.

Cookson, W. 2004. The immunogenetics of asthma and eczema: a new focus on the epithelium. Nature Reviews Immunology 4(12):978-988.

De Lisle, H. 2007. Observations on *Varanus. s. salvator* in North Sulawesi. Biawak 1(2):59-66.

Erchiga, V.C. and R.J. Hay. 2010. *Pityriasis versicolor* and other Malassezia skin diseases. Pp. 175-199 *In* Boekhout, T., P. Mayser, E. Guého-Kellermann and A. Velegraki (Eds.). Malassezia and the Skin. Springer, Berlin, Heidelberg.

Gaulke, M. and H.-G. Horn. 2004. *Varanus salvator* (Nominate Form). Pp. 244-257 *In* Pianka, E.R., D.R. King and R.A. King (Eds.), Varanoid Lizards of the World. Indiana University Press, Bloomington.

Hashmi, M.U.A., M. Zaheer Khan, Amtyaz and N. Ul Huda. 2013. Current status, distribution and threats of Varanus species (*Varanus bengalensis* & *Varanus griseus*) in Karachi & Thatta of Sindh. International Journal of Fauna and Biological Studies 1(1):34-38.

Khatiwada, J.R. and B.C. Ghimire. 2009. Conservation status of *Varanus flavescens* in Chitwan, Nepal. Biawak 3(4):100-105.

von Kobyletzki, L.B., C.-G. Bornehag, M. Hasselgren, M. Larsson, C.B. Lindström and Å. Svensson. 2012. Eczema in early childhood is strongly associated with the development of asthma and rhinitis in a prospective cohort. BMC Dermatology 12(11):1-9.

Koch, A., T. Ziegler, W. Böhme and M. Auliya. 2013. Pressing problems: Distribution, threats, and conservation status of the monitor lizards (Varanidae: Varanus spp.) of Southeast Asia and the Indo-Australian archipelago. Herpetological Conservation and Biology 8:1-62.

Luxmoore, R. and B. Groombridge. 1990. Asian Monitor Lizards - A Review of Distribution, Status, Exploitation and Trade for Four Selected Species. World Conservation Monitoring Centre (WCMC), Cambridge, UK. 195 pp.

Subramanean, J. and M.V. Reddy. 2012. Monitor lizards and geckos used in traditional medicine face extinction and need protection. Current Science 102(9):1248-1249.

Uyeda, L.T., E. Iskandar, R.C. Kyes and A.J. Wirsing. 2012. Proposed research on home ranges and resource use of the water monitor lizard, *Varanus salvator*. The Forestry Chronicle 88(5):542-546.

Uyeda, L., E. Iskandar, A. Wirsing and R. Kyes. 2013. Nocturnal activity of *Varanus salvator* on Tinjil Island, Indonesia. Biawak 7(1):25-30.

Table 5.1. Individual knowledge and use of *Varanus salvator* meat for medicinal purposes in Muarabinuangeun (MB) and Cisiih, Indonesia

Location	Knowledge from a third-party source / personal experience	Ailment Treated	Preparation	Reported Effectiveness
MB	local knowledge	eczema	--	--
MB	local knowledge	eczema, asthma	--	--
MB	local knowledge	"itching"	satay	--
MB	local knowledge	"itching"	grill meat	--
MB	local knowledge	"skin disease"	satay	--
MB	local knowledge	"itching"	--	--
Cisiih	local knowledge	asthma	satay	--
Cisiih	local knowledge	--	satay	--
Cisiih	local knowledge	"itching"	--	--
Cisiih	local knowledge	"itching"	--	--
MB	consumed meat	*P. versicolor*, eczema, *T. corporis*	satay	healed by the next day
MB	consumed meat	eczema, "skin disease"	--	healed
MB	consumed meat*	eczema, "sores"	grill meat	healed within a week
Cisiih	consumed meat	eczema	satay	healed within 2-3 days

*the interviewee and his wife indicated that their young son had consumed the meat for his skin ailment

CONCLUSIONS

On Tinjil Island, Indonesia, *V. salvator* behavior in human-subsidized areas differed from that in wildland areas but varied across seasons, indicating that the presence of anthropogenic subsidies may have a greater impact on this population when natural resources are scarce. On the island, a taboo, official regulations, and anthropogenic resource subsidies preserve and sustain a relatively large and abundant *V. salvator* population. However, in nearby Muara Dua and Cisiih the species is subject to harvest for medicinal use and is persecuted amid concerns over livestock depredation. Not surprisingly, anecdotal reports indicate that populations in Muara Dua and Cisiih are becoming depleted, and that mainland *V. salvator* are generally smaller than Tinjil Island counterparts.

Our results highlight the complex nature of wildlife behavior and human responses in areas of anthropogenic resource subsidy. On Tinjil Island, anthropogenic subsidies augmented limited dry season resources, but concentrated *V. salvator* activity around those clumped resources corresponded to smaller activity areas and increased intraspecific interactions. In the future, Tinjil Island's *V. salvator* population could also see declines should the island's anthropogenic resource subsidies be discontinued. On the island, subsidies in the form of garbage and water runoff are easily conceded to wildlife, but in Muara Dua and Cisiih, *V. salvator* competition with villagers over valuable livestock is a consistent source of conflict. Similarly, official protection and local beliefs decrease the threat of *V. salvator* harvest on Tinjil Island, whereas mainland villagers may collect *V. salvator*, further impacting local populations of this species.

The future is likely to bring further habitat loss and human development throughout this species' range, increasing overlap between humans and *V. salvator*, and in turn increasing the

potential for altered behavior and conflict. As documented here, meaningful differences in both wildlife and human behavior can occur in response to changing variables, even in adjacent areas. Understanding these differences is the key to managing the potential for human-wildlife conflicts and devising effective conservation management strategies. With Indonesia alone comprising over 17,000 islands and representing only a portion of *V. salvator*'s range, it is essential that each investigation of this species provides precise, location-specific data while also contributing to the greater understanding of *V. salvator* behavior in areas of anthropogenic resource subsidy across Southeast Asia. Continued research on this species throughout its range will aid in assessing not only the effects of anthropogenic subsidy on *V. salvator* behavior, but in quantifying the effects of commercial and subsistence harvest on *V. salvator* populations. In addition, to better understand impacts that extend beyond the species level, future directions should include investigation of potential cascading effects to prey populations and system-wide ecological consequences in areas of human-provided subsidy.