Proposed research on home ranges and resource use of the water monitor lizard, *Varanus salvator*

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ABSTRACT

Throughout the world, population growth and conversion of land for human development increase the potential for areas of human and wildlife activity to overlap. Anthropogenic effects on animal behavior may have ecological consequences if response to human disturbance or dependence on anthropogenic food sources prevents wildlife from carrying out traditional ecological roles. The presence of large predatory species such as the water monitor lizard, *Varanus salvator,* in areas of human development may also result in conflict if animals become habituated to the presence of humans or begin to compete for resources. Understanding anthropogenic effects on *V. salvator* resource use and activity is a key to predicting behavior and informing conflict mitigation in systems where humans and *V. salvator* coexist. *V. salvator* home ranges and resource use will be investigated on Tinjil Island, Indonesia, where radiotelemetry will be used to track *V. salvator* individuals across areas of varying human presence in both wet and dry seasons. Greater insight into anthropogenic influences on *V. salvator* resource use will contribute increased knowledge of *V. salvator*'s ecological role in undisturbed and human-altered communities and can serve to inform the prevention of human–*V. salvator* conflict.

Key words: monitor lizard, *Varanus*, radiotelemetry, resource use, home range, resource utilization function

RÉSUMÉ

Partout dans le monde, la croissance de la population et la conversion des terres pour le développement humain ont accentué le risque de chevauchement entre les activités humaines et celles de la faune. Les effets anthropogéniques sur le comportement animal peuvent avoir des impacts écologiques si les réactions aux perturbations humaines ou la dépendance envers des sources anthropogéniques d'alimentation empêchent la faune de maintenir ses fonctions écologiques habituelles. La présence d'espèces prédatrices de grande taille comme le varan, *Varanus salvator*, dans les zones de développement humain peut également entraîner des conflits si les animaux s'habituent de la présence d'humains ou entrent en compétition pour l'accès aux ressources. La compréhension des effets anthropogéniques sur l'utilisation des ressources par le *V. salvator* ainsi que sur ses activités est essentielle pour pouvoir prédire leur comportement et procéder à l'atténuation des conflits latents dans des environnements où les humains et le *V. salvator* cohabitent. Le domaine vital ainsi que les activités du *V. salvator* seront relevés sur l'île de Tinjil en Indonésie au moyen d'appareils de radio-télémétrie pour retracer les différents individus de *V. salvator* dans les zones de présence humaine variable au cours de la saison des pluies et de la saison sèche. Un portrait plus précis des influences anthropogéniques sur l'utilisation des ressources par le *V. salvator* contribuera au développement des connaissances du rôle écologique du *V. salvator* dans les zones non perturbées et dans celles modifiées par les humains et pourra servir de source d'information pour prévenir les conflits entre l'homme et le *V. salvator*.

Mots clés : varan, *Varanus*, radio-télémétrie, utilisation des ressources, domaine vital, fonction d'utilisation des ressources

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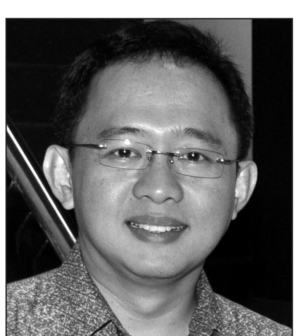

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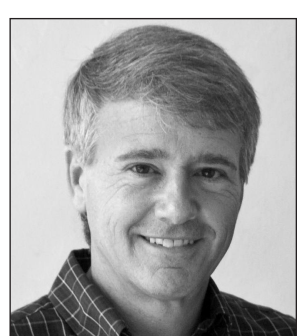

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Introduction

Urbanization and the conversion of native ecosystems for human use are occurring throughout the world (Sodhi *et al.* 2004, 2010; FAO 2006; Pauchard *et al.* 2006; United Nations 2012). As human development continues and areas of human and animal activity increasingly overlap, anthropogenic effects on animal behavior, human-animal conflict mitigation, and preservation of animal populations at the human-wildlife interface have emerged as a global focus (Whittaker and Knight 1998, Treves and Karanth 2003, George and Crooks 2006, Dar *et al.* 2009). Anthropogenic effects on animal behavior may have ecological consequences (Chapin III *et al.* 2000, Marzluff and Neatherlin 2006) in addition to increasing the potential for human–animal conflict (Whittaker and Knight 1998, Beckman and Berger 2003). For example, the presence of humans may result in sensitive species choosing suboptimal conditions to avoid encountering human activity (Gaulke 1991, Colescott and Gillingham 1998). Conversely, generalist species may be attracted to greater food availability in human-modified areas (Treves and Karanth 2003, Dar *et al.* 2009), and may exhibit a loss of avoidance or escape response in the presence of humans (Whittaker and Knight 1998, Smith *et al.* 2005). Habituated wildlife and those attracted to anthropogenic food sources may no longer perform the same ecological functions as their wildland counterparts (Whittaker and Knight 1998). For example, animals taking advantage of anthropogenic food resources have been shown to have smaller ranges than naturally foraging counterparts (Traeholt 1997c, Beckman and Berger 2003, Marzluff and Neatherlin 2006). The prospect of human development overlapping with large predatory species' ranges creates additional concerns regarding loss of livestock or human safety (Treves and Karanth 2003, Dar *et al.* 2009). In contributing to a greater understanding of wildlife behavioral ecology in systems where humans and animals interact, researchers can help to inform conflict mitigation efforts by providing detailed information on activity patterns and resource use of potential pest species.

One generalist species that has been known to adapt well to human disturbed habitats throughout its broad Southeast Asian range is the water monitor lizard, *Varanus salvator* (Traeholt 1997a,b,c; Shine *et al.* 1998a; Gaulke *et al.* 1999; Horn 1999; Auliya 2003; Gaulke and Horn 2004; Uyeda 2009; Stanner 2010). *V. salvator* is a large, carnivorous species that has been consistently harvested from the wild to meet a global demand for reptile leather products (Luxmoore and Groombridge 1990, Jenkins and Broad 1994, Shine *et al.* 1998a, Traeholt 1998, Auliya 2003, CITES/UNEP-WCMC n.d.). 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) with annual Convention on International Trade in Endangered Species (CITES) quotas of approximately 400 000 skins (CITES/UNEP-WCMC n.d.). However, the commercial harvest of *V. salvator* in Indonesia is concentrated in a few areas, affecting only a portion of the species' Indonesian population. In unharvested areas, *V. salvator* has demonstrated ecological flexibility, adapting easily to areas of human development and even thriving in such circumstances (Traeholt 1994b, 1997a,b,c, 1998; Shine *et al.* 1996; Shine *et al.* 1998a,b; Gaulke *et al.* 1999; Amarasinghe *et al.* 2009; Uyeda 2009; Stanner 2010).

V. salvator has been reported to subsist on a wide range of prey such as snails, insects, crabs, rodents, and fish, and will also scavenge broadly (Gaulke 1991; Traeholt 1993, 1994a,b; Shine *et al.* 1996; Gaulke and Horn 2004; Amarasinghe *et al.* 2009). In some areas *V. salvator* appears to play a role in pest control by consuming crop pests (Traeholt 1998), though the species also has a reputation for preying on domestic chickens (Gaulke 1991). In areas where regular anthropogenic food supplementation occurs, *V. salvator* has been observed foraging on human food leftovers (Traeholt 1994a,b, 1997a,b,c; Uyeda 2009). While in undisturbed habitats *V. salvator* may forage widely for food (De Lisle 1996, Traeholt 1997a), smaller *V. salvator* activity spaces have been documented in areas where resources are concentrated and when wide-ranging foraging becomes unnecessary. Traeholt (1997c), for example, documented reduced activity spaces in seasons where turtle nesting and tourist visits resulted in increased food concentration as compared to seasons where food supplementation did not occur.

Preliminary observations of *V. salvator* on Tinjil Island, Indonesia indicate that individual activity spaces and resource use may be different in areas of varying human presence (Uyeda 2009). Tinjil Island, an approximately 600-ha island located off the south coast of Java, Indonesia, has been designated as a Natural Habitat Breeding Facility for long-tailed macaques (*Macaca fascicularis*) since 1987 (Kyes *et al.* 1997). There are officially no permanent residents on Tinjil Island, and the island remains largely undisturbed by humans. However, areas of human activity provide regular scavenging opportunities for *V. salvator* in the form of discarded food scraps (Uyeda 2009). A main base camp represents Tinjil Island's area of greatest human food supplementation, while three fisherman camps spaced along the northern edge of the island offer additional opportunities for *V. salvator* to scavenge human-discarded leftovers (e.g., fish entrails). *V. salvator* have also been observed drinking from dripping spigots in the base camp area (Uyeda, personal observation). Such human-provided water resources may be vital, particularly in the dry season when the only other sources of fresh water on the island are ephemeral puddles, rainwater barrels and a few human-made wells. In the base camp area a number of *V. salvator* appear to be habituated to human presence, and do not react in response to nearby human activity. *V. salvator* that are encountered in areas of the island without anthropogenic influence, however, predictably avoid human activity (Uyeda 2009). These *V. salvator* may be playing the species' more natural role as a generalist scavenger and pest predator (Traeholt 1998).

Previous research on *V. salvator* movement patterns, ecology, and behavior has created a solid foundation for further examination of this species (Gaulke 1991; Traeholt 1994 a,b, 1995, 1997 a,b,c; Shine *et al.* 1996, 1998a,b; Auliya and Erdelen 1999; Gaulke *et al.* 1999; Horn 1999; Auliya 2003). However, several key studies have focused solely on harvested populations of *V. salvator* (Shine *et al.* 1996, 1998a,b; Gaulke *et al.* 1999) and research on unharvested populations has provided limited detail on seasonal variation in *V. salvator* resource use and differences in activity spaces across areas of varying human disturbance. Accordingly, we aim to take advantage of spatial variation in human use on Tinjil Island to conduct a "natural experiment" to investigate *V. salvator* home ranges and resource use across a gradient of human disturbance. Specifically, we will use radiotelemetry to relate *V. salvator* activity spaces on Tinjil Island to variation in human presence in dry and wet seasons.

Methods

We will trap *V. salvator* in multiple locations across Tinjil Island to gain a representative sample of animals across both human-disturbed and undisturbed areas. Animals will primarily be caught in box traps baited with food scraps. Box traps will be approximately 225 cm long by 50 cm high by 50 cm wide, with a vertically sliding trap door that will fall in response to bait movement. *V. salvator* will also be opportunistically caught with noose poles (a noose attached to a long pole) and by hand capture.

Once captured, each *V. salvator* will be marked for identification with a wax crayon. These superficial markings will either be washed away in time or shed off with the skin. Distinguishing scars or individual markings will also be documented and photographed as a means to permanently identify individuals. Lizards will be weighed and morphometric measurements such as snout-to-vent length, abdomen length, tail length, and tail base circumference will be recorded. Each lizard will then be fitted with an external radio-transmitter prior to release at the point of capture. Radio-transmitters will be attached to the back of each lizard by means of a waterproof "backpack" harness fitted to the pelvic girdle, the antenna extending parallel to the tail. Harnesses have been successfully utilized to mount transmitters on *V. salvator* (Traeholt 1997a, 1995; Gaulke *et al.* 1999), and Komodo monitors (*V. komodoensis*) (Ciofi *et al.* 2007) with no apparent adverse effect to the animal (personal correspondence with Ciofi 2011). Four LPR-3800 transmitters with custom-designed backpack mounts (Wildlife Materials, Murphysboro, IL, USA) were field tested on adult *V. salvator* on Tinjil Island in July 2011 with no noticeable unfavorable consequences to any of the subject animals. The harnesses were constructed with a biodegradable weak point to ensure that the harness would fall off automatically after a period of time if a lizard could not be recaptured. Three of the four harnesses were found after having detached from the lizards (due to failure at the designed weak point), and the remaining harness was removed at the end of the study period. All *V. salvator* captures and handling were carried out in accordance with the University of Washington Institutional Animal Care and Use Committee Protocol #3143-04. We will deploy a minimum of 20 radiotelemetric harnesses throughout the course of the proposed research.

Once released, each animal will be tracked on foot with a TRX-48S receiver and three-element folding yagi directional antenna (Wildlife Materials, Murphysboro, IL, USA). As *V. salvator* are diurnal, tracking will take place between 0600h and 1800h each day, with the goal of locating each individual at least two times per day. A Garmin eTrex Vista HCx handheld GPS unit will be used to record the position of each animal each time it is located via radiotelemetry. If an animal is active, the observer will wait for it to depart the initial area of activity before recording the exact coordinates of the location where it was first observed. If an animal is basking or sleeping, the observer will record a point as close to the individual as possible without inducing a change in its behavior. Tinjil Island's *V. salvator* appear undisturbed when approached as close as 2 m when resting or sleeping (e.g., in leaf litter or a tree buttress), with active animals typically exhibiting a flight distance of 2 m to 3 m in the base camp area and 8 m to 10 m in areas outside of the base camp area (Uyeda, personal observation). Researchers will maintain distances greater than these when engaged in tracking to avoid influencing *V. salvator* behavior. Tracking will take place across both wet and dry seasons.

Home range estimates will be determined by calculating 95% and 99% use distributions from each instrumented animal. This will be accomplished by utilizing an ArcGIS 10 (ESRI 2011) polygon tool in the Hawth's Tools extension (Beyer 2004). A fixed-kernel home range estimate (Utilization Distribution or UD) will be created using the Kernel Density Estimator in Hawth's Tools. The UD 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. Distribution density estimates can either be converted in to probability contours, or as a three-dimensional "map" with a chosen percent use distribution.

For each UD, a smoothing factor, or bandwidth, must be selected, determining the amount of smoothing that will be applied to the data. There are several choices of bandwidth selection techniques used to calculate the UD, and the size and shape of the resulting three-dimensional home range estimates will vary depending on the method selected (Kernohan *et al.* 2001, Kertson and Marzluff 2010). The least squares cross-validation (LSCV) selection method (Millspaugh *et al.* 2006), has been used by Ciofi *et al.* (2007) in studying *V. komodoensis*. Thus, we propose to use this method for the purposes of our study. However, 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 may be the case with animals with core areas around the base camp. For this reason, the use of alternative bandwidth selection methods such as the plug-in or reference techniques (Kernohan *et al.* 2001, Kertson and Marzluff 2010) may also be considered when carrying out the final analysis.

For each kernel method, home range estimation will continue to improve as the total number of location data points, or "fixes", increases up to some threshold; each method requires a minimum number of fixes before the cumulative home-range size will reach an asymptote. If an asymptote is not attained, the area studied can only be considered representative of a portion of the animal's true home range. For the LSCV method, a minimum sample size of 30 (with a preference of 50) fixes has been recommended for estimating home range sizes; the asymptote typically reached at around 90 to 100 fixes (Seaman *et al.* 1999). Animals will be radio-tracked with the goal of obtaining a minimum of 30 fixes per animal per season.

The UD will be combined with landscape metrics to produce a Resource Utilization Function (RUF) depicting intensity of resource use across each instrumented individual's range. Developing a RUF requires the selection of landscape metrics to use as predictor variables in a multiple regression.

Currently, as there are no resource data available for Tinjil Island, we plan to map key features to develop landscape metrics for the purpose of resource analysis. This effort will involve mapping the size and position of landscape characteristics hypothesized to be strong predictors of *V. salvator* use, such as fresh water, trails, areas of food supplementation, and presence or absence of forest throughout the island. In carrying out the RUF analysis, we propose the following continuous variables: distance to (fresh) water, distance to trail, and distance to high food supplementation (defined as an area where food is left on a daily basis). The presence of forest will also be documented as a discrete variable. RUFs will be used to calculate mean resource use coefficients for all radio-telemetered *V. salvator*, with 95% confidence intervals calculated to identify landscape metrics that are significantly positively or negatively correlated with *V. salvator* activity. Differences in individual use and data from wet vs. dry seasons will also be examined.

Application of Results

The proposed research will provide additional insight into the influence of human presence, food supplementation, and seasonal hydrology on *V. salvator* habitat use. The use of telemetry data to produce home range estimates will also add to widely varying reports of *V. salvator* home ranges: from 1.4 ha to 31.7 ha based on radiotelemetry data from Tulai Island Malaysia (Traeholt 1997c), 20 ha to120 ha (De Lisle 1996), to >150 ha for an individual *V. salvator* living in the Ujung Kulon Nature Reserve in West Java, Indonesia (Vogel 1979 *in* Gaulke *et al*. 1999). As differences in reported home range sizes may be due to varying data collection methods or differences between space use in island and mainland populations across *V. salvator*'s large geographic range, documentation of methodology and data produced through our research may provide a valuable contribution towards understanding discrepancies in recorded *V. salvator* ranges. To build upon previous efforts, the analysis of resource data to identify key resources as predictors of *V. salvator* habitat use will add an additional layer of understanding in the study of this species.

With Tinjil Island's total area of 600 ha it is probable that adult *V. salvator* do not range across the entire island and instead choose to occupy distinct core areas, with some individuals concentrating in human disturbed areas, and others occupying areas without human presence. If the results of our research indicate that *V. salvator* do in fact adjust habitat use seasonally and in response to human-provided resources, then our study should aid in predicting future impacts of *V. salvator* habitat disturbance on *V. salvator* behavior. Greater understanding of *V. salvator* resource use will also aid in assessing the potential for conflict between *V. salvator* and humans as urbanization and human development continues throughout the species' range.

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