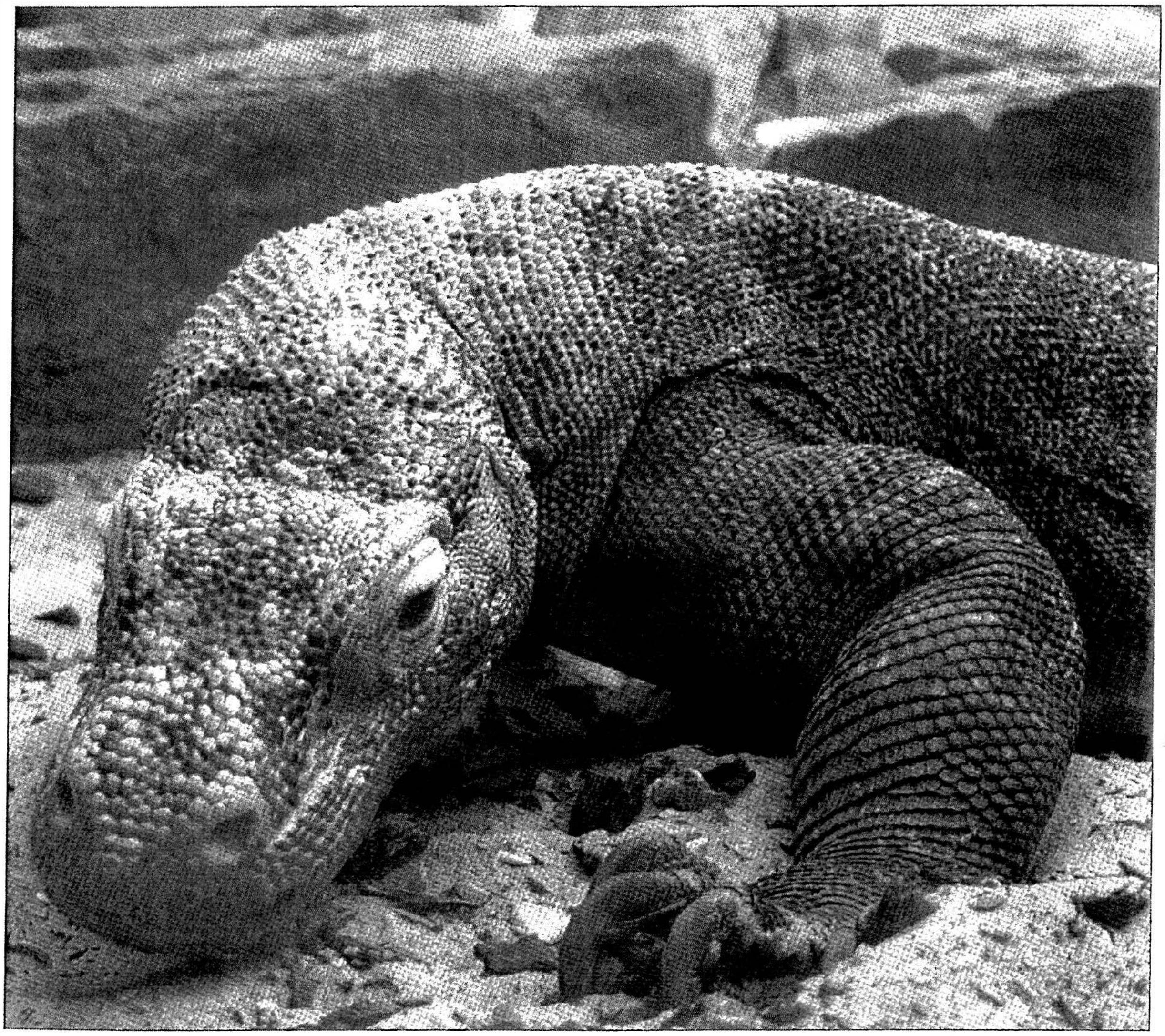
Volume 14, Number 2

April 2004

ISSN 0268-0130

THE HERPETOLOGICAL JOURNAL



Published by the
BRITISH HERPETOLOGICAL SOCIETY

Indexed in
Current Contents

HERPETOLOGICAL JOURNAL, Vol. 14, pp. 99-107 (2004)

DISTRIBUTION AND CONSERVATION OF THE KOMODO MONITOR (*VARANUS KOMODOENSIS*)

CLAUDIO CIOFI[1,2] AND MURIEL E. DE BOER[3]

[1]*Department of Ecology and Evolutionary Biology, Yale University, New Haven, Connecticut 06520, USA*

[2]*Institute of Zoology, Zoological Society of London, Regent's Park, London NW1 4RY, UK*

[3]*Department of Animal Ecology, Institute of Ecological Science, Free University, Amsterdam, The Netherlands*

Information on population size and distribution of the Komodo monitor (*Varanus komodoensis*) has so far been restricted to early reports or to surveys conducted on only part of the species' range. We carried out a study based on transects through sampling plots and single-catch trapping events to assess the extent to which the distribution of *V. komodoensis* has changed since the last comprehensive survey was conducted, in 1971. We also report on the status of the habitat and identify conservation priorities. Resident Komodo monitor populations are now found on only four islands in Komodo National Park and on the island of Flores in south-east Indonesia. Average population density estimates recorded on Flores were more than 60% lower than those reported for Komodo National Park. Habitat fragmentation and poaching of prey species currently represent the main threats to the Komodo monitor, and protection of monsoon forest in west and north Flores is crucial for the long-term conservation of the species.

Key words: geographical distribution, lizard conservation, population density estimates, Varanid

INTRODUCTION

The Komodo monitor (*Varanus komodoensis*) has long captured the interest of ecologists and evolutionary biologists for having one of the narrowest naturally occurring ranges of all large terrestrial predators. Since its first description (Ouwens, 1912), this species of monitor lizard has been reported from six islands in the Lesser Sunda region, Indonesia (Auffenberg, 1981), and no fossil records have been found so far that can provide evidence of a larger distribution in the past.

After a number of preliminary surveys conducted on a few islands (e.g. Horst, 1926; Burden, 1928; De Jong, 1937; Pfeffer, 1959), between 1969 and 1972 Auffenberg (1981) provided the first detailed – although not comprehensive – account on the extent of the species' range. The Komodo monitor was recorded on the islands of Komodo, Rinca, Padar, Gili Motang, Gili Dasami and Flores (Fig. 1). However, Auffenberg did not report estimates of population size nor conduct an exhaustive search throughout the island of Flores.

In 1980, five islands (not including Flores) became part of Komodo National Park, while later legislation established two nature reserves within the Komodo monitor range on Flores: the Wae Wuul reserve on the west coast and the Wolo Tado reserve on the north coast. According to estimates conducted in 2001 by the Indonesian Department of Forest Protection and Nature Conservation (Perlingdungan Hutan dan Konservasi Alam – PHKA) the islands of Komodo (340 km^2) and Rinca (210 km^2) contain populations of approximately 1,150 and 1,110 Komodo monitors, respectively. PHKA obtained these estimates by counting animals observed in a number of baited areas of known size and then extrapolating the counts to the size of each island. Surveys conducted in 1991 by PHKA on Gili Motang counted 106 individuals. This figure, however, was based on an overestimate of the island size. Gili Motang is about 10 km^2 (Pet & Yeager, 2000) and since four animals were counted during that survey over an area of 125 ha (PHKA, personal communication), the actual estimate would give a population of 32 lizards. Using the same method, 66 animals were estimated in 1991 by PHKA in the Wae Wuul reserve (about 30 km^2). Estimates of population size are not available for Gili Dasami and Padar, and the distribution of the species on Flores has never been monitored since Auffenberg last visited this island in 1971.

In this study, we conducted a survey on Padar, Gili Dasami and Flores, compared our data to previous information given by Auffenberg (1981), and assessed the extent to which the Komodo monitor distribution has changed in the last three decades. We carried out transects and set up baiting stations on sampling plots to assess the presence or absence of monitor lizards, and provided an example of how preliminary information on reptile population densities can be obtained when only data based on single-catch trapping events are available (Lancia *et al.*, 1996). We also report on the status of the habitat within the former and present range of the species on Flores, and identify conservation priorities.

MATERIALS AND METHODS

NATURAL HISTORY

Varanus komodoensis occurs principally from sea level up to 800 m in altitude, mainly in tropical dry and moist deciduous monsoon forest and savannah. It is a carnivorous lizard which both actively seeks or am-

Correspondence: C. Ciofi, Department of Animal Biology and Genetics, University of Florence, Via Romana 17, 50125, Florence, Italy. *E-mail*: claudio.ciofi@unifi.it

bushes its prey, and eats carrion. Information on the life history of the species is provided in Auffenberg (1981) and Murphy *et al.* (2002). The Komodo monitor has faced some major human-related pressures in the past 20 years; it is now listed in Appendix I of CITES and considered "vulnerable" according to the red list of threatened animals of IUCN.

STUDY AREA

The study was conducted during three two-month sessions in 1997, 1998 and 2000 on the islands of Padar, Gili Dasami and Flores. On Flores, we surveyed about 110 km of coast, in the western and northern part of the island (Fig. 1), covering the range of *V. komodoensis* formerly described by Auffenberg (1981).

Padar is about 20 km². Savannah is the dominant biome. Narrow strips of dry deciduous monsoon forest occur along a few seasonal water streams and on the south-west and north-east coast, on flat terrain by the seashore. There are no human settlements. The island of Gili Dasami covers an area of about 10 km² and has a round elongated shape roughly centred on a hill of about 350 m of altitude. It is mainly covered by dry deciduous monsoon forest. Gili Dasami is also uninhabited. Flores has an area of 13 540 km² and harbours a population of about 1.5 million inhabitats. Main habitat types in the study area, from the south-western to the northern coast of the island are savanna, small patches of thorn forest, and dry and moist deciduous monsoon forest, with different degrees of occurrence depending on the location, distance from the seashore, altitude and degree of human disturbance. The study sites included the nature reserves of Wae Wuul and Wolo Tado.

SURVEY TECHNIQUES

We carried out linear transects and transects on rectangular plots of different sizes, and set up baited box traps (300 × 50 × 50 cm) with vertically-sliding doors (see Ciofi [1999] for further details) to assess for presence of Komodo monitors on the island of Padar. Transects were conducted on two plots of approximately 500 × 2000 m and 500 × 1500 m, respectively,

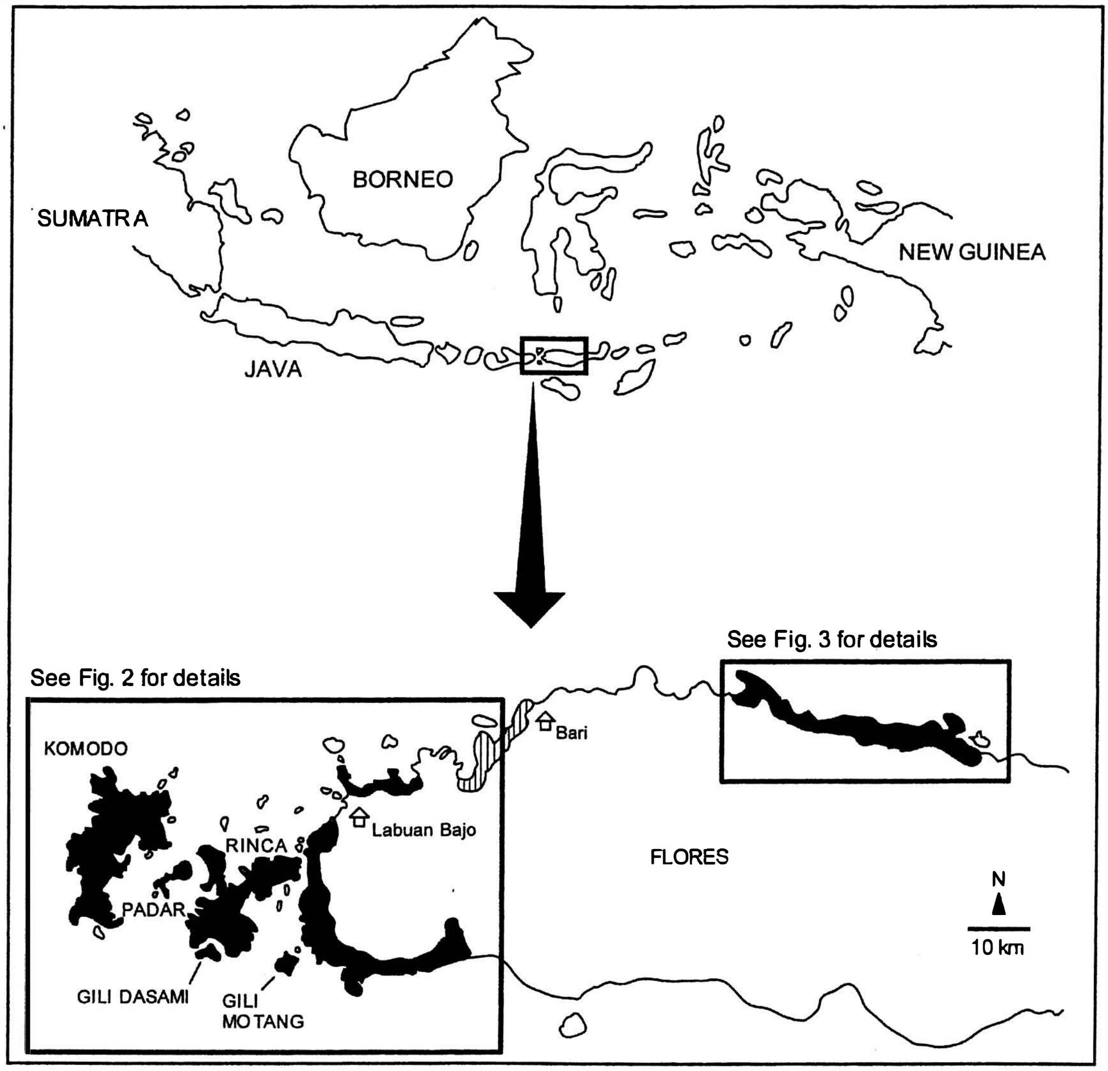


FIG. 1. Known distribution of the Komodo monitor *Varanus komodoensis*. Grey areas show current range. Black regions are sites described as part of the species' distribution by Auffenberg (1981) where no evidence of Komodo monitors was recorded during this study. Previous reports on additional sites in which Komodo monitors may be found (hatched areas) need to be substantiated.

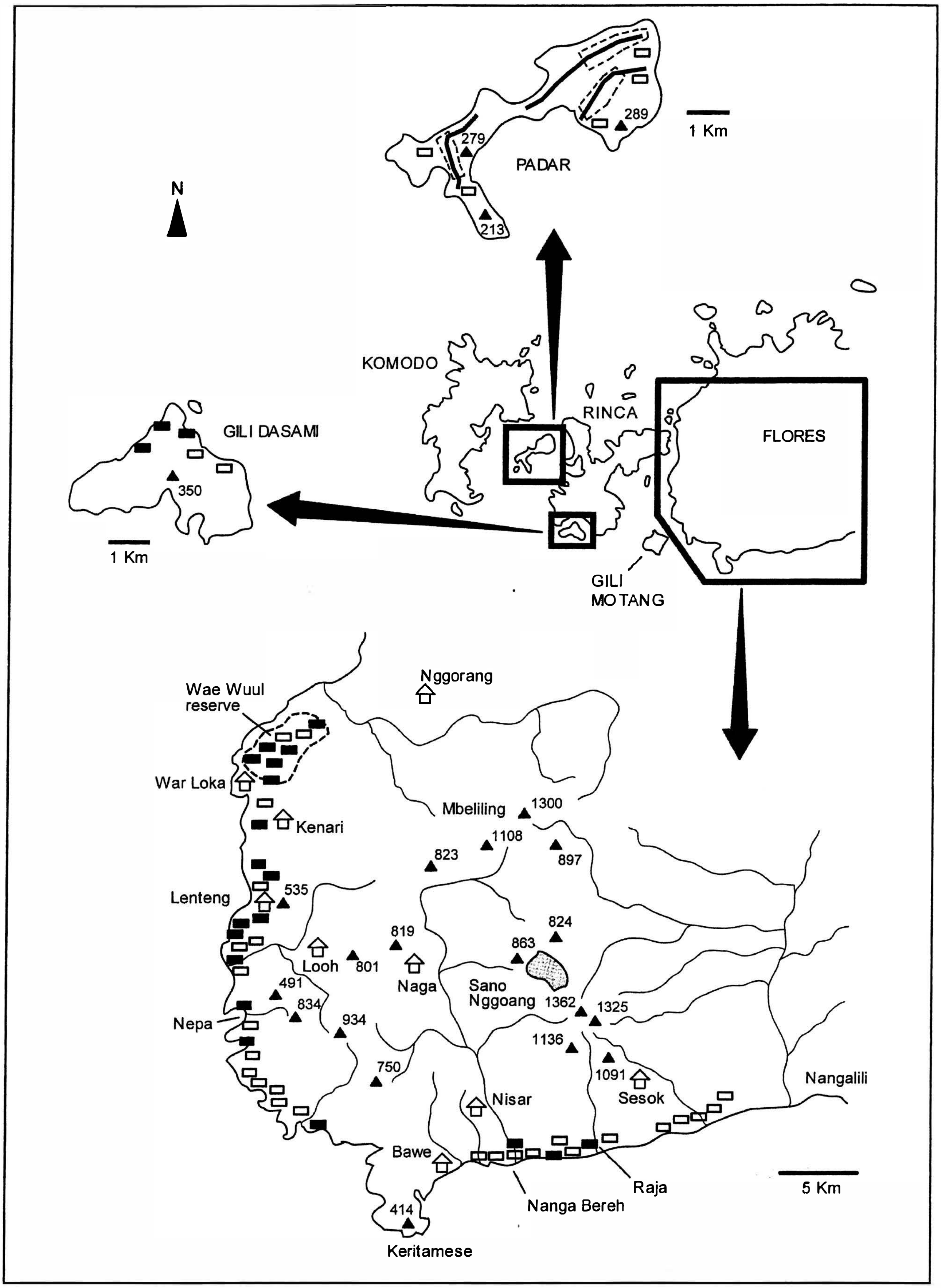


FIG. 2. Distribution of *V. komodonesis* on Padar, Gili Dasami and West Flores. Black rectangles are baited traps where at least one specimen was captured. Empty rectangles represent baiting stations where no Komodo monitors were trapped. Polygons on Padar represent transects on sample plots; heavy lines are trails used for linear transects. On Flores, heavy lines are rivers, grey areas are lakes. Elevations are reported in metres.

on the north of Padar, and on one plot of about 400 × 800 m in the south, covering an area of 2.07 km^2, equal to about 10% of the total size of the island. Plots included savannah and monsoon forest. Two transects using 10 beaters and three observers were conducted for each plot at an interval of approximately 10 days. Linear transects partially overlapped with rectangular plots; they were carried out by a single observer every third day for a period of one month. A maximum observation distance can be established in linear transect. However, animals can also be counted regardless of their location with respect to the transect line (Lancia *et al.*, 1996). We adopted the latter design. The number of investigators required by each of the two methods entailed different levels of logistic difficulties and determined the different number of surveys conducted for each type of transect. Baiting stations were set on the southern and northern parts of the island (Fig. 2).

On Gili Dasami and on Flores, tree foliage and forest undergrowth interfered with the view of the study area, and rendered surveys by transects unsuitable to assess the distribution of the species. Therefore, only baited traps were used to assess the presence and population density of the Komodo monitor on these islands. We set up five baited traps on the north of Gili Dasami. On Flores, 10 traps were used in each of five approximately contiguous plots on the west coast, and in four plots on the north coast (Fig. 2 and Fig. 3). Traps were set at distance of between 600 m and 1 km from each other, depending on the terrain, in grassland, savannah and dry deciduous monsoon forest. We used meat as bait. In each plot, traps were kept open for up to six days in order to provide enough scent and sufficient time for the animal to locate the baiting station. We defined this period as a trapping session.

Baiting stations were checked once a day and positioned in shaded areas in order to avoid overheating of trapped individuals. Weight was recorded by hanging the cage, with the animal inside, from a spring balance and later subtracting the weight of the trap from the total measure. Sliding doors were then used to restrain the lizard in the trap so that measures of snout-vent length and total length could be taken. Young individuals were handled outside of the cage. Specimens were marked with paint for short-term identification so that double counts could be avoided. This technique was used in previous field studies (e.g. Ciofi & Bruford, 1999) and no injuries due to handling procedures were recorded in any instance.

DATA ANALYSIS

Transects were designed according to standard methods based on total counts on sample plots (e.g. Lancia *et al.*, 1996). However, analysis of data was not performed as our survey found no evidence of monitor lizards on Padar (see Results).

The survey on Gili Dasami and Flores was based on single-catch trapping events. This method can often provide information on animal density when time and logistical constraints do not allow implementation of surveys, such as mark-recapture, based on data collection over multiple time periods (Lancia *et al.*, 1996). In our survey, traps were set at approximately equal distances over an area that was divided into sampling units of equal size (Fig. 4), each with a trap located at its centre. The proportion (p) of sampling units that contains at least one animal is a frequency index which can be related to abundance or density of individuals in the study area (Seber, 1982). We considered the study sites (Gili Dasami, West and North Flores) subdivided into S adjacent sampling units each of area a. According to Cochran (1963), if n sampling units from a sample of s units contain animals, then $p=n/s$ can be considered an unbiased estimate of p. If animals are randomly distributed, the number of individuals in the sampling unit follows a Poisson distribution, and the frequency index can be converted into an estimate of the absolute population density D (Seber, 1982). However, we assumed that the different ecotypes and altitudes found on coastal Flores were likely to affect both directly and indirectly

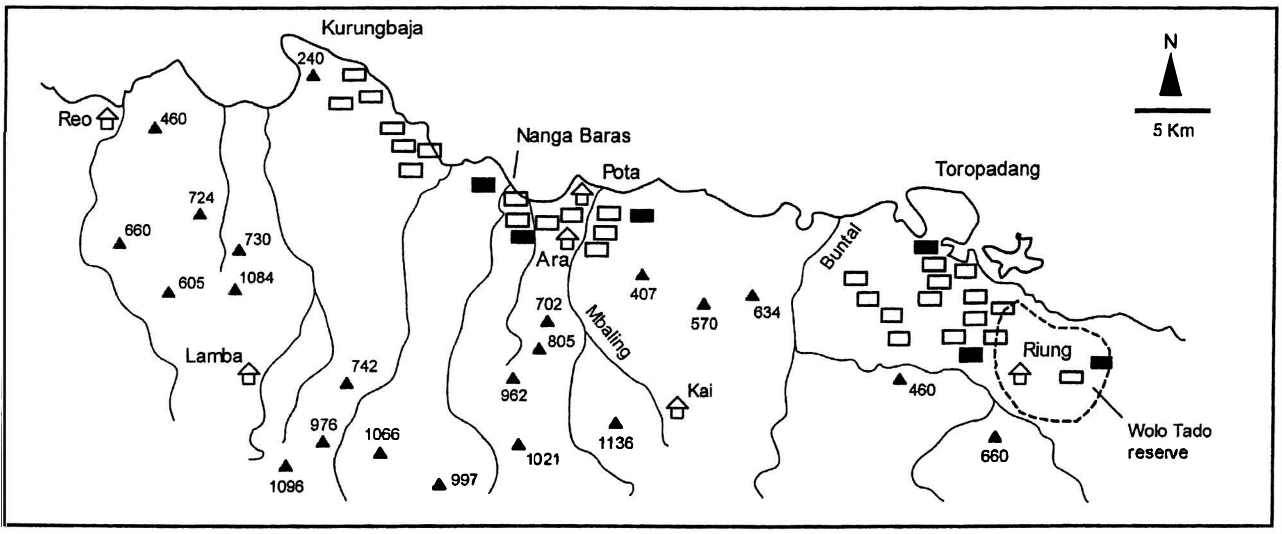


FIG. 3. Distribution of *V. komodonesis* on North Flores. Legend as in Fig. 2.

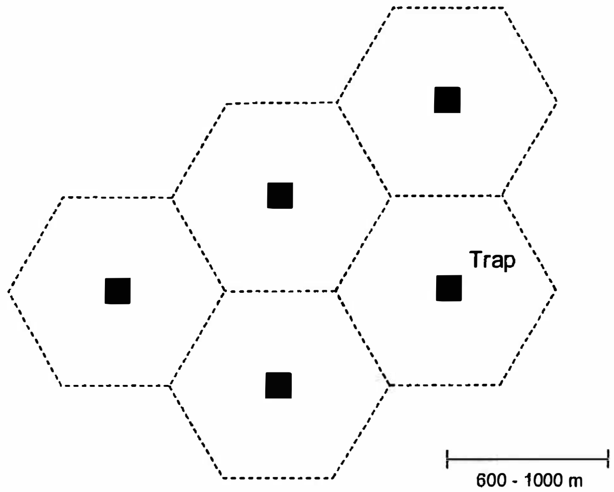


FIG. 4. Example of hexagonal sampling units used to position baited traps during the survey on Gili Dasami and Flores (see text for further details).

(for instance, through different availability of main prey species) the distribution of *V. komodoensis* in the study areas. We therefore considered a pattern of non-random distribution of the species. In this case, the size of the sampling unit should be reduced until the probability that the unit contains more than one individual is very small (Cochran, 1963). A trapping event would then correspond to the presence of roughly one individual in the sampling unit. Considering the ability of Komodo monitors to locate carcasses at distances of up to 10 km (Auffenberg, 1981), we regarded the space between baiting stations as a conservative figure for a trapping design

TABLE 1. Estimates of Komodo monitor population density for Komodo National Park and Flores. Refer to Fig. 2 and Fig. 3 for location of study sites. [a] Indonesian Department of Forest Protection and Nature Conservation. [b] Not available.

Location	Area size (ha)	Population density	Source
Komodo	34 000	1 lizard / 30 ha	PHKA[a]
Rinca	21 000	1 lizard / 19 ha	PHKA[a]
Gili Motang	1000	1 lizard / 32 ha	PHKA[a]
Gili Dasami	700	1 lizard / 52 ha	This study
West Flores			
Raja-Bawe	na[b]	1 lizard / 141 ha	This study
Keritamese-Nepa	na[b]	1 lizard / 141 ha	This study
Nepa-Lenteng	na[b]	1 lizard / 71 ha	This study
Wae Wuul	3000	1 lizard / 60 ha	This study
North Flores			
Nanga Baras-Pota	na[b]	1 lizard / 141 ha	This study
Toropadang	na[b]	1 lizard / 424 ha	This study
Wolo Tado	4000	1 lizard / 212 ha	This study

to conform to the above assumption. The unbiased estimate of the frequency index p was then calculated as $\hat{p}\approx\hat{D}a$ (Seber, 1982), and the population density by $\hat{D}=n/(sa)$. The unbiased estimate of the variance is given in Seber (1982).

RESULTS

PADAR AND GILI DASAMI

We found no evidence of *V. komodoensis* on the island of Padar along linear transects and transects on sample plots. During a third survey, carried out using baited traps, we found no monitor lizards either at the baiting stations set in the north or at those located in the south-western part of the island (Fig. 2). The results of these surveys strongly suggested either a very low Komodo monitor population density or – most probably – the absence of a resident population on Padar.

On Gili Dasami, we caught three individuals in one trapping session. Specimens had a mean body mass of 13.3±4.4 kg (mean±SE), SVL of 90.6±8.7 cm, and total length of 192.7±20.8 cm. The average area for each sampling unit was 31.2 ha. Considering the presence of one animal in three out of the five sampling units set on the island, we estimated an unbiased population density of about 1±0.1 individual per 52 ha.

FLORES

Population survey. On the west of Flores, 19 monitors were caught during five trapping sessions conducted from Nangalili bay to the Wae Wuul reserve (Fig. 2). Specimens had an average weight of 11.6±2.7 kg, SVL of 76.6±5.4 cm and total length of 168.7±9.3 cm. Six Komodo monitors were trapped at baiting stations set on the north coast (Fig. 3). Specimens had a mean body mass of 13.0±3.6 kg, SVL of 83.3±7.9 cm and total length of 184.5±16.0 cm. Population densities were assessed for each trapping session on sampling units of 42.4 ha calculated using an average distance between traps of about 700 m. No Komodo monitors were found between Nangalili and the river Raja, on the south-west coast, or at baiting stations set in the Kurungbaja peninsula, in northern Flores. Population density estimates for the other areas are reported in Table 1.

Habitat status. The south-west coast around Nangalili was covered mainly by livestock grazing grounds and crop plantations, while grassland and savannah dominated the coastal area as far as Bawe (Fig. 2). From this village to the north-west, through the Keritamese peninsula as far as the Wae Wuul reserve, dry deciduous monsoon forest was the predominant habitat. Cultivates and pastures extend inland from Wae Wuul along with small patches of dry deciduous monsoon forest. To the north-east of the reserve, new settlements have been established as part of the government transmigration program from inland Flores (PHKA, personal communication). We also observed evidence of arson in savannah forest along the entire west coast, from the north of the Keritamese peninsula to the Wae Wuul reserve.

According to reports collected by Auffenberg (1981) from local villagers, Komodo monitors were found along part of the coastal region north-east of the town of Labuan Bajo. Settlements now extend north of Labuan Bajo where natural habitats have been cleared for cultivation or grazing grounds. On the other hand, interviews with the local community suggest that the species may still occur in dry deciduous monsoon forest along the coast near the village of Bari (Fig. 1). However, no direct evidence of this was collected during our study.

On the north coast, wide patches of dry deciduous monsoon forest have been converted to cultivated areas from the town of Reo to Pota. Slash-and-burn agricultural plots were observed east of Nanga Baras, while cultivated areas and rice fields were common around Pota and surrounding hamlets. Dry deciduous monsoon forest, savannah and grassland covered the coast eastwards as far as Wolo Tado and Riung (Fig. 3).

DISCUSSION

According to our survey, the range of *Varanus komodoensis* as described by Auffenberg (1981) in 1971 has decreased appreciably during the last three decades both in Komodo National Park and on the island of Flores. Here, we describe the extent of such reduction and compare, when possible, estimates of population size with counts reported by previous studies. We report an example of estimation of population density using frequency indexes for a case study where logistics allowed the determination of the presence or absence of animals by single-catch trapping events only (Lancia *et al.*, 1996). Our estimates represent the first data set for the Komodo monitor populations on Flores. However, because a number of factors may have affected the rigor of our analysis, we regard our results as preliminary, but at the same time as valuable information for guiding pilot conservation initiatives.

We acknowledge, for instance, that overestimates of population density could result from trapping individuals coming from a region outside of the area where the trapping session was being conducted. However, Auffenberg (1981), describing the scavenging behaviour of the species, noticed that environmental variables affected the search pattern of lizards the greater the distance between the animal and the bait. In our study, monitor lizards were generally caught within 48 hours from the day the bait was set, suggesting that we were more probably catching monitors from nearby areas rather than animals from other regions. Underestimates of population density, on the other hand, might have resulted if more than one lizard occurred within the same sampling unit. Although the vagility of the species observed during feeding excursions (Auffenberg, 1981) suggests that an animal could easily move to a vacant trap nearby, this possibility cannot be excluded and represents a factor difficult to account for. In a few cases, we caught the same animal more than once, but success rates were limited to one lizard per trap. Also, baiting stations that did not capture any monitor lizard were found empty for the whole duration of a trapping session. Other factors, relating to the season in which our survey was carried out, could also have determined low counts. However, Auffenberg (1981) found no significant seasonal difference in the number of Komodo monitors observed per day or in habitat preference, and recorded no evidence of lizard congregation.

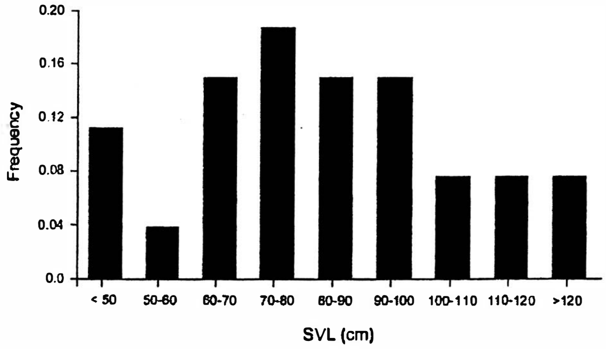


FIG. 5. Distribution of snout-vent lengths (SVL) of 28 Komodo monitors trapped during surveys on the islands of Gili Dasami and Flores.

Trap response may have varied among individuals (Lancia *et al.*, 1996), although no reports are available of differences between individuals in the motivation of a Komodo monitor to feed (Auffenberg, 1981; PHKA, personal communication). Gender-biased trapping events cannot be ruled out, but we are not able to assess this possibility yet. Unlike other species of monitor lizards (King & Green 1999), gender of *V. komodoensis* is difficult to determine in the field and a DNA test is necessary for sex determination (Halverson & Spelman, 2002). A similar type of bias could have been introduced if animals of only a certain size were trapped. However, lizards varied from 650 g to 42 kg in weight and from 34 cm to 135 cm in snout-vent length, corresponding to the body size of a juvenile and an adult individual, respectively (Auffenberg, 1981; Walsh *et al.*, 1993). It is difficult, from our data set to identify a significant bias towards a specific body size (Fig. 5).

PADAR AND GILI DASAMI

No evidence of *V. komodoensis* was recorded on Padar. In the last two decades, fires have frequently been set on this island in connection with poaching of the deer *Cervus timorensis*. Although juvenile Komodo monitors feed primarily on insects and small vertebrates, both adult and subadult individuals rely heavily on ungulates (PHKA, unpublished data). Indeed, Auffenberg (1981) found that 51% of the prey represented in faecal pellets collected on Padar was deer, and it is possible that past depletion of deer populations due to illegal hunting contributed to a significant decrease or to the disappearance of resident Komodo monitors on this island (PHKA, personal communication).

The island of Gili Dasami, where Komodo monitor population estimates have never been reported prior to this study, appears to have a lower population density than that recorded in 1991 on Gili Motang, a slightly larger island with similar topography and habitat characteristics.

FLORES

The survey conducted by Auffenberg (1981) showed that the Komodo monitor had a continuous, narrow distribution along the south-west coast of Flores, from Nangalili to Labuan Bajo. At present, Komodo monitors are still found, although with a relatively low density, along the coastal area from the river Raja to the Wae Wuul reserve (Fig. 2). Habitat changes around Labuan Bajo and Nangalili have probably caused a decrease in the species' range. We did not extend our survey to the mountain ridges of Mbeliling and Sano Nggoang. Reports from Naga and Sesok (PHKA, personal communication) confirmed the distribution described by Auffenberg (1981) in which high altitudes and moist forest habitat types would represent a main constraint to the presence of *V. komodoensis* beyond 5-6 km from the coastline.

A habitat survey carried out by the Food and Agriculture Organization of the United Nations (unpublished report) on the north of Flores, 10 years after the study of Auffenberg (1981), described a continuous forest canopy with little open grassland habitat from the town of Reo eastwards to the village of Nanga Baras. Expansion of human settlements and forest clearance have substantially reduced Komodo monitor habitats in this region. The trapping events recorded during our survey, in fact, strongly suggest that the northern distribution of the Komodo monitor has decreased, since 1971, to approximately 45 km of coastline, between Pota and the Wolo Tado reserve. Reports obtained from the villages of Kai and Riung (PHKA, personal communication) suggest that the species' range is confined to low altitudes (see Fig. 3).

Average population density values recorded on the western and northern coasts of Flores were 68% and 88% lower, respectively, than those recorded in Komodo National Park (see Table 1). Land conversion represents the main threat to Komodo monitors on this island. Forest fragmentation reduces thermoregulatory sites, diminishes the number of arboreal species that form the diet of juvenile lizards, and depletes nests located on breeding mounds of the megapode bird *Megapodius reinwardt* (Monk *et al.*, 1997). Interspecific competition, for instance with the sympatric (on Flores only) and more versatile water monitor *V. salvator*, may also increase as the forest is converted into cultivated areas. The survey conducted in 1991 by PHKA in the Wae Wuul reserve estimated a density of about one individual per 45 ha, a value approximately 25% higher than that recorded during our study. Until 1995, Wae Wuul was managed by Komodo National Park and was subject to frequent and regular patrolling. In 1996, the jurisdiction of the reserve changed and surveillance diminished due to lack of personnel (PHKA, personal communication). Since then, arson and deer poaching have intensified. According to PHKA (unpublished report) fires burn more than 3000 ha of savannah each year. Fires promote grass growth, thus providing fresh grazing ground, which in turn entices deer into the open glades where they can be better identified by poachers and pursued by dogs (PHKA, personal communication). In west Flores, deer comprised 46% of the diet of Komodo monitors (Auffenberg, 1981). It is conceivable, therefore, that the differences in population density recorded between 1991 and the present study may reflect the increased human-related pressure on both the Wae Wuul habitat and main prey species.

CONSERVATION IMPLICATIONS

In Komodo National Park, illegal deer hunting has been significantly reduced since 1996, when local authorities gained logistical and financial support from international NGOs (J. Pet personal communication). However, poaching still represents an indirect anthropogenic threat to the four island populations of *V. komodoensis*. Other factors likely to affect Komodo monitor populations within the park boundary include genetic and demographic stochasticity, particularly in small populations (Lande, 1988, 1993; Frankham, 1998). Reduced genetic variation and a low degree of gene flow to and from the other islands was recorded, for instance, on Gili Motang by Ciofi & Bruford (1999). Regional regulations are now enforced to limit illegal hunting of ungulates in Komodo National Park (PHKA, personal communication) and annual surveys of population demography, genetics and reproductive physiology are being conducted to monitor the viability of the species (Jessop *et al.* 2004; Ciofi *et al.*, unpublished data).

The results of the survey on Padar may raise questions as to whether a reintroduction (or augmentation) plan would help the conservation of the species as a whole. A higher number of island populations may, in fact, reduce extinction probabilities in the face of environmental changes by augmenting intraspecific genetic variation (e.g. Lande, 1993; Ballou *et al.*, 1995). Population genetic studies have already described different gene pools within Komodo National Park and identified possible source populations for reintroduction (Ciofi *et al.*, 1999). Several other parameters would need to be considered, however, prior to the implementation of a potential reintroduction on Padar (Dodd & Seigel, 1991; Denton *et al.*, 1997; Genet & Burrows, 1999). Forest coverage is crucial for hatchling survival and for thermoregulation, while soil characteristics are important to assess the presence of potential nesting grounds. These data can be integrated with information on thermoregulatory behaviour and physiology (Green *et al.*, 1991; Wikramanayake *et al.*, 1999) to identify suitable habitat types. Preliminary information on carrying capacity has been obtained for Padar by a recent survey on ungulate population density (C. Ciofi unpublished data), but data on smaller prey species that form the diet of juvenile Komodo monitors are not yet available. A number of demographic parameters also need attention for creating models to predict probability of population persistence (e.g. Saenz *et al.*, 2002). This would include information on reproductive cycles, recruitment and survival rates, age and size structure, sex ratio (e.g. Sarrazin & Legendre, 2000), dispersal, home range and activity patterns (Ciofi *et al.*, unpublished data). The collection of such data sets – which conform to the IUCN Species Survival Commission guidelines for reintroduction – should be part of a regular monitoring program which would assess, after translocation, whether a viable, self-sustaining population has been established.

Despite habitat encroachment, relatively wide patches of tropical dry deciduous monsoon forest are still present both on the western and northern coasts of Flores. On the west coast, this habitat represents a good candidate for a potential buffer zone to Komodo National Park, or for an extension of currently protected land. Monitoring and protection measures implemented on the northern range of the species would also allow for further representation of Komodo monitor habitat in the Indonesian network of protected areas (Trainor & Lesmana, 2000), and would significantly help the protection of extant, genetically distinct (Ciofi *et al.*, 1999) Komodo monitor populations. Monitoring programs should include regular estimates of population distribution and abundance conducted over consecutive years and different areas to infer average direction and magnitude of change of populations over time and habitat types. Although indices of population density obtained at one point in space and time can provide preliminary information on the general status of a species, other methods, based for instance on capture and recapture of marked individuals, would give more accurate estimates of animal abundance and also allow collection of demographic data. Information should also be obtained on the distribution and level of threats to the Komodo monitor in the north-west and particularly in the east of Flores. Reports from the local community suggest, in fact, that one or more small populations may still be present on the north-east coast, in the district of Maumere. A comprehensive survey of the species' distribution on Flores may provide new information that can help PHKA in setting forestry planning and conservation priorities to protect the Komodo monitor throughout its range.

Finally, the preliminary data reported in this study may serve as a base to consider a potential revaluation of the most appropriate category to describe the level of threat to *V. komodoensis*. Although it is difficult to determine the proportional reduction in the number of individuals with respect to past total population size (the first criteria defined for all three main IUCN red list categories), the total range of the Komodo monitor is most likely to be lower than 5000 km^2, extant populations are fragmented, and decline in the extent of occurrence, area of occupancy, and natural habitats has been observed. This would comply with criteria B1 of the "endangered" category (IUCN, 2001).

ACKNOWLEDGMENTS

We thank the Indonesian Department of Forest Protection and Nature Conservation (PHKA) and the Indonesian Institute of Science (LIPI) for issuing the required research permits. We also thank Komodo National Park, the PHKA branch of Ruteng, Flores (PKSDA Nusa Tenggara Timur) and Putra Sastrawan for administrative and logistical support. We sincerely appreciate the help of Earthwatch volunteers during field work. This study was supported by Earthwatch Institute, the Komodo Dragon Conservation Fund administered at the Smithsonian Institution, the Rufford Foundation (through the Whitley Award Scheme and Royal Geographical Society of London), and the Wildlife Conservation Society.

REFERENCES

Auffenberg, W. (1981). *The behavioral ecology of the Komodo monitor*. Gainesville, Florida, USA: University Presses of Florida.

Ballou, J. D., Gilpin, M. & Foose, T. J. (Eds) (1995). *Population Management for Survival and Recovery.* New York: Columbia University Press.

Burden, W. D. (1928). Observations on the habits and distributions of *Varanus komodoensis* Ouwens. *American Museum Novitates* **316**, 1-10.

Ciofi, C. (1999). The Komodo dragon. *Scientific American* **280**, 92-99.

Ciofi, C., Beaumont, M. A., Swingland, I. R. & Bruford, M. W. (1999). Genetic divergence and units for conservation in the Komodo dragon *Varanus komodoensis*. *Proceedings of the Royal Society of London B* **266**, 2269-2274.

Ciofi, C. & Bruford, M. W. (1999). Genetic structure and gene flow among Komodo dragon populations inferred by microsatellite loci analysis. *Molecular Ecology* **8**, S17-S30.

Cochran, W. G. (1963). *Sampling Techniques.* New York: John Wiley and Sons.

De Jong, J. K. (1937). Een en ander over *Varanus komodoensis* Ouwens. *Natuurwetenschappelijk Tijdschrift voor Nederlandsch Indie* **97**, 173-208.

Denton, J. S., Hitchings, S. P., Beebee, T. J. C. & Gent, A. (1997). A recovery program for the natterjack toad (*Bufo calamita*) in Britain. *Conservation Biology* **11**, 1329-1338.

Dodd, C. K. & Seigel, R. A. (1991). Relocation, repatriation, and translocation of amphibians and reptiles: are they conservation strategies that work? *Herpetologica* **47**, 336-350.

Frankham, R. (1998). Inbreeding and extinction: Island populations. *Conservation Biology* **12**, 665-675.

Genet, R. & Burrows, C. J. (1999). The ecological restoration of Otamahua/Quail Island: 1. The island's physical setting and history, and planning for ecological restoration. *New Zealand Natural Sciences* **24**, 113-125.

Green, B., King, D., Braysher, M. & Saim, A. (1991). Thermoregulation, water turnover and energetics of free-living Komodo dragons, *Varanus komodoensis*. *Comparative Biochemistry and Physiology* **99A**, 97-101.

Halverson, J. Spelman, L. H. (2002). Sex determination and its role in management. In *Komodo dragons: Biology and Conservation.* Murphy, J. B., Ciofi, C., De La Panouse, C. and Walsh, T. (Eds). Washington, DC: Smithsonian Institution Press.

Horst, O. (1926). *Varanus komodoensis. De Tropische Natuur* **15**, 118-121.

IUCN (2001). *IUCN Red List Categories and Criteria: Version 3.1.* IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK.

Jessop, T., Sumner, J., Rudiharto, H., Purwandana, D., Imansyah, M. J. & Phillips, J. A. (2004). Distribution, use and selection of nest type by Komodo dragons. *Biological Conserbation* **117**, 463-470.

King, D. & Green, B. (1999). *Goanna: the Biology of Varanid Lizards.* Melbourne, Florida: Krieger Publishing Company.

Lancia, R. A., Nichols, J. D. & Pollock, K. H. (1996). Estimating the number of animals in wildlife populations. In *Research and Management Techniques for Wildlife and Habitats*, 215-253. Bookhout, T. A. (Ed). Bethesda, Maryland, U.S.A.: The Wildlife Society.

Lande, R. (1988). Genetics and demography in biological conservation. *Science* **241**, 1455–1460.

Lande, R. (1993). Risks of population extinction from demographic and environmental stochasticity and random catastrophes. *American Naturalist* **142**, 911-927.

Monk, K. A., de Fretes, Y. & Reksodiharjo-Lilley, G. (1997). *The Ecology of Nusa Tenggara and Maluku.* Oxford, UK: Oxford University Press.

Murphy, J. B., Ciofi, C., De La Panouse, C. & Walsh, T. (Eds) (2002). *Komodo dragons: Biology and Conservation.* Washington, DC: Smithsonian Institution Press

Ouwens, P. A. (1912). On a large *Varanus* species from the island of Komodo. *Bulletin Jardin Botanic de Buitenzorg* **6**, 1-3.

Pet, J. S. & Yeager, C. (2000) *25 Year Master Plan for Management, Komodo National Park.* Jakarta: Direktorat Jenderal Perlindungan dan Konservasi Alam and The Nature Conservancy.

Pfeffer, P. (1959). Observations sur le varan de Komodo (*Varanus komodoensis*). *Terre et Vie* **106**, 195-243.

Saenz, D., Baum, K. A., Conner, R. N., Rudolph, D. C. & Costa, R. (2002). Large-scale translocation strategies for reintroducing red-cockaded woodpeckers. *Journal of Wildlife Management* **66**, 212-221.

Sarrazin, F. & Legendre, S. (2000). Demographic approach to releasing adults versus young in reintroductions. *Conservation Biology* **14**, 488-500.

Seber, G. A. F. (1982). *The Estimation of Animal Abundance and Related Parameters.* New York: Macmillian.

Trainor, C. & Lesmana, D. (2000). *Exploding volcanoes, unique birds, gigantic rats and elegant ikat: identifying sites of international biodiversity significance on Flores, Nusa Tenggara.* Rep. No. 11. PKA/Birdlife/WWF, Bogor, Indonesia.

Walsh, T., Rosscoe, R. & Birchard, G. F. (1993). Dragon tales: the history, husbandry, and breeding of Komodo monitors at the National Zoological Park. *Vivarium* **4**, 23-26.

Wikramanayake, E., Ridwan, W. & Marcellini, D. (1999). The thermal ecology of free-ranging Komodo dragons, *Varanus komodoensis*, on Komodo island, Indonesia. In *Advances in Monitor Research II - Mertensiella*, **11**, 149-156. Horn, H.-G. and Böhme, W. (Eds). Rheinbach: Deutsche Gesellschaft für Herpetologie und Terrarienkunde.

Accepted: 20.6.03