First report of introduced African Rainbow Lizard *Agama agama* (LINNAEUS, 1758) in the Cape Verde Islands

Introduced reptile species can have various negative impacts on native ones, including predation, competition for food, basking sites and other resources, hybridization and other genetic effects, spread of diseases and parasites, and poisoning through toxic skin glands or venomous bites. They may also alter the habitat of native species and disrupt ecosystem dynamics. These processes are especially dangerous if they happen on islands (BUTTERFIELD et al. 1997), where the number of endemic species is higher (WHITTAKER 1998) and ecosystems more vulnerable to introductions (SHINE et al. 2000). Unfortunately, it is on islands that this phenomenon is occurring 110 times more frequently and with a higher probability of successful establishment relative to mainland systems (KRAUS 2003). CASE & BOLGER (1991a, 1991b) examined introduction success rates for exotic reptiles (primarily lizards) on Pacific islands and found that communities with a rich reptile fauna were more resistant to invasion by exotic reptiles than communities with fewer reptile species. They also presented evidence supporting the hypothesis that predation and competition set important constraints on the distribution, colonization and abundance of lizards, predominantly on islands. Other authors confirm this theory through various case studies on islands around the globe. For example, in the West Indies, where introduced Cuban Green Anole *Anolis porcatus* GRAY, 1840 occurred, its ecological analogue, the native Hispaniolan Green Anole *Anolis chlorocyanus* DUMÉRIL & BIBRON, 1837 was uncommon or absent and vice-versa, suggesting competition occurs between the two species (POWELL et al. 1990). Similarly the anthropogenically introduced Common House Gecko *Hemidactylus frenatus* SCHLEGEL, 1936 has displaced on the Christmas Island the endemic Christmas Island Gecko *Lepidodactylus listeri* (BOULENGER, 1889) (COGGER et al. 1983). The same happened to the Polynesian gecko *Hemidactylus garnotii* DUMÉRIL & BIBRON, 1836 (CASE et al. 1994) and the native common smooth-scaled gecko *Lepidodactylus lugubris* (DUMÉRIL & BIBRON, 1836) throughout the Pacific (PETREN & CASE 1996) and to the endemic night gecko *Nactus* populations in the Mascarene Islands (COLE et al. 2005) that suffered catastrophic decline and extinct by competition. In the Aeolian Islands, on the Mediterranean, the Italian Wall Lizard *Podarcis sicula* (RAFINESQUE, 1810) has reduced the range and eradicated many populations of the native *Podarcis raffonei* (MERTENS, 1952) partly through competitive exclusion and hybridization (CAPULA 1993). In the Madeira Island, in Macaronesia, the Moorish Gecko *Tarentola mauritanica* LINNAEUS, 1758 and House Gecko *Hemidactylus mabouia* (MOREAU DE JONNÈS, 1818) were introduced a few decades ago and are spreading (BAÉZ & BISCOITO 1993; JESUS et al. 2002a); in the Azores, Madeiran Lizard *Lacerta dugesii* MILNE-EDWARDS, 1829 was also introduced recently. The Cape Verde Islands are relatively poor in reptile species diversity but very rich in endemisms (SCHLEICH 1987; CARRANZA et al. 2001; JESUS et al. 2002b; ARNOLD et al. in press). The introduction of alien house gecko species, *Hemidactylus angulatus* HALLOWELL, 1852 (FEA 1899) and *H. mabouia* (JESUS et al. 2001), is probably already causing problems in the endemic Cape Verde Leaf-toed Gecko *Hemidactylus bouvieri* BOCOURT, 1870 (ARNOLD et al. in press). Given that some endemic forms such as *H. bouvieri razoensis* GRUBER & SCHLEICH, 1982 and *Tarentola gigas* (BOCAGE, 1875) are in a delicate situation (critically endangered and endangered, respectively, SCHLEICH 1996) (MATEO et al. 1997), knowledge regarding additional introductions is vital. This note details the collection of an introduced reptile, *Agama agama* (LINNAEUS, 1758) in the Cape Verde Islands.

The specimen was collected dead on the 22 of June of 2006 nearby Porto Novo (Lagedos, N 17,0184 W 25,0561 - WGS84) in Santo Antão Island. The voucher is deposited in the collection of Centro de Investigação em Biodiversidade e Recursos Genéticos, Vairão, Portugal (CIBIO). Genomic DNA was extracted following a standard high-salt protocol. Part of the 16S rRNA gene (483 base pairs) was amplified by Polymerase Chain Reaction using the universal primers 16sA-L (light chain) and 16sB-H (heavy chain) (PALUMBI et al. 1991) and conditions described in HARRIS et al. (2007). The amplified products were sequenced on an automated sequencer (ABI 310® by Amersham Biosciences®) and then aligned with other agamas from GenBank and others collected in continental Africa (Fig. 1) as part of a separate phylogeographic study of these species (unpublished data). These new sequences were deposited on GenBank under the accession numbers: FJ159558 to FJ159562.

Morphological analysis of the voucher found in Santo Antão Island clearly indicates that it is an agamid. However due to the bad conservation status of the animal, some characters such as coloration and scale count can not be taken into account to allow identification to the species level. The results of the phylogenetic analyses indicate that it is an *Agama agama* since it is nested within this species (Fig. 2). The phylogenetic position of the sample from Cape Verde suggests it might have originated in Mali but further sampling would be needed to confirm this.

Porto Novo is a port, so it is easy to imagine an accidental introduction of this animal by cargo boats from western continental Africa, from countries situated in front of the Cape Verde islands. In fact, more introductions in the Macaronesian Islands have occurred in the last 20 years than in the entire history of the islands. Indeed the greatest danger for many endemic species results from recent introductions (PLEGUEZUELOS 2002). Reduction of entrance events of exotic species by biological control is the only way to minimize impacts since it is known that after becoming widespread, eradication becomes extremely expensive if not impossible. The Agamidae is one of the top-ten most successful introduced families in the world, with a successful establishment rate around 70% in North America (BOMFORD et al. 2005). It has been introduced in many islands systems such as in Malta (SCHEMBRI & LANFRANCO 1996) and in the Comoros (CARRETERO et al. 2005) possibly also as a result of accidental importation with cargo. In Florida, the introduced *A. agama* population is spreading (ENGE et al. 2004). After intensive sampling throughout the island in 71 sites (conducted between 5 to 27 of June of 2006) with at least 2 observers, no other agamids were found. However, locals suggested at least two specimens had been seen together in the wild. It is therefore essential both to inform local authorities of the presence of exotic species and to take actions against these introductions as quickly as possible.

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REFERENCES: ARNOLD, E. N. & VASCONCELOS, R. & HARRIS, D. J. & MATEO, J. A. & CARRANZA, S. (in press): Systematics, biogeography and evolution of the endemic *Hemidactylus* geckos (Reptilia, Squamata, Gekkonidae) of the Cape Verde Islands, based on morphology and mitochondrial and nuclear DNA sequences.- Zoologica Scripta, Oxford [Blackwell]. BAEZ, M. & BISCOITO, M. (1993): First record of *Tarentola mauritanica mauritanica* from the island of Madeira (NE Atlantic).- 1st symposium on fauna and flora of the Atlantic Islands. October 1993, Funchal, Madeira, abstract p. 7. BOMFORD, M. & KRAUS, F. & BRAYSHER, M. & WALTER, L. & BROWN, L. (2005): Risk assessment model for the import and keeping of exotic reptiles and amphibians. A report produced by the Bureau of Rural Sciences for The Department of Environment and Heritage. Commonwealth of Australia, Canberra. 110 pp. BROWN, R. P. & SUÁREZ, N. M. & PESTANO, J. (2002): The Atlas mountains as a biogeographical divide in North–West Africa: evidence from mtDNA evolution in the Agamid lizard *Agama impalearis*.- Molecular Phylogenetics and Evolution, Orlando [Academic Press]; 24: 324–332. BUTTERFIELD, B. P. & MESHAKA, W. E. JR. & GUYER, C. (1997): Non-indigenous amphibians and reptiles; pp 123–137. In: SIMBERLOFF, D. & SCHMITZ, D. C. & BROWN, T. C. (eds): Strangers in paradise: impact and management of non-indigenous species in Florida. Washington D.C. (Island Press). CAPULA, M. (1993): Natural hybridization in *Podarcis sicula* and *P. wagleriana* (Reptilia: Lacertidae).- Biochemical Systematics and Ecology, Amsterdam [Elsevier]; 21: 373-380. CARRANZA, S. & ARNOLD, E. N. & MATEO, J. A. & LÓPEZ-JURADO, L. F. (2001): Parallel gigantism and complex colonization patterns in the Cape Verde scincid lizards *Mabuya* and *Macroscincus* (Reptilia: Scincidae) revealed by mitochondrial DNA sequences.- Proceedings of the Royal Society of London; (B) 268: 1595-1603. CARRETERO, M. A. & HARRIS, D. J. & ROCHA, S. (2005): Recent observations of reptiles in the Comoro islands (Western Indian Ocean).- Herpetological Bulletin, London; 91: 19-28. CASE, T. J. & BOLGER, D. T. (1991a): The role of introduced species in shaping the abundance and

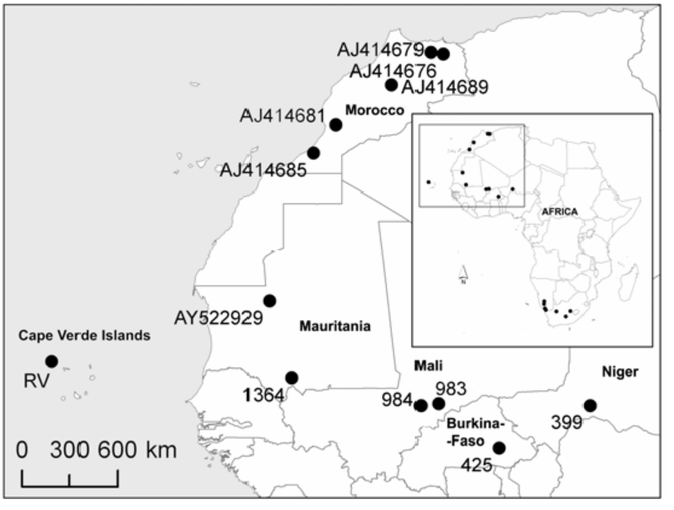

Fig. 1: Sampling localities (from this study, BROWN et al. 2002 and MATTHEE & FLEMMING 2002).

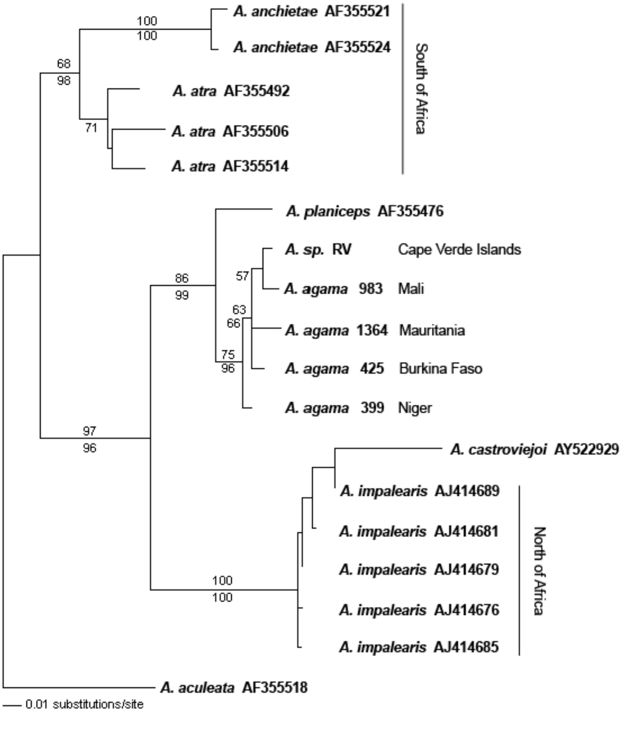

Fig. 2: Maximum Likelihood (ML) tree for the 16S sequences using GTR+γ model, following methodology of HARRIS et al. (2007). A strict consensus of 10 Maximum Parsimony (MP) trees (197 steps) differed only in being less well resolved and in that *Agama castroviejoi* was sister taxon to a monophyletic *Agama impalearis*. ML and MP bootstraps (1000 replicates) are given above and below nodes, respectively.

distribution of island reptiles.- Evolutionary Ecology, Dordrecht, London; 5: 272–290. CASE, T. J. & BOLGER, D. T. (1991b): The role of interspecific competition in the biogeography of island lizards.- Trends in Ecology and Evolution, Amsterdam [Elsevier]; 6: 135–139. CASE, T. J. & BOLGER, D. T. & PETREN, K. (1994): Invasions and competitive displacement among house geckos in the tropical Pacific.- Ecology, New York; 75: 464–477. COGGER, H. G. & SADLIER, R. A. & CAMERON, E. E. (1983): The terrestrial reptiles of Australia's island territories. Australian National Parks and Wildlife Service Special Publication, Canberra; 11: 1–80. COLE, N. C. & JONES, C. G. & HARRIS, S. (2005): The need for enemy-free space: the impact of an invasive gecko on island endemics.- Biological Conservation, Amsterdam [Elsevier], Barking; 125: 467-474. ENGE, K. M. & KRYSKO, K. L. & TALLEY, B. L. (2004): Distribution and ecology of the introduced African rainbow lizard, *Agama agama africana* (Sauria: Agamidae), in Florida.- Florida Scientist, Gainsville; 67: 303-310. FEA, L. (1899): Della isola del Capo Verde. Lettera del socio corrispondente Leonardo FEA al presidente della società, marchese G. DORIA. Queimada (Fogo), 12 Iuglio 1898.- Bolletino della Società Geografica Italiana, Genoa; 1: 7-26. HARRIS, D. J. & VASCONCELOS, R. & BRITO, J. C. (2007): Genetic variation within African spiny-tailed lizards (Agamidae: *Uromastyx*) estimated using mitochondrial DNA sequences.- Amphibia-Reptilia, Leiden [Brill]; 28: 1-6. JESUS, J. & BREHM, A. & PINHEIRO, M. & HARRIS, D. J. (2001): Relationships of *Hemidactylus* (Reptilia: Gekkonidae) from the Cape Verde Islands: what mitochondrial DNA data indicate.- Journal of Herpetology, Washington D. C., Houston; 35: 672-675. JESUS, J. & FREITAS, A. I. & BREHM, A. & HARRIS, D. J. (2002a): An introduced population of *Hemidactylus mabouia* (MOREAU DE JONNES, 1818) on Madeira island.- Herpetozoa, Wien; 15: 179–180. JESUS, J. & BREHM, A. & HARRIS, D. J. (2002b): Relationships of *Tarentola* (Reptilia: Gekkonidae) from the Cape Verde Islands estimated from DNA sequence data.- Amphibia-Reptilia, Leiden [Brill]; 23: 47-54. KRAUS, F. (2003): Invasion pathways for terrestrial vertebrates; pp. 68–92. In: CARLTON, J. & RUIZ, G. & MACK, R. (eds): Invasive species: vectors and management strategies. Washington, D. C. (Island Press). MATTHEE, C. A. & FLEMMING, A. F. (2002): Population fragmentation in the southern rock agama, *Agama atra*: more evidence for vicariance in Southern Africa.- Molecular Ecology, Oxford [Blackwell]; 11: 465-471. MATEO, J. A & GARCÍA-MÁRQUEZ, M. & LÓPEZ-JURADO, L. F. & PETHER, J. (1997): Nuevas observaciones herpetológicas en las Islas Desertas (Archipiélago de Cabo Verde).- Boletín de la Asociación Herpetológica Española, Madrid; 8: 8-10. PALUMBI, S. & MARTIN, A. & ROMANO, S. & MCMILLAN, W. & STICK, L. & GRABOWSKI, G. (1991): The simple fools guide to PCR. Version 2, Honolulu (University of Hawaii Press). PETREN, K. & CASE, T. J. (1998): Habitat structure determines competition intensity and invasion success in gecko lizards.- Proceedings of the National Academy of Sciences of the United States of America, Washington D. C.; 95: 11739-11744. PLEGUEZUELOS, J. M. (2002): Las especies introducidas de anfibios y reptiles; pp. 501-532. In: PLEGUEZUELOS, J. M. & MÁRQUEZ, R. & LIZANA, M. (Eds.): Atlas y libro rojo de los anfibios y reptiles de España. Madrid (Dirección General de Conservación de la Naturaleza – Asociación Herpetológica Española). POWELL, R. & SMITH, D. D. & PARMERLEE, J. S. JR. & TAYLOR, C. V. & JOLLEY, M. L. (1990): Range expansion by an introduced anole: *Anolis porcatus* in the Dominican Republic.- Amphibia–Reptilia, Leiden [Brill]; 11: 421–425. SCHEMBRI, P. J. & LANFRANCO, E. (1996): Introduced species in the Maltese Islands; pp. 29-54. In: BALDACCHINO, A. E. & PIZZUTO, A. (eds): Introducton of alien species of flora and fauna. Proceedings of a seminar held at Qwara, Malta, 5 March 1996, Floriana, Malta (Environment Protection Department). SCHLEICH, H. H. (1996): Lista Vermelha para os répteis (Reptilia); pp. 121–125. In: LEYENS, T. & LOBIN, W. (eds.): Primeira Lista Vermelha de Cabo Verde.- Courier Forschungsinstitut Senckenberg, Frankfurt a.M.; 193. SCHLEICH, H. H. (1987): Herpetofauna Caboverdiana.- Spixiana, München; 12: 1-75. SHINE, S. & WILLIAMS, N. & GÜNDLING, L. (2000): A guide to designing legal institutional frameworks on alien invasive species. Gland, Cambridge and Bonn (IUCN). WHITTAKER, R. J. (1998): Island biogeography – ecology, evolution and conservation. Oxford (Oxford University Press), pp. xi+285.

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