Population size, distribution and status of the remote and Critically Endangered Bawean deer *Axis kuhlii*

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Abstract Conservation of rare ungulates requires reliable population size estimates and distribution maps for prioritizing investments and assessing the effectiveness of conservation measures. We used both camera trapping and a random encounter model approach, and faecal pellet group counts, to update the range and population size of the Bawean deer *Axis kuhlii* in the Bawean Island Nature Reserve and Wildlife Sanctuary, Indonesia. We studied 2-month periods to fulfil the assumption of population closure. Both methods provided similar population density estimates (higher in the dry season) of c. 227–416 individuals. The estimated range of the species is significantly narrower than previously reported. The main threats (habitat loss as a result of illegal logging, and disturbance by dogs and hunters) are ongoing. Based on these results we suggest that the species should retain its Critically Endangered status on the IUCN Red List.

Keywords *Axis kuhlii*, Bawean deer, camera trapping, Cervidae, conservation, faecal pellet count, random encounter model

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Introduction

Reliable information on population size and range, and any trends in these parameters, is required to assess the conservation status of a species using the Red List criteria (IUCN, 2001). In the absence of such information, conservation management is often based on crude estimates, expert opinion or educated guesses, which may result in erroneous decisions that can be counter-productive (Akçakaya, 2002; Blake & Hedges, 2004; Murray et al., 2009). The Bawean deer *Axis kuhlii* (Temminck, 1836), the most isolated deer in the world and the only endemic deer species in Indonesian tropical rainforest, is categorized as Critically Endangered on the IUCN Red List (Semiadi et al., 2015). The Bawean deer is reported to range over a very small area restricted to the Bawean Island Nature Reserve and Wildlife Sanctuary and a peninsula on the north-west side of the island (Tanjung Cina; Lachenmeier & Melisch, 1996; Grubb, 2005). The protected area is relatively close to human settlements, and illegal logging is not uncommon in the forest habitat. Listed in Appendix I of CITES (2016), this taxon is legally protected and is one of 25 species prioritized for conservation by the Indonesian government on the basis of their threatened status (decree SK.180/IV-KKH/2015; Ministry of Environment and Forestry, 2015). Despite this status, and threats across its range, surprisingly little is known about the Bawean deer and no long-term monitoring has been implemented, partly because this is not a charismatic species.

Several methods have previously been used to study population trends and distribution in this species: faecal sampling (Blouch & Atmosoedirdjo, 1978; Blouch, 1980; LIPI & IPB, 1999; Semiadi, 2004; BBKSDA East Java, 2009), footprint (UGM & BBKSDA East Java, 2003) and call counts (BBKSDA East Java, 2009), and camera trap surveys (UGM & BBKSDA East Java, 2004). The latter study, in which 10 camera traps were installed at seven locations (Lang Pelem river, Lampeci river, Tambelang river, Mt Tinggi, Angsana block, Tanjung Putri block and Tanjung Cina) during 20 days, recorded no evidence of the Bawean deer, although this may be attributable to the short duration of the study and the placement of cameras in unsuitable locations.

Capture–recapture methods for estimating population size require individuals to be recognizable, either by rings or collars (e.g. Trolle et al., 2008; Oliveira-Santos et al., 2010) or by natural marks such as stripes, spots or scars (e.g. Kumbhar et al., 2013). They are not applicable to the many mammal species that lack distinctive marking, such as the Bawean deer, except when bucks are seasonally antlered.

The development of the random encounter model, a by-product of an ideal gas model (Hutchinson & Waser, 2007), has facilitated estimations of species densities from unmarked individuals with a known speed, and sensor detection parameters (Rowcliffe et al., 2008). The random encounter model has been implemented successfully for ungulate species by deploying cameras in systematic or fully randomized arrays (Rowcliffe et al., 2008; Rovero & Marshall, 2009; Zero et al., 2013; Carbajal-Borges et al., 2014).

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