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Density estimates and habitat preferences derived from camera trap rate provide the first empirically based population assessment for the Bawean warty pig (*Sus blouchi*) on Bawean island, Indonesia.

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Abstract

The Bawean warty pig (*Sus blouchi*) is an endemic confined to the 192km^2 Bawean island in the Java-sea. Due to a lack of quantitative ecological research, population assessments have so far been based solely on interviews with local inhabitants. Hunting and habitat degradation in Bawean's protected areas might have caused the species to have become very rare. From 3 November 2014 until 10 January 2015, a camera trap study was conducted on Bawean to provide the first quantitative population assessment of *Sus blouchi* and to provide sufficient data for a Red List Assessment. In total, camera traps were placed at 100 locations. These reached 669.6 camera days and captured 92 independent *Sus blouchi* videos. Camera trapping reached satisfactory precision after 500 camera days. Based on these results an estimated 233 – 466 individuals are expected to be present on the island. Activity patterns and habitat data indicate that *Sus blouchi* is mainly nocturnal and prefers semi-open cultivated areas for foraging. Based on the lower population estimate *Sus blouchi* would qualify for categorization as Endangered on the IUCN Red List, but multi-annual data on habitat degradation on Bawean is still needed to see if the species should not be listed as Critically Endangered instead.

Introduction

South-east Asia (SEA) hosts the highest wild pig (*Sus sp.*) diversity in the world. Sea level fluctuations since the early Pliocene created frequent island connections and isolations, which provided ample opportunities for speciation to occur. (Lucchini *et al.,* 2005) The exact number of species and subspecies of wild pigs in SEA remains a debated topic among taxonomist (Larson *et al.,* 2005; Cucchi *et al.,* 2009; Groves & Grubb, 2011). The IUCN currently acknowledges 9 species within the *Sus* genus, 6 of which are considered to be facing a high risk of extinction in the wild (IUCN, 2014).

Recognizing the threats faced by many of these species, the IUCN/SSC Wild Pig Specialist Group (WPSG) organized a workshop in November 2013. The aim was to develop immediate action points for improved conservation of threatened wild pig taxa in Asia. (Meijaard *et al.,* 2014) A taxon on which extensive discussion took place was the Bawean warty pig (*Sus blouchi*), an island endemic confined to Bawean in the Java sea. (Blouch, 1988; Meijaard *et al.,* 2014) Based on morphological research, the species was recently upgraded from a subspecies of the Javan warty pig (*Sus verrucosus*), to full species level. (Groves & Grubb, 2011) Both taxa are still considered subspecies and categorized as Endangered on the IUCN Red List (Semiadi *et al.,* 2008). Regardless of their exact taxonomic position, little is known about both *Sus verrucosus* taxa in general.

Given the absence of quantitative ecological research, population assessments and species descriptions for both taxa have so far been based on data obtained through interviews with local inhabitants and captive or shot individuals. (Blouch, 1988; Semiadi & Meijaard, 2004, 2006; Semiadi & Nugraha, 2009; Groves & Grubb, 2011) A Red List Assessment of *Sus blouchi* was attempted during the November 2013 workshop, but insufficient information was found to determine conservation status. (Meijaard *et al*., 2014). However, previous interview surveys on the island suggested it might have become very rare (Semiadi & Meijaard *et al*., 2004).

Camera trap research has shown to be able to estimate abundances and ecological requirements for several illusive animals, such as Tigers (*Panthera tigrus*), Leopards (*Panthera pardus*) and Mouse deer (*Maschiola indica*) (Karanth *et al.,* 2011; Maffei *et al.,* 2011; Ramesh *et al.,* 2013), while requiring relatively low labour costs (Henschel & Ray, 2003). Furthermore, the increasing availability of adequate camera traps at the mid-and low ends of the price range (Rovero *et al.,* 2013), can lower equipment costs without necessarily reducing data quality. However, two possible pitfalls in study design can limit the suitability of camera trapping methods for acquiring valid data on density and habitat preferences.

Firstly, true density estimations from camera trap data have so far relied on the ability to differentiate individuals using capture-recapture models (Karanth, 1995; Silver 2004). This is often not possible for species without distinctive markings. Secondly, the functional relationships between abundance indexes and true abundance are often based on untested assumptions, making indexes a measure of last resort in population research. (O'Brien, 2011)

The Random Encounter Model (REM) for estimating density for species with non-recognizable individuals has provided potential solutions for these pitfalls (Rowcliffe *et al.,* 2008). The density estimates based on REM were validated for the first time for wild populations in a comparative research by Rovero *et al.,* (2009). However, multiple revisions on the parameter estimates have been made since (Rowcliffe *et al*., 2011, 2014) and further developments are still in progress (Rowcliffe, personal communication).

Based on the strong linear relation between camera trap rate and density found in his comparative research, Rovero *et al.,* (2013[2]), later used camera trap rate in a null- hypothesis Generalized Linear Model (GzLM) to determine habitat preferences. However, due to the poor performance of traditional null-hypothesis significance in model selection (Stephens *et al.,* 2006; Whittingham *et al.,* 2006), the use of Information Theoretic (IT) approaches, such as the Akaike Information Criteria (AIC), are now emerging as a more reliable method in the inference of ecological patterns (Burnham & Anderson, 2001; Mazerolle, 2004; O'Hara & Tittensor, 2010).

Bearing in mind on-going developments and inherent uncertainties, we present the most up to date parameter estimators in the Random Encounter Model and an IT approach to habitat use modelling. The research goals were to provide the first quantitative estimates of *Sus blouchi* population size and habitat preferences. This information should provide sufficient quantitative ecological data for a successful Red List Assessment.

Materials and Methods

Ethics statement

Data collection used non-invasive, remotely set camera traps and did not involve contact or direct interaction with animals. Fieldwork was performed under research permit number 367/SIP/FRP/SM/X/2014 to MAR, issued by The Indonesian Ministry for Research and Technology (RISTEK). A permit to enter and work in strict nature reserves and wildlife reserves was obtained from the Office of Conservation of Natural Resources (BBKSDA), part of the Ministry of Forestry, under SIMAKSI no. SI.21/BBKSDA.JAT-2.1/2014 to MAR.

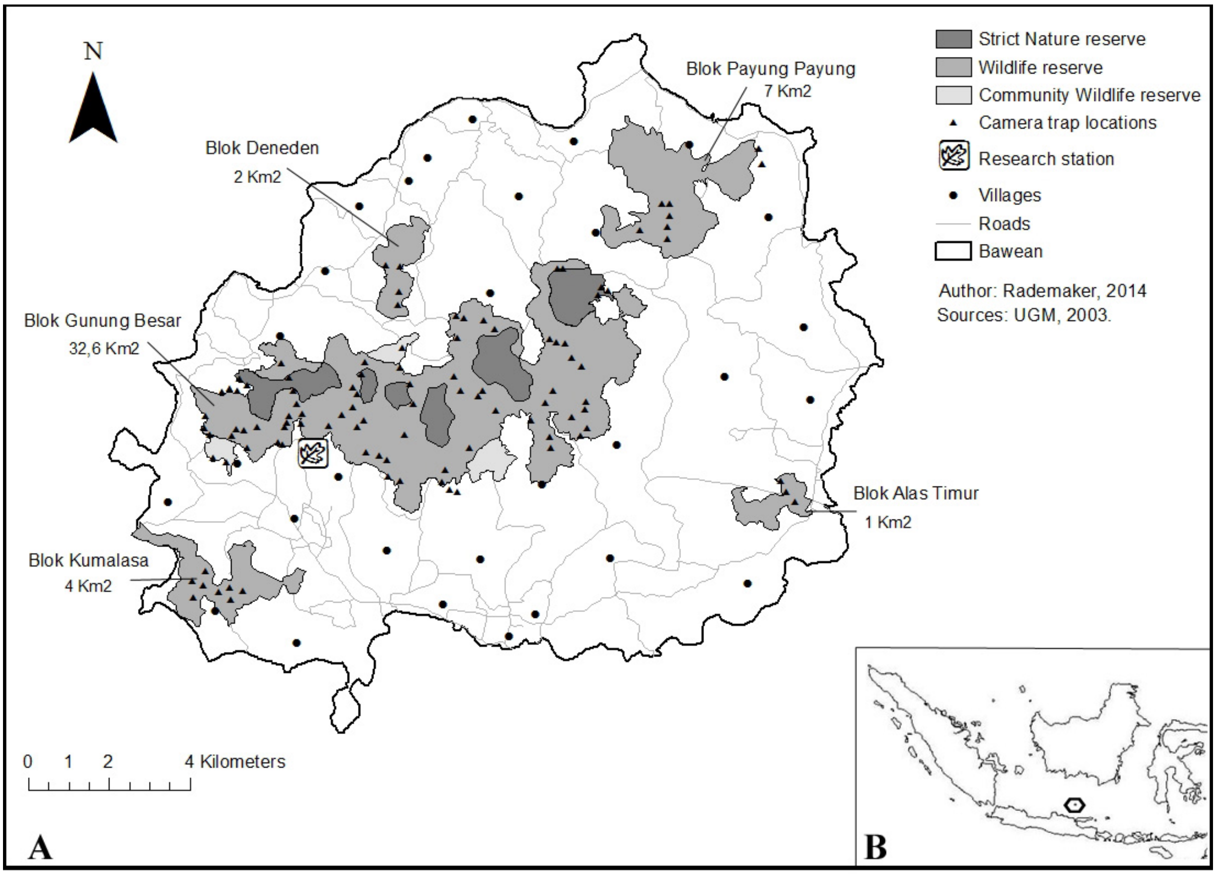

Figure 1. Map of Bawean island. (**A**) shows the zonation of the protected areas, camera traps, research station, villages and roads. (**B)** Shows the location of Bawean in the Java sea.

Study site

The 192 km^2 Bawean island (Fig 1.; S 05^{0}84'94.8'', E 112^{0}61'45.5'') is a remnant of an extinct volcanic mountain located in the Java sea approximately 120 km north of Java and 260 km south of Kalimantan. The island is covered with numerous small mountains with altitudes ranging from approximately 200 to 600m in the island's centre and from 100 to 200m towards the shore (Rademaker *et al.,* unpublished data). The highest peak is formed by Gunung Besar at 646 m (Nijman, 2006). The climate on the island is seasonal with heavy rains from December through March, and a dry season from April through November. The average temperature ranges from 22 – 28 ^{o} C and annual precipitation can be as much as 2500 mm. (Blouch, 1978; Mantra, 1998) Light alluvial clayey soils are found along the northern and southern coastal plains, whereas the soil in other parts of the island is mainly formed by materials of volcanic rock, limestone and sediments of tertiary age (Posthumus, 1929). Historically, Bawean was covered with dense forests. These were felled by the local communities, mainly to make place for the cultivation of cassava and maize. (Mantra, 1998) The remaining five forested areas were designated as protected areas in 1995 (46,6km^2). (Semiadi & Meijaard, 2013) These protected areas can be sudivided into wildlife reserves (38km^2), strict nature reserves (7km^2) and community wildlife reserves (1,6km^2). Despite these designations, small scale illegal logging and burning continue to occur due to a lack of clear area boundaries. (Nijman, 2006; Syamsi, personal communication). This study was conducted in all of the protected areas present on Bawean. A buffer of 100 meters from the outer forest edge was included into our ArcGIS base map due to the uncertainty of the official zonation as described before. Four distinct habitat types were recognized in the study area (Table 1), which largely followed the habitat descriptions from Nijman (2006).

Table 1. Distinct habitat types found at the study site after Nijman (2006).

Habitat type	Description
Community forest	Community owned forested gardens at the assumed borders of the protected areas consisting of a mixture of cultivated trees such as *Spondias pinnata*, *Artocarpus heterophyllus*, *Tectona grandis*, *Tamarindus indica, Bambussa spp.*, *Arenga pinnata* and undergrowth dominated by either shrubs or grasses.
Teak stands	Monoculture *Tectona grandis* stands inside the protected areas with an undergrowth dominated by grasses and sparse herbaceous plant and shrub cover.
Shrubland and Degraded forest	Patches inside the protected areas characterized young (DBH<30cm) trees in high density and clear signs of logging and burning. Undergrowth is either dominated by a mix of grassland and herbaceous plants, or dense shrub cover. Tree species primarily represent those found in Community forest, such as mixtures of *Bambussa spp.*, *Arenga pinnata* and *Tectona grandis*.
Tall Forest	Mature secondary or tertiary forest characterized *Ficus variegata, Ficus septica, Podocarpus rumphii,* and multiple *Eugenia* species, interspersed with dense patches of small trees.

Data collection

Camera trapping took place from November 3th 2014 until the 10^{th} of January 2015. For the estimation of density 20 Cuddeback LongRange IR/E2 camera traps were randomly deployed in five consecutive runs. An additional 3 cameras were used to sample specific habitat types extra if the random deployment did not yield enough samples for analysis. Cameras were set at 30 seconds video mode with 1 minute intervals. Camera locations were determined based on the following procedures. For Blok Gunung Besar (32,6km^2), a grid with 100 x 100m cells was superimposed over the study area using the Fishnet and Clip tools in Arcmap 10. This generated a total of 3636 potential camera locations. Afterwards 150 camera locations were randomly assigned to these points using the Random point option in Arcmap. A minimum between-point distance of 150 meters was maintained to reduce the likelihood of capturing same individual twice (Kays *et al.,* 2011). From these 150 random points, a subset of 80 points was selected for final camera placement. These locations were neared as close as possible in the field. Cameras were installed and picked up every 7 days. The Blok was sampled from east to west in a total of 4 runs. Due to terrain difficulties experienced in the first 4 runs, the areas Blok Alas Timur (1km^2), Blok Deneden (2km^2), Blok Payung Payung (7km^2) and Blok Kumalasa (4km^2) were sampled differently. The first randomly generated point was neared as close as possible. Afterwards, a camera was placed every 300 meters after the last camera. Active trails and roads were avoided in the non-randomly generated locations. This was to prevent oversampling as species might actively seek out roads and trails (Rowcliffe *et al.,* 2008). Random locations can occasionally include roads or trails, but this will only be in proportion to their actual density in the landscape. (Rowcliffe *et al,.* 2013). After installing the camera traps, a 10 x 10m plot was constructed and a habitat assessment of the location was made (Table 2). Following Rowcliffe *et al.,* (2011) we measured the angle of detection, radial distance at detection and the distance travelled for the first three *Sus blouchi* videos on each camera. These variables are required for computing the parameter estimates for the REM analysis (Rowcliffe *et al.,* 2011).

Table 2. Habitat variables measured at each camera trap location for the analysis of habitat preferences

Variable	Description and categories
Habitat type	1. Shrubland and degraded forest 2. Teak stand 3. Tall forest 4. Community forest
Tree Density	T-square (4 trees)
Altitude	In meters
Distance to nearest border	In meters
Mean litter depth in cm	Average depth in cm's in four 1m subplots in the corners of the 10 x 10m plot.
Wallow presence	1. Present 2. Absent

Data analysis

All videos collected had a date and time descriptor. To prevent capturing the same individual twice, a minimal 1 hour interval between videos with juveniles or adult females only was maintained (Rovero *et al*., 2009). Adult males could generally be distinguished by size of the warts, but where this was unclear the same rule was applied. For density estimates the camera trap rate was defined as the number of independent video events per 24 hour period. For habitat preferences camera trap rate was defined as the total number of independent videos at each plot. All statistical tests were performed in SPSS 20.0 and parameter estimates computed in Excel 2013.

Population characteristics

Standard descriptors of population characteristics such as group size and sex ratio were derived by filtering data records and using descriptive statistics with bootstrapping. Sampling precision was computed as the coefficient of variation (CV) of *Sus* blouchi camera trap rates across cumulative camera days (Rovero *et al*., 2009; Foster & Harmsen, 2011). Density estimation followed the formula from Rowcliffe *et al.,* (2008; Equation 1), with parameter estimators adjusted to be in line with later improvements to the model.

$$D = \frac{y}{t}\frac{\pi}{vr(2+\theta)} * g$$

In which D is the density. D is obtained by multiplying the number of independent observations y per unit time t, with π divided by the product of parameter estimators day range v, effective radial distance r and effective detection angle θ. The outcome can then be multiplied by group size g for group animals. (Rowcliffe *et al.,* 2008). Effective radial distance and detection angle were computed by filling in the radial distances and angle of detection for *Sus blouchi* videos in Distance (6.0, Thomas *et al.,* 2009) using a line-transect model for angle and point-transect model for distances. (Rowcliffe *et al.,* 2011) Afterwards, effective angle was multiplied by 2 and converted to radians to obtain the full field of detection. Despite the Rowcliffe *et al.,* (2011) paper stating that average speed can be measured as a geometric mean, it is now thought more likely to represent a harmonic mean. (Rowcliffe, personal communication). Parameter v should instead be filled in as the average speed while active, multiplied by the proportion of time active. The proportion of time active was obtained by using the method presented in Rowcliffe *et al.* (2014; Bolker, 2010). As camera traps might not be successful in capturing all individuals in a social group, its inclusion in the model based on the average number of individuals in all videos might still give an underrepresentation of the actual number of individuals. However, basing group size on counts at wallows alone (Passon *et al.,* 2012), can result in overestimating group size as multiple groups might migrate to the same wallow if water is scarce (Hörning *et al.,* 1999). Therefore, we included the multiplier group size based on merging the average group size from videos at wallows (N=35) and without wallows (N=92). The formula is filled in twice, once without the multiplier to provide a lower estimate of density and once with the multiplier to provide an upper estimate. The outcome densities per km^2 were extrapolated to total protected area size on Bawean to provide estimations of population size. The Standard Error (S.E.) of the density estimation was computed through the S.E.'s of each of the parameters in the formula (Urdan, 2001).

Habitat preferences

An information theoretic approach for model selection and inference based on the AICc values in GzLM's was used to determine which of the 6 habitat variables had a discernible effect on camera trap rate (Burnham & Anderson, 2002). As we detected overdispersion, a negative binomial GzLM type was chosen (Nelder & Wedderburn, 1989). A natural logarithmic transformation of camera trap hours was included as an offset variable as camera trap rate was expected to increase with increasing camera hours. Multicollinearity was checked using collinearity diagnostics with a threshold at VIF <2.5. Although sample size of camera traps at wallows was too small to be included into the GzLM (N=4), wallows may have important social and thermoregulatory functions in pig communities (McGlone, 1999; Graves, 1984; Bracke, 2011). Therefore, we analysed its potential relationship separately using a Kruskall-Wallis One-way Anova. We ran multiple GzLM's covering all combinations for the remaining 5 habitat variable with a minimum of two variables in each model (N=26). To prevent bias from too few variables being present in the model we maintained a minimum of two variables in each model (Burnham & Anderson, 2002). There were a total of 4 competing models for the first ranking model (i.e. Delta AICc <2; Table 3). Therefore, instead of relying on the estimates of the best model (i.e. lowest AICc value) we computed a weighted average of the estimates for each variable across all the models in which that given variable was included. Following Grueber *et al.,* (2011), more complex models i.e. containing more variables, with a lower AICc value than less complex models with the same set of variables were excluded from the weighted average. A discernible effect was obtained if the confidence intervals for the weighted averages excluded 0. (Mazerolle, 2004)

Table 3. Top Models included in the computation of weighted average estimates for each variable. AIC value represents the amount of information lost when approximating true values of a given parameter. Akaike weights can be seen as the probability that a given model has the best fit for another set of data drawn from the same underlying process. (Mazerole, 2004; O'Hara & Tittensor, 2010).

Model ID	Habitat type	Tree density	Altitude	Distance to nearest border	Litter depth	No. of parameters	AICc	Delta AICc	Akaike weight
1	•	•		•		6	239.5	0	0.3220
2	•			•		5	239.8	0.3	0.2761
3		•		•		2	240.1	0.6	0.2365
4		•		•	•	3	240.5	1.0	0.1953
5	•	•				5	242.1	2.7	0.0838
6	•				•	5	242.2	2.7	0.0832
7				•	•	2	242.4	3.0	0.0728
8			•	•		2	242.7	3.3	0.0627
9	•		•			2	242.8	3.4	0.0598
10		•			•	2	248.8	9.4	0.0030
11		•	•			2	249.4	9.9	0.0022
12			•		•	2	249.8	10.3	0.0019

Results

Population estimation

The total number of camera days reached 669.6 with 92 independent video events. Overall we obtained one or multiple *Sus blouchi* videos at 45 of the 105 sampled locations. Camera trap precision increased considerably untill a trapping effort of approximately 500 camera days was reached (Fig. 2). A mean camera trap rate of 0.12 (*SD* ± 0.20) was observed with a total of 162 individuals recorded.

Adult female to adult male sex ratio amounted to 2:1 (N. adult females= 67, N. adult males= 35, N. Juveniles= 30, N. unknown= 30) and mean group size in videos was 2.18 (Wallow presence Mean= 2.60 *SD* ± 1.35; No wallow presence Mean= 1.76 *SD* ± 1.36). The proportion of time spent active per day was found to be 0.47 with high proportions of observations during the night and peaks in the early morning and late afternoon (Fig. 3). Based on the included parameter estimates (Table 4) in the REM, a lower and upper density estimate of 5 (S.E.=19%) and 10 (S.E.= 9%) individuals per km^2 was obtained. This, if extrapolated to total area size, amounts to an estimated population size of 233 to 466 individuals for Bawean, assuming that no pigs are permanently resident outside of the protected areas.

Table 4. Parameter estimates for *Sus blouchi* included in the REM.

Parameter estimates	**Value**	**S.E.**	**N. videos**
Trap rate (*y/t*)	0.1374	0.0338	92
Day range (*v,* km day)	9.7802	3.7170	57
Radial distance (*r*, km)	0.0039	0.0003	63
Angle (radians, θ)	0.3920	0.0330	62
Group size (*g*)	2.18		57

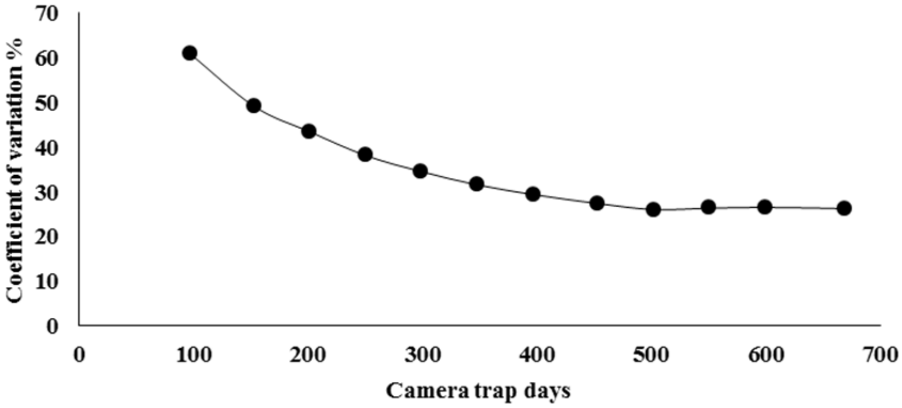

Figure 2. Camera trapping sampling precision for *Sus blouchi*. Sampling precision was expressed as CV of *Sus blouchi* camera trap rate with cumulative sampling effort (number of camera trap days) in the protected areas

Habitat preferences

Based on the confidence intervals computed from the weighted averages of the habitat variables, two were found to have a discernible effect on camera trap rate (Fig. 4.a,b). Camera trap rate was higher in community forest compared to shrubland and degraded forest (-0.133, -3.129) and tall forest (-0.136, -2.094), but no effect was observed when compared to teak stands (0.031, -3.015). Next to this, camera trap rate was discernibly lower with increasing distance to the nearest border (-0.125, -1.175). Tree density (1.626, -0.189), altitude (1.577, -1.494) and litter depth (0.868, -2.660) were not found to possess an effect. Camera trap rate was significanlty higher at locations that had a wallow than locations were no wallow was present (Kruskal-Wallis, *d.f.*=1, *H*= 11.262, *p*= 0.001), indicating a potential effect.

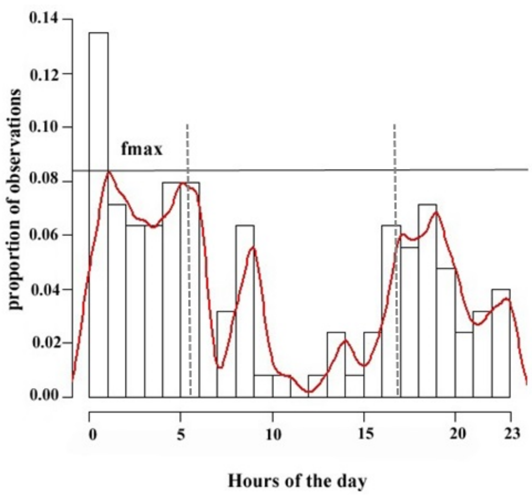

Figure 3. Proportion of observations per time of day spent active fitted with a line function using bbmle package (Bolker, 2010) to determine proportion of time spent active. Dashed lines indicate sunrise and sunset at approximately 05.30 and 17.50 year-round.

Discussion

Population characteristics

The minimum number of 50 independent observations required for REM analysis suggested by Rowcliffe in Rovero *et al.,* (2013[1]), was reached after 343 camera days. However the CV of camera trap rate only started to level off after 500 camera days. This indicates that a higher number of camera days may be required for a reliable density estimate than what is required for obtaining the minimum number of observations alone.

The male to female sex ratio in wild suidae varies across species. Wild boar (*Sus scrofa*) and Bush pigs (*Potamochoerus porcus*) both have a sex ratio close to 1:1 (Massei *et al.,* 1997; Seydack & Bigalke, 1992). The 1:2 ratio found in this study for *Sus blouchi* has been observed in Forest hogs (*Hylochoerus meinertzhageni*) (d'Huart, 1993) and a ratio of 1:1.7 was observed in the Sulawesi warty pig (*Sus celebensis*) (MacDonald, 1993). The proportion of time spent active per day by *Sus blouchi* (47%) is high compared to activity levels obtained from other medium sized tropical animals using the same method (Rowcliffe *et al.,* 2014). In the concerning camera trap study of neo-tropical animals in a largely undisturbed rainforest, a general range of 30-40% of time spent active per day was found. The only representative of the new world pig species in the study, the collared peccary (*Tayassu tajacu*), spent 38% of the time per day active with a sharp crepuscular activity pattern. We found a mainly nocturnal activity pattern for *Sus blouchi* with peaks in the early morning and late afternoon. A similar activity pattern has been observed in feral pigs (*Sus scrofa domesticus*) in tropical forest (Caley, 1997). In a general review of wild pig species by the WPSG (Oliver *et al.*, 1993), activity patterns of wild suidae are viewed to be naturally crepescular, with hunting pressure as the main drivers forcing wild pigs into a nocturnal activity pattern. Our findings and the peccary activity levels in an habitat free of hunting seem to support this view.

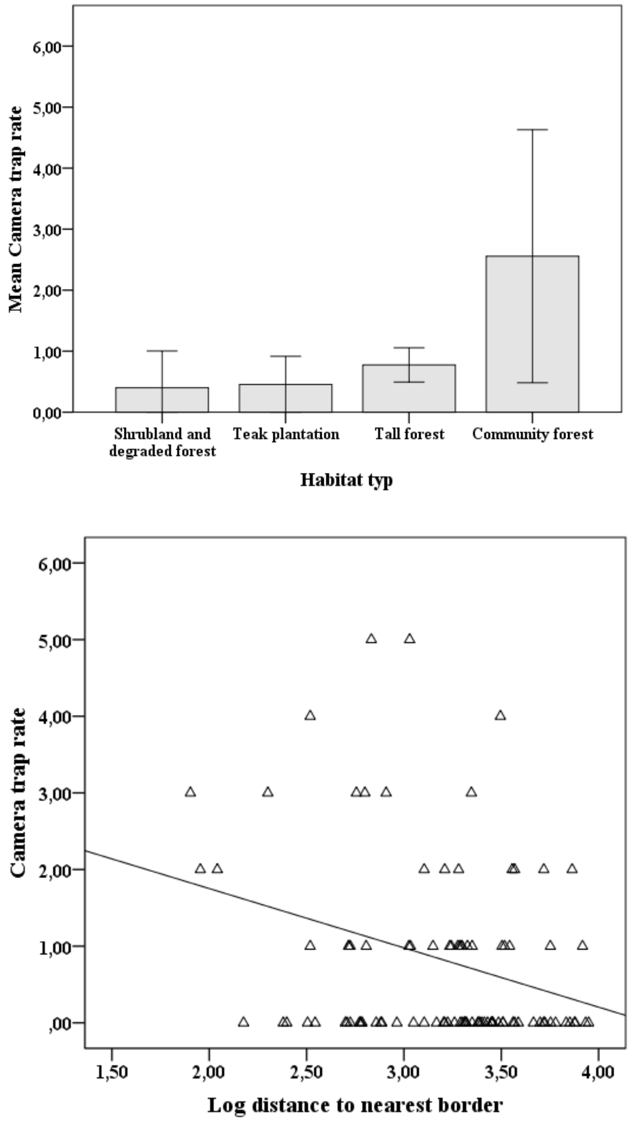

Figure 3. (a) mean camera trap rate across the different habitat types, (b) camera trap rate as a function of distance to neareTst border (R^2=0.067).

As is the case with the previously mentioned topics, comparative data on densities of SEA's wild pig species is scarce. The observed density of 5-10 pigs/km^2 complies to densities found for *Sus celebensis* (12 pigs/km^2) and *Sus scrofa* (4.5-6 pigs/km^2) in Indonesia. (O'Brien & Kinaird, 1996; O'Brien, 2003) However, research performed by Jamuladin (2008) indicate that *Sus celebensis* can reach considerably higher densities of up to 30 pigs/km^2. These high densities are likely due to an absence of pronounced seasonality and fluctuations in fruit availability on Sulawesi (Kinaird & O'Brien, 2005). Research by Pauwels (1980), Ickes (2001) and Yong *et al.,* (2010), found high *Sus scrofa* densities of up to 27-47 pigs/km^2 in seasonal tropical forest sites in Java, Malaysia and Singapore as well. In these cases, high abundances were linked to the abscence of natural predators and mast-years in dipterocarp forests. Bawean's situation is most likely to represent the latter situations as, it to, is characterised by strong seasonality and an absence of predators. Multi-annual research might give an indication whether strong fluctuations in population numbers takes place on Bawean or not.

Overall *Sus blouchi* can be regarded as a habitat generalist with a preference for semi-open cultivated habitat for nighttime feeding. During the day the species retreats into the tall forest and is mainly inactive. The most likely explanation for this preference is the availability of more energy rich foods e.g. roots and tubers, in the cultivated areas compared to tall forest and shrubland and degraded forests (Genov *et al.,* 1995). The negative relationship between *Sus blouchi* density and distance to nearest border is interpreted as a direct link with increasing distance to the community forests at the edge of the forest. No difference was found between densities in community forest and teak stands. Literature on mainland Java *Sus verrucosus* suggests teak plantations might actually be a preffered habitat (Blouch, 1988; Semiadi & Meijaard, 2006). During this study, we frequently observed signs of *Sus blouchi* rooting in the teak stands. Research by Bonnington *et al.,* (2007) and Jenkins *et al.,* (2003) in Africa showed that *Potamochoerus porcus* will forage in teak stands of varying age classes, but has a preference for older stands. In the younger teak stands the species will root for bulbs, and in older teak stands it feeds on insects in the leaf litter and fallen wood and bark (Ghiglieri, 1982; Kingdon *et al.*, 1997). Considering the older age of the teak stands in Baweans protected areas, we hypothesize that *Sus blouchi* mainly forages on arthropods in these areas. Generally arthropod abundance and diversity decreases in plantation habitat compared to natural habitat (Kouadio *et al.,* 2009; Turner & Foster, 2009). However, some species groups show an inverse effect, such as fungus-growing termites in teak plantations (Attignon *et al.,* 2005; Turner & Foster, 2009). A potential effect of wallow presence on warty pig density was found, as is expected based on the important roles these habitat features play in thermoregulation and social interactions (Bracke, 2011).

Red listing

Following the IUCN criteria for Red Listing version 3.1. Second Edition (IUCN, 2012), the separate listing of endemic subspecies is validated. Listing focuses on the population trends, geographic range, number of adult individuals and the risk of extinction. As our data encompasses a single year, we briefly review only the geographic range and number of mature individuals criteria. Based on chapter V. Criteria for Critically Endangered (CR), Endangered (EN) and Vulnerable (VU), *Sus blouchi* meets multiple criteria. Firstly, the species would meet the number of mature individuals threshold to qualify for the VU category (Criteria D). Secondly, based on the lower estimate of approximately 230 individuals, *Sus blouchi* would qualify for listing as EN (Criteria D). The species might actually qualify for listing as CR as its estimated area of occurrence is less than $100km^2$ in a single location (Criteria B1.a). However, before being eligible for CR listing, a quantitative measure of habitat degradation is required (Criteria B1.b). In line with Nijman (2006), we regularly observed signs of illegall logging and burning,but no multi-annual trends can currently be established. The use of sattelite imagery might provide an adequate tool for establishing these trends (Liu *et al.,* 2001; Borghesio & Giannetti, 2005). However, the Global Land Survey imagery from Bawean seems to be distorted and of poor quality, especially from the period of 2005-2010. Following Chapter II, point 8, Uncertainty, we suggest that the number of mature individuals criteria is sufficiently credible to allow *Sus blouchi* to be listed as EN. However, we stress the need for a quantitative measurement of habitat trends on Bawean to clarify if the species should be uplisted to CR. A succesfull Red List assessment might benefit lobbying efforts for national protection, as the species is currenlty still unprotected in Indonesia.

Conclusion

Our study applied a relatively new but underutilized camera trap method for obtaining density estimations. Combined with habitat-plots, the method was successful in obtaining sufficient quantitative population and ecological data to provide a basic population assessment of *Sus blouchi*. Future dietary studies focussing on food availability and faecal analysis might provide more detailed proximate explanations underlying *Sus blouchi* habitat use. Next to this, longer-term camera trapping might establish population trends and reveal if *Sus blouchi* populations are following the same trends as observed in other suidae in locations with similar ecological circumstances. At this moment, sufficient reliable data is available to justify *Sus blouchi*'s listing as EN in a future red list assessment, but focus should be given for providing a quantitative measure of habitat degradation to clarify if the species should not be listed as CR instead. In short, the method looks promising for rapid assessments and population monitoring of individually non-recognizable species given a suitable minimum camera trap rate and a levelling CV.

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Author contributions

Conceived and designed the camera trap experiments MAR, EJRM. Performed the data collection MAR, SB, SZ. Analysed the data MAR. Contributed to writing of the manuscript MAR, (EJRM, SB, SZ, GS, EM)

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