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Hyper-abundance of Native Wild Pigs (*Sus scrofa*) in a Lowland Dipterocarp Rain Forest of Peninsular Malaysia[1]

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ABSTRACT

This study reports extraordinarily high density estimates for the wild pig (*Sus scrofa)* from an aseasonal tropical forest site within the species' native range. At Pasoh Forest Reserve, a 2500 ha area of lowland dipterocarp rain forest in Peninsular Malaysia, line transects were used to estimate pig density from May to October in 1996 and 1998. In 1996, 44 sightings of *S. scrofa* consisting of 166 individuals were recorded along 81 km of transects. In 1998, 39 sightings documented 129 individuals along 79.9 km of transects. Estimated population density was 47.0 pigs/km^2 in 1996 and 27.0 pigs/km^2 in 1998. *Sus scrofa* biomass in this forest was estimated at 1837 kg/km^2 and 1346 kg/km^2 in 1996 and 1998, respectively. Differences between years were attributed to changes in the density of young pigs, coincident with a mast-seeding year of dipterocarp trees in 1996. Pig densities at Pasoh Forest Reserve were much higher than at other forest locations within the species' native range in Europe and Asia. Because Pasoh Forest Reserve is a forest fragment, two factors likely account for the extremely high pig densities: (1) local extinction of natural predators (mainly tigers and leopards) and (2) an abundant year-round food supply of African oil palm fruits from extensive plantations bordering the reserve.

Key words: biomass; density; edge effect; line transect; Malaysia; Pasoh Forest Reserve; Sus scrofa; *tropical forest; wild pigs.*

VERTEBRATE FRUGIVORES, GRANIVORES, GRAZERS, AND BROWSERS play important roles in plant species population and ecosystem dynamics by acting as agents of seed dispersal (Schupp 1993, Mack 1998), seed predation (Becker & Wong 1985, Blate *et al.* 1998, Curran & Webb 2000), herbivory (Crawley 1983, Johnston & Naiman 1990), and physical disturbance (Holcroft & Herrero 1984, Whicker & Detling 1988). Particularly when the relative or absolute densities of vertebrates fluctuate to unusually high levels, the impact on individual plant species or ecosystems can be profound. For example, elephants (*Loxodonta africana*) in parts of Africa and bearded pigs (*Sus barbatus*) in Borneo have increased in density at a local scale because logging, forest fragmentation, or fencing have forced them to concentrate foraging in smaller areas. High local elephant density has resulted in increased tree damage and mortality, forest degradation, and retarded forest succession (Struhsaker 1997, Tafangeyasha 1997). In a Bornean national park, the dominant tree family (Dipterocarpaceae) showed a complete lack of seedling recruitment over a ten-year period due to intense seed predation by pigs (Curran *et al.* 1999). Because medium- to large-bodied vertebrates can have such profound impacts on surrounding environments, there is a need for information on their densities as habitats are modified anthropogenetically. Habitat fragmentation and top-level predator removal may lead to local increases in density for some species, which in turn may provoke faster changes in ecosystem processes. Addressing such negative interactions is likely to be an ongoing challenge facing conservation biologists in our increasingly fragmented landscape.

Another example of elevated population densities of a terrestrial mammal is the wild pig (*Sus scrofa*). In its native range at Pasoh Forest Reserve (PFR) in Peninsular Malaysia, the wild pig population is thought to have increased considerably in recent decades and consequently to have had negative impacts on plants and animals. Soil rooting by pigs is believed to have facilitated the spread of an exotic plant into the primary forest (Laurance 2000, Peters 2001) and to have reduced the local density of small terrestrial mammals (Kemper & Bell 1985). A pig exclosure study at PFR showed that after only two years, woody seedling recruitment, stem density, and species richness increased inside exclosures compared with control plots to which pigs had access (Ickes *et al.* 2001). In addition to soil rooting, female pigs build large reproductive nests out of up to 500 uprooted or snapped off woody saplings that may be 2.5 cm in diameter at breast height and 3.5 m tall. Liu *et al.* (1999) modeled the effects of nest building by pigs within

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PFR and estimated that even moderate densities of pigs and the subsequent damage to trees would likely result in lowered tree species richness.

Despite the documented and hypothesized negative effects of pigs on plants and animals in Peninsular Malaysia, there are no estimates of pig density. I present evidence that the current density at PFR is extremely high in comparison with other sites at which *S. scrofa* occurs naturally. It is impossible to know if the high density reported here is typical of the region because these data represent the first estimates of pig density from the highly diverse aseasonal rain forests of Southeast Asia. I suggest, however, that pig density at PFR is much higher than historical levels in this forest type, and that the increase is due to an absence of feline predators and a year-round food supply from tree plantations that surround the reserve.

STUDY SITE

Pasoh Forest Reserve (PFR) is located in the state of Negeri Sembilan, 110 km southeast of Kuala Lumpur, Malay Peninsula (2°59′N, 102°18′E). The reserve is comprised of three areas: a 650 ha core of primary lowland dipterocarp forest; a 650 ha buffer zone of lowland forest selectively logged almost 50 years ago; and another 650–1000 ha of primary hill forest. Aside from a narrow corridor of hill forest that connects PFR to the southern end of the main mountain range, the remaining perimeter (*ca* 85%) abuts mature African oil palm (*Elaeis guineensis* Jacq.) plantations. Annual rainfall is *ca* 2000 mm with a known range of 1700–3200 mm (Kochummen *et al.* 1990). Monthly rainfall means exceed 100 mm, resulting in an aseasonal climate.

A number of herbivorous/frugivorous terrestrial mammals no longer occur at PFR, which may influence the population dynamics of *S. scrofa* through lack of competition. Locally extinct species include Indian elephant (*Elephas maximus*), Javan rhinoceros (*Rhinoceros sondaicus*), Sumatran rhinoceros (*Dicerorhinus sumatrensis*), and gaur (*Bos gaurus;* Medway 1983, Kemper 1988, Kochummen 1997). Other potential competitors of wild pigs that still may be present in the reserve at extremely low densities include the Malayan tapir (*Tapirus indicus*), sambar (*Cervus unicolor*), barking deer (*Muntiacus muntjak*), greater mouse-deer (*Tragulus napu*), and bearded pig (*S. barbatus*). The leopard (*Panthera pardus*) and tiger (*Panthera tigris*), the primary natural predators of wild pigs, have been rare or absent in the area since the 1960s. Hunting is not allowed within the borders of PFR, but poaching is not uncommon and legal hunting occurs at the boundaries of the reserve.

MATERIALS AND METHODS

LINE TRANSECTS.—To minimize the amount of clearing required to conduct this study, only trails already established previously in the reserve were used as line transects. Ideally, line transects should be established randomly throughout the habitat being surveyed (Buckland *et al.* 1993). This is seldom possible in forest reserves, however, because of limitations on how many trails may be cut and where they can be placed. As a consequence, it was not possible to survey the hill dipterocarp forest in the northeast portion of the reserve (Fig. 1). Therefore, the resulting density estimates apply only to the flat, fairly homogeneous habitat that comprises the rest of the reserve. All transects were located in primary forest except transect 1, which was located in the selectively logged forest (Fig. 1).

Line transect surveys were conducted during two separate periods: 5 May–10 October 1996, and 17 May–28 October 1998. The 13 transects were 500–1600 m in length and each was walked five to ten times over the course of the study period. Total transect length of 12,880 meters in 1996 was reduced to 12,495 m in 1998 due to treefalls that caused two transects to be shortened. Transects were walked on foot at an approximate rate of 1 km/hr, primarily by K. Ickes, but occasionally a second observer was present or conducted a survey alone. To standardize for time, all transects were completed within the first 3 hours or the last 2.5 hours of daylight. On days when surveys were conducted, one or two transects were walked in the morning and one or two at night, although the same transect was never walked twice in one day. An attempt was made to walk all transects an equal number of times over the course of the study, but in two cases, transects had to be temporarily abandoned due to nests of a king cobra and an aggressive wasp species. When it was difficult to detect pigs due to darkness or rain, a measurement of how much of the transect had been completed to that point was taken and the survey stopped. For example, if 400 m of a 1000 m transect had been completed when a storm developed, any observations (or lack thereof) to that point were recorded and the length of that transect was recorded as 400 m for that day. Transects 4–13 had been established previously as part of an ornithological study plot, which was used by researchers in July

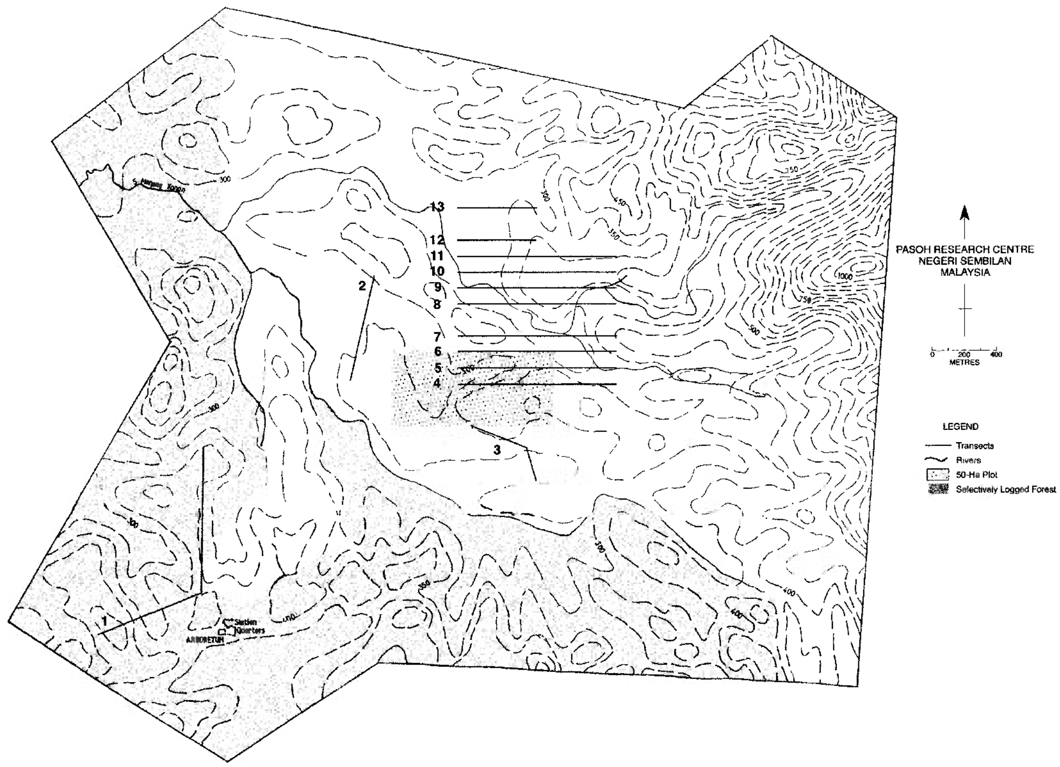

FIGURE 1. Topographic map of Pasoh Forest Reserve, Peninsular Malaysia (modified from a map provided by the Forestry Research Institute Malaysia). Contour lines are in 50 ft increments. The 13 transects are numbered along which searches were conducted for *Sus scrofa* in 1996 and 1998.

1996 (Fig. 1). In that month, no pig surveys were conducted on those transects. Outside of the ornithological study, the transects were used minimally or not at all by researchers.

When a solitary pig was encountered, the animal was observed until it moved away. The perpendicular distance from the trail to the point where the pig was first observed was measured to the nearest meter using a tape measure. The time of observation, location along the transect, size of animal, and sex (when possible) were also recorded. Careful notice was taken of the direction in which the animal moved to minimize recording the same individual later on that transect. When multiple solitary individuals were seen on the same transect, in all but one case, it could be reliably determined that they were separate individuals due to differences in size, sex, or the direction of movement of the prior individual. In the one case when it was not possible to make such a decision clearly, the second observation was discarded. When a group of pigs was encountered, perpendicular distance was measured to the center of the group. Groups were followed when possible to obtain better counts of individual numbers.

Two age classes of pigs were recognized. "Young" pigs have a distinctive striped appearance consisting of yellow–brown longitudinal bands separated by brown, a pattern retained for up to four months (Eisenberg & Lockhart 1972, Diong 1973). Large pigs possessing uniform coloration were considered "adult." Because pigs become reproductive around six to eight months in age (Diong 1973), all pigs considered young would have been pre-reproductive individuals; some of the adult pigs were probably pre-reproductive but most were likely of reproductive age.

To compare the density of pigs at PFR with other studies, estimates were obtained from the literature for locations and habitats within the native range of *S. scrofa*. These estimates were obtained by various methods that differed in precision. Nonetheless, all prior density estimates encountered in the literature were listed here if the meth-

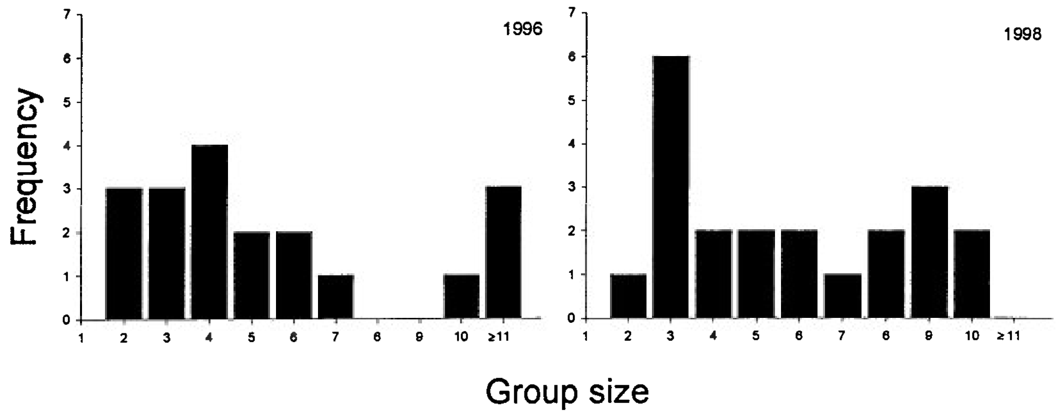

FIGURE 2. Number of pigs in all group sightings (*i.e.*, sightings of 2 or more individuals) for the line transect surveys conducted at Pasoh Forest Reserve, Malaysia, in 1996 and 1998. The three groups of more than 11 pigs in 1996 had 16, 23, and 32 individuals. In 1996 and 1998, the number of solitary pig sightings was 25 and 19, respectively.

odology used to generate the estimate was moderately rigorous. Reports in languages other than English were not listed if an adequate translation of methodology could not be obtained.

DATA ANALYSIS.—Density estimates were generated using the program Distance version 3.5 (Thomas *et al.* 1998). Calculations of mean group size included solitary sightings as a group size of one.

Biomass estimates of *S. scrofa* were calculated using two average weights, one for young and one for adults. The proportion of the total estimated density with uniformly gray coloration was multiplied by 62.0 kg, a mean weight value used by Dinerstein (1980). No weight estimates of young *S. scrofa* in southeast Asia could be found in the literature; thus, an arbitrary weight of 10.0 kg was used to calculate biomass of young individuals (see Results).

RESULTS

During the 1996 survey, 88 transects were walked for a total of 81.0 km. There were 44 pig sightings: 25 solitary individuals and 19 groups with 2 or more individuals (see Fig. 2 for group size distributions). Mean group size was 3.8 individuals. The largest group of pigs encountered was comprised of 32 animals: 6 large adults and 26 striped young. Overall, 166 pigs were seen, including 73 striped young. A half-normal/cosine detection function was used to generate a density estimate of 47.0 pigs/km^2 with a 95 percent confidence interval of 28.2 to 78.6 pigs/km^2 and a coefficient of variation of 26.4 percent. Biomass of *S. scrofa* was estimated to be 1837 kg/km^2.

A similar search effort was made during the survey in 1998, when 91 transects were walked for a total of 79.9 km. The 1998 survey yielded 39 sightings: 19 solitary individuals and 20 groups with 2 or more individuals (Fig. 2). The largest group encountered in 1998 contained 10 animals: 4 adults and 6 striped young. Mean group size was 3.3 individuals. In total, 129 pigs were seen, of which 30 were striped young. The half-normal/cosine detection function estimated pig density in 1998 to be 27.0 pigs/km^2 with a 95 percent confidence interval of 16.2 to 44.7 pigs/km^2 and a coefficient of variation of 26.0 percent. Biomass was estimated to be 1346 kg/km^2.

Determining the sex of individual pigs was not always possible. When sexual determinations could be made, adult males were usually seen as solitary individuals. Adult females were often observed in same-sex groups with our without young, or in groups of one adult female with young.

Within the native range of *S. scrofa,* few studies have estimated population densities greater than 5–10 individuals/km^2 (Table 1). On Peucang Island off the west coast of Java, an island too small to maintain predator populations of pigs, Pauwels (1980) estimated a density of 27 to 32 individuals/km^2. The highest estimates of *S. scrofa* within its native range were from two sugarcane fields in Pakistan. One 3327 ha sugarcane field had 32.2 pigs/km^2, and a 2037 ha field had 72.1 pigs/km^2. No natural predators occurred in these agricultural areas and the pigs fed voraciously on the cane, de-

TABLE 1. *Density estimates of* Sus scrofa *within its native range. Locations are organized by country in alphabetical order. An * indicates that the authors specifically mention human hunting of pigs to be common in the study area. Data from this study are shown in bold.*

Country	Location	Vegetation type	Density *N*/km^2	Predators present	Source
Assam	Kaziranga Wildlife Sanctuary	Riparian forest, grassland	1.3–1.5	Yes	Spillett (1967a)
India	Keoladeo Ghana Sanctuary	Grassland, marsh	2.9	Yes	Spillett (1967b)
India	Jaldapara Wildlife Sanctuary	Riparian forest, grassland	1.2–1.4	Yes	Spillett (1967c)
India	Nagarahole National Park	Tropical moist deciduous and dry deciduous forest	4.2	Yes	Karanth & Sunquist (1992)
India	Gir Forest, Gujarat	Tropical dry deciduous forest	0.1	Yes	Berwick & Jordan (1971)
India	Gir Forest, Gujarat	Tropical dry deciduous forest	<1.0	Yes	Khan *et al.* (1996)
India	Kanha national Park	Tropical dry deciduous forest, Sal forest, grassland	1.2	Yes	Schaller (1967)
Indonesia	Peucang Island, Ujung Kulong Nat. Park, Java	Coastal, disturbed, and dipterocarp forest; swamp	27–32	No	Pauwels (1980)
Italy	Maremma Natural Park	Mediterranean	5.1–6.1	No	Massei & Tonini (1992)
Malaysia	**Pasoh Forest Reserve 1996**	**Lowland dipterocarp rain forest**	**47.0**	**No**	**This study**
Malaysia	**Pasoh Forest Reserve 1998**	**Lowland dipterocarp rain forest**	**27.0**	**No**	**This study**
Malaysia	Dindings district, Perak	Dipterocarp and coastal forest, agriculture	<1.0	?*	Diong (1973)
Nepal	Royal Chitwan National Park	Riverine forest, tall grassland	5.8	Yes	Seidensticker (1976)
Nepal	Royal Karnali-Bardia Wildlife Reserve	Sal, riverine, and hardwood forest; grassland	4.2	Yes	Dinerstein (1980)
Nepal	Royal Karnali-Bardia Wildlife Reserve	Savanna, grassland	3.8	Yes	Dinerstein (1980)
Pakistan	Chiniot, Sargodha district	Sugarcane fields	32 and 72	No	Shafi & Khokhar (1985)
Pakistan	Changa Manga Forest, West Pakistan	Irrigated forest plantation	10.4	No	Inayatullah (1973)
Pakistan	Thatta district, southern Pakistan	Riparian forest, agricultural fields, swamp	3.7	No*	Smiet *et al.* (1979)
Poland	Various locations	Deciduous forest/agriculture	1.2–1.8	?	Mackin (1970)
Poland	Augustow Forest	Coniferous forest	0.3–2.0	?	Pucek *et al.* (1975)
Poland	Bialoweiza Forest	Coniferous forest	3.5	?	Pucek *et al.* (1975)
Poland	Józefów Forest	Coniferous forest	0.2	?	Pucek *et al.* (1975)
Poland	Dulowska Forest	Coniferous forest	1.9	?	Pucek *et al.* (1975)
Poland	Pszczyna Forest	Coniferous forest	1.0	?	Pucek *et al.* (1975)
Poland	Niepolomice Forest	Coniferous forest	0.2	?	Pucek *et al.* (1975)
Poland	Smolniki Forest	Coniferous forest	1.0	?	Pucek *et al.* (1975)
Poland	Zielonka Forest	Coniferous forest	1.6	?	Pucek *et al.* (1975)
Poland	Bialoweiza Forest	Deciduous forest	2.0	?	Pucek *et al.* (1975)
Poland	Niepolomice Forest	Deciduous forest	0.4	?	Pucek *et al.* (1975)
Poland	Zielonka Forest	Deciduous forest	3.1	?	Pucek *et al.* (1975)
Sri Lanka	Ruhuna National Park	Lowland monsoon forest, savanna woodland, grassland	0.7	Yes	Santiapillai & Chambers (1980)
Sri Lanka	Wilpattu National Park	Lowland monsoon and monsoon scrub forest	0.3–1.2	Yes	Eisenberg & Lockhart (1972)
Sri Lanka	Gal Oya National Park	Lowland monsoon forest, savanna woodland, grassland	0.6	Yes	McKay (1973)
Thailand	Huai Kha Khaeng Wildlife Santuary	Several dry forest habitats	<0.5	Yes	Srikosamatara (1993)

stroying up to 35 percent of the crop before being removed with poison (Shafi & Khokhar 1985).

DISCUSSION

This study, conducted in lowland equatorial rain forest within the native range of *S. scrofa,* estimated that densities at PFR were 47.0 and 27.0 individuals/km^2 in 1996 and 1998, respectively. There are three possible interpretations of these high pig density estimates for this aseasonal rain forest in Malaysia. First, the data may over- or underestimate pig densities at this site. Without additional independent estimates, this possibility cannot be excluded. Line transects, however, are recognized as one of the most practical and reliable methods for estimating densities of larger mammals in most habitats (Buckland *et al.* 1993, Mandujano & Gallina 1995, Varman & Sukumar 1995). Furthermore, pigs were reported to be common in the reserve during the mid 1980s (Kemper 1988), and that pigs are still extremely common is obvious from the amount of soil area rooted daily and the frequency of sightings (pers. obs.).

A second interpretation for these data is that they accurately represent the situation at PFR and that *S. scrofa* naturally occurs at these densities in aseasonal dipterocarp rain forests of southeast Asia. Data from two other studies in Malaysia, however, suggest that the densities reported here for PFR are much higher than elsewhere in the peninsula. Diong (1973) investigated *S. scrofa* in the northern state of Perak and estimated the total pig population of the "Dindings district" to be only 800 animals. Although Diong (1973) did not state how large an area this covered, based on his map it appears that *S. scrofa* density in the area was well below 1.0/km^2. Laidlaw (1994) walked line transects in seven different Virgin Jungle Reserves in Peninsular Malaysia (PFR not among them) and averaged only one sighting (group or solitary individual) of *S. scrofa* for every 14.0 km surveyed. Encounter rates were much greater in this study at PFR: in 1996, *S. scrofa* was encountered once every 1.8 km surveyed, and in 1998, once every 2.1 km surveyed. If it is assumed that the average group size was comparable between studies, the density of pigs at PFR was approximately seven times higher than at the Virgin Jungle Reserves. Taken together, the results of Diong (1973) and Laidlaw (1994) suggest that density estimates of 47 and 27 pigs/km^2 reported here for Pasoh Forest Reserve do not accurately reflect typical *S. scrofa* densities in lowland aseasonal dipterocarp forest.

The third, and most probable, interpretation for these high pig densities is that they accurately represent the current situation at PFR, and there have been changes in and around the reserve in recent decades that have contributed to a dramatic increase in pig density. Two such changes that may have been especially important in allowing pig density to rise and be maintained at such high levels in this forest are the local extinction of the natural predators of wild pigs and the presence of African oil palm tree plantations surrounding the reserve (Ickes & Williamson 2000).

In various locations and habitats within the native range of *S. scrofa,* where native large predators and *S. scrofa* still co-occur, pigs are a principal food item in the diets of several carnivorous species (Eisenberg & Lockhart 1972, Rabinowitz 1989, Karanth & Sunquist 1995). Within the aseasonal dipterocarp forests of Peninsular Malaysia and Sumatra, pigs are probably a major prey item for both tigers and leopards, particularly since there are fewer potential Cervid prey species in this habitat compared to the more open seasonal forests elsewhere in southeast Asia. Under less disturbed circumstances, these top-level predators may play an important role in controlling population densities of pigs in these forests. Both large felids are currently absent from PFR, however, and it seems unlikely that tigers and leopards will ever successfully recolonize PFR because the reserve is too small in area given the territory sizes of large predators. Furthermore, when dangerous animals enter the plantations surrounding the forest, they are removed by the wildlife department, as predicted for large carnivores inhabiting small reserves (Woodroffe & Ginsberg 1998). Support for the hypothesis that pig densities rise in the absence of predators comes from other studies in the literature; within the native range of *S. scrofa,* the highest density estimates all come from areas with no extant natural predators (Table 1).

Even in the absence of natural predators, however, populations of prey species can only increase if enough food is present. Consequently, diet is an important consideration in terms of population regulation and density of *S. scrofa* at PFR (Ickes & Williamson 2000, Laurance 2000). *Sus scrofa* is an omnivorous species for which diet varies greatly across habitats and geographic locations (Diong 1973, Klaa 1992). Nevertheless, in most areas the seasonal availability of large quantities of fruits and seeds is considered an important food source (Matschke 1964). In dipterocarp forests of Southeast Asia, mast fruiting of the majority of tree species occurs at a supra-annual scale, with little fruit fall during the intervening years (Whitmore 1984). At PFR, mast fruiting occurred in 1983, 1990, and 1996. For West Kalimantan, Curran and Leighton (2000) reported that over a 520-week study period between 1986 and 1996, 95 percent of all dipterocarp seedfall occurred in only two 6-week mast periods. Such extreme phenology severely limits the amount of fruit and seed available to pigs and may play an important role in limiting population densities under typical conditions in the region.

If food is an important limiting factor in *S. scrofa* demography in dipterocarp forests, particularly when natural predators are absent, the pig population in PFR may have reached a supranormal carrying capacity due to the proximity of African oil palm tree plantations. Oil palm trees fruit continuously, provide an extremely rich food source, and are cultivated in extensive monoculture plantations in the areas surrounding PFR. Pigs appear to make good use of this abundant food source, moving back into the reserve after feeding. Thus, in a forest where food may once have been limiting, there is currently a tremendous food supply in the surrounding area.

The supranormal pig densities at PFR result in extensive damage to understory saplings (Ickes *et al.* 2001), which may alter the future forest composition and structure within the reserve (Liu *et al.* 1999). Small reserves such as PFR are subject to severe edge effects (Gascon *et al.* 2000), particularly where edge effects operate over a large scale (Ickes & Williamson 2000, Laurance 2000).

In conclusion, *S. scrofa* was found to occur at extremely high densities at PFR. Although it is impossible to say for certain, it is probable that pig densities of this magnitude do not reflect historical density in this forest reserve or this forest type in general. Rather, the combination of an absence of feline predators and an abundant food supply from the surrounding agricultural plantations has allowed pigs to thrive in this area. Several studies have now documented that pigs are having strong impacts on other plant and animal species at PFR. Additional multispecies interactions in which pigs may play a role are in urgent need of investigation in this reserve.

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