

Modern Hunting Practices and Wild Meat Trade in the Oil Palm Plantation-Dominated Landscapes of Sumatra, Indonesia

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Abstract The ongoing expansion of plantation agriculture has changed the ecological, demographic, and social conditions of Southeast Asia's forested areas, yet little is known about hunting practices in these novel landscapes. Using information from 73 in-depth interviews with hunters, agricultural workers and wild meat dealers in the Jambi province of Sumatra, Indonesia, we describe contemporary hunting practices, including how hunting methods, wildlife harvest and consumption rates vary between different indigenous and immigrant ethnic groups. Hunting is now primarily a commercial endeavor for harvesting wild boar (*Sus scrofa*) meat; over 7500 wild boars were sold in Jambi City alone in 2011. The Muslim majority avoids wild boar for religious reasons, but there is substantial local and export demand driven by Chinese and Christian Batak. We conclude that hunting within oil palm plantations may reduce crop damage from wild boar and also yield large amounts of wild meat with relatively little by-catch of threatened animals.

Keywords Wildlife harvest · Bushmeat · Tropical rain forest · Human-wildlife conflict · Palm oil · Rubber · Wild boar (*Sus scrofa*) · Livelihoods · Jambi · Southeast Asia · Sustainable hunting

Introduction

Southeast Asia's forested regions are undergoing a period of rapid environmental and social change, largely driven by plantation agriculture (Sandker *et al.* 2007; Bradshaw *et al.* 2009; Sayer *et al.* 2012). Socially, there are higher

population densities made up of a diverse set of immigrants (Hirawan 2011). Economically, livelihood options are now largely market-based rather than forest or subsistence-based (Rigg 2006). Ecologically, forests have been reduced in area, fragmented and often also disturbed (e.g., selective logging), with myriad cascading effects on the remaining floral and faunal communities (Sodhi *et al.* 2004). These changes occur in inter-connected ways and coalesce to shape new human-environment relations, one of the most direct articulations of which can be seen through hunting practices.

To date, most research on hunting in Southeast Asia has focused on traditional peoples with forest-based livelihoods living in areas with extensive forest cover (Caldecott 1988; Rye 2000; Robinson and Bennett 2000; Corlett 2007; Pangau-Adam *et al.* 2012). However, as 'new frontiers of land control' emerge, including plantation agriculture development, they bring with them a complex array of political, social and cultural changes (Peluso and Lund 2011). These changes are often manifested in changing patterns of access to, and use of, forest resources (Cramb *et al.* 2009; Fox *et al.* 2009). Despite this, research has only begun to explore hunting conditions in developed plantation landscapes that now dominate the region. For example, Pangau-Adam *et al.* (2012) recently described the emergence of commercial hunting practices following new oil palm plantation establishment in Papua, Indonesia. Building on this work, in this paper, we describe hunting practices across a variety of indigenous groups (i.e. groups that historically have lived in a region), as well as immigrant ethnic groups, in extensively developed agricultural landscapes in Sumatra, Indonesia.

Two plantation crops, oil palm (*Elaeis guineensis*) and rubber (*Hevea brasiliensis*), dominate recent agricultural development in Southeast Asia and drive the world's highest deforestation rates in the region (Achard *et al.* 2002; Koh and Wilcove 2008; Gibbs *et al.* 2010; FAO 2012). Both oil palm and rubber are labor-intensive to cultivate, harvest, and

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process, and require larger labor forces than are usually available locally (Sayer *et al.* 2012). In Indonesia, the large-scale immigration that regularly accompanies plantations is often encouraged by government transmigration programs (Hirawan 2011; Li 2011). Further, even where sufficient labor is locally available, immigrants are often preferred by companies who seek an easily disciplined labor force (Li 2011). Developed plantation landscapes are thus often associated with large-scale demographic change (Sandker *et al.* 2007; Cramb *et al.* 2009; Hirawan 2011).

Parallel to biophysical and demographic changes, wildlife communities (e.g., species composition and relative abundances) are also changing in plantation-dominated landscapes (Mohd. Azlan and Sharma 2006; Maddox *et al.* 2007; Fitzherbert *et al.* 2008; Luskin 2010; Luskin and Potts 2011). In areas characterized by a forest-plantation mosaic, there is often an increase in generalist or edge-adapted species and a decrease in forest-interior and area-demanding species (Laurance *et al.* 2012). In Southeast Asia, wild boar (Ickes 2001), monitor lizards, pythons, and cobras (Shine *et al.* 1999), and other edge or generalist species have been observed to become hyper-abundant in and around oil palm plantations (Bennett and Dahaban 1995; Fitzherbert *et al.* 2008), while larger species like tigers, gaur, Asian elephants and Sumatran rhinos have often been found to be absent (Sodhi *et al.* 2004; Nyhus and Tilson 2004; Corlett 2007; Fitzherbert *et al.* 2008; Maddox *et al.* 2007; Alfred *et al.* 2012). In Indonesia, these wildlife conditions have led to the commercial harvest of wildlife from plantations (e.g. reptiles; Shine *et al.* 1999) and the construction of expensive fencing systems to reduce crop damage from wild pigs and elephants (Alfred *et al.* 2012).

Changing socio-ecological conditions in plantation landscapes also affect hunting practices and wildlife harvest. Immigrants often bring culturally distinctive wildlife preferences and hunting methods, potentially leading to the over-hunting of preferred game or economically valuable species (Redford and Robinson 1991; Wilkie and Curran 1991; Koster 2008; Pangau-Adam *et al.* 2012). Simultaneously, hunting practices may adapt to capture or deliver important ecosystem services (e.g., to reduce crop damage) and new economic opportunities to sell wildlife (Robinson and Bennett 2000; Corlett 2007). Exploring how hunting practices change in association with changing socio-ecological landscapes is thus integral to broader understandings of contemporary conservation efforts and livelihood strategies.

Our objective is to describe contemporary hunting practices in a characteristic plantation-dominated region of Indonesia in the Jambi province of Sumatra. We conducted semi-structured in-depth interviews with knowledgeable professional and sport hunters, local plantation agriculture workers and managers, government officials from relevant

departments, and wild meat market dealers in Jambi City. In this paper, we explore four important aspects of hunting in detail: (1) motivations for hunting, (2) modern practices, with specific consideration of how practices differ between ethnic groups, (3) species harvested and extraction rates, and (4) wildlife consumption patterns and trade.

Study Area

Our study area of Jambi province is located in central Sumatra, Indonesia, extending from the eastern coast to the Barisan mountains in the west. Our respondents primarily lived, worked and hunted within the central regencies of Muara Jambi (5,246 km²), Batang Hari (5,180 km²) and parts of Tebo (6,461 km²), which surround the Jambi City regency (01°37'S, 103°36'E; Fig. 1). The total population of Jambi province was 3,088,618 in 2010 with the capital of Jambi city having a population of 531,857 (BPS 2010).

The dominant forms of land use in Sumatra have evolved considerably over the past 50 years. Prior to 1960, small-holder rice was the predominant human land use, along with small areas of rubber, coffee, tea, tobacco, cinnamon, and *Agathis* plantations (Rye 2000; Tomich *et al.* 2000; Margono *et al.* 2012). Beginning in early 1970, this shifted to large-scale logging concessions, timber plantations, and rubber, cocoa and coffee estates, often in association with transmigration programs (Margono *et al.* 2012). Since the early 1990s, oil palm has dominated agricultural expansion, with new plantations often coming at the expense of previously forested land (Miettinen *et al.* 2011). Today, Sumatra is a primary growing region for oil palm, accounting for 73 % of

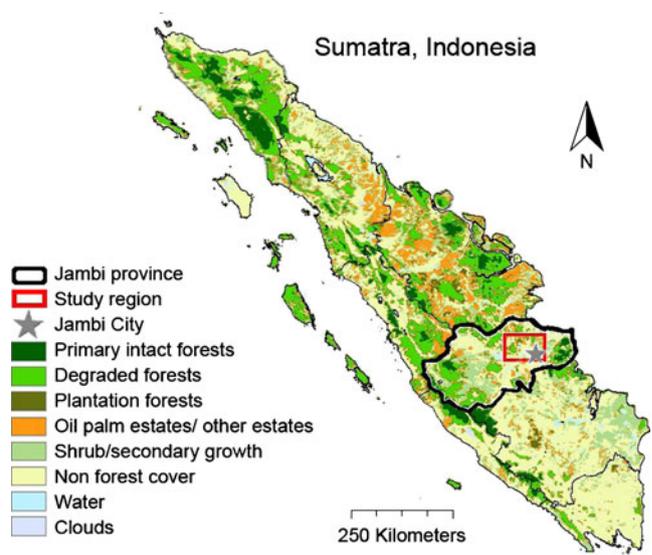


Fig. 1 Landcover map of Sumatra showing the study region and Jambi City (adapted from Margono *et al.* 2012 with permission)

Table 1 Change in area between 2000 and 2010 of intact and disturbed forests, and major plantation crops in Jambi and Indonesia. Forest cover data from Margono *et al.* (2012) for Jambi and Miettinen *et al.* (2011)

	Jambi		Indonesia	
	Km ² in 2010	Change (2000–2010)	Km ² in 2010	Change (2000–2010)
Forest	15,100	–17 %	86,039	–9.3 %
Oil palm	4,894	+85 %	53,700	+167 %
Rubber	6,451	+19 %	30,646	+28 %
Coconuts	1,186	–15 %	30,807	+19 %
Coffee	249	–15 %	11,660	–8 %
Cocoa	13	–61 %	10,260	37 %

for all of Indonesia, agricultural data from Dinas Perkebunan Provinsi Jambi (2011) for Jambi and FAO (2012) for all of Indonesia

Indonesia's palm oil production, which is the world's largest producing country (Table 1; Colchester *et al.* 2006; FAO 2012). Jambi is a microcosm of Sumatra, losing 32 % of its forest cover from 1990 to 2000, and another 17 % from 2000 to 2010 (Margono *et al.* 2012). During that time, oil palm and rubber grew by 85 % and 19 % from 2000 to 2010 in Jambi, respectively (Table 1).

Despite this rate of development, Jambi is still known for its forests and biodiversity. Jambi is home to part of the Kerinci Seblat National Park, Sumatra's largest national park, which supports a plethora of threatened wildlife including tigers (*Panthera tigris sumatrae*), Sumatran rhinoceros (*Dicerorhinus sumatrensis*), Asian elephants (*Elephas maximus sumatrensis*), malay tapirs (*Tapir indicus*), Sunda pangolins (*Manis javanica*), serows (*Capricornis sumatraensis*), dholes (*Cuon alpinus sumatrensis*), gibbons (*Hylobatidae spp.*), and Sunda clouded leopards (*Neofelis diardi*; IUCN 2012). Some wildlife species are protected under Indonesian law, but hunting is loosely regulated and many species, such as wild boar (*Sus scrofa*), are completely legal to hunt and sell (IUCN 2012). However, firearms are tightly controlled and expensive (Corlett 2007). There are also numerous smaller protected areas in Jambi, as well as scattered production and secondary forests (Margono *et al.* 2012; Fig. 1).

As elsewhere in Indonesia, substantial recent social and demographic change in Sumatra has been strongly associated with transmigration programs enacted to encourage agricultural development (Sandker *et al.* 2007). Jambi's population has tripled in the last 40 years (BPS 2010) and immigration consistently accounts for 15–20 % of population growth (Suryadinata *et al.* 2003; Colchester *et al.* 2006; Table 2). Immigration into oil palm producing regions is widespread across Indonesia (Table 2). Immigrants then supply the large year-round workforces in rubber and oil palm plantations by tapping rubber trees, harvesting oil palm fruits by hand, processing these commodities, and building supporting infrastructure (Li 2011). In 2004, for example,

4.5 million people on Sumatra and Kalimantan were employed in oil palm production alone (Sandker *et al.* 2007).

The largest ethnic group in central Jambi is the indigenous Malays, who are primarily Muslim, and made up 38 % of Jambi's population in 2000 (Suryadinata *et al.* 2003). The second largest group is Muslim Javanese immigrants who constitute 30 % of the population (Suryadinata *et al.* 2003). The largest minority groups are Batak (collective term for related ethnic groups) who are indigenous to North Sumatra and primarily Christian (6 % of the population), the Minangkabau who are indigenous to West Sumatra and are predominately Muslim (5 % of the population), and the Chinese (3 % of the population), who are predominately Buddhist but also Confucianists, Taoist or Christian (Suryadinata *et al.* 2003). The Batak and Minangkabau also retain some of the historical "adat" animist traditions (INRN 2003). Across all ethnic groups in Jambi, about 91 % of the population is Muslim, 5 % are Christian, and 3 % practice either Buddhism or Confucianism (Suryadinata *et al.* 2003). The 2000 ethnic-specific census is most current available, and Jambi's specific demographic makeup continues to change.

Table 2 Net migration from 1980 to 2005 for selected Sumatran provinces, Java, and all Indonesian oil palm producing provinces versus non-oil palm provinces ('+' denotes in-migration and '-' denotes out-migration). West Sumatra is the historical center of the Minangkabau; North Sumatra is historical center of the Batak. Oil palm producing provinces contained more than 35 km² of plantations in 2005. Data compiled from Hirawan 2011 and BPS 2010

Island(s)	Province(s)	Net migration (1980–2005)
Sumatra	Jambi	+ 209,476
	West Sumatra	– 313,332
	North Sumatra	– 764,543
Java	All provinces	– 4,478,859
All Indonesia	All oil palm producing provinces	+ 4,842,719
	All non-oil palm producing provinces	– 4,245,343

Methods

We conducted 73 in-depth semi-structured interviews that lasted between 30 min and 1 h each with hunters, plantation laborers, owners and managers, and wild meat dealers from May through August 2011. One of the authors (EDC), a native of Jambi City, conducted the interviews in Indonesian. Respondents were first identified through conversations with plantation owners and managers, smallholder farmers, police and forestry officials, wild meat dealers, hunting equipment vendors, and the hunting organizations *Persatuan Olah Raga Buru Babi Indonesia* (PORBBI; translated to *Pig Sport Hunting Association of Indonesia*) and *Persatuan Menembak Sasaran dan Berburu Seluruh Indonesia* (PERBAKIN; translated to Target Shooting and Hunting Association of Indonesia). We used a combination of targeted subjects and referral sampling where existing study subjects recruited future subjects from among their acquaintances. Referral sampling allowed us to find a large number of knowledgeable respondents and engage them with a higher level of trust due to shared intermediary acquaintances. A weakness of referral sampling is that it is non-random and thus does not necessarily reflect the entire hunting population, which prevents some statistical analyses and limits population-wide conclusions. By targeting active, experienced and knowledgeable informants, we were able to more efficiently accumulate a wealth of collective expert knowledge stratified by ethnic group and occupation than if had we randomly sampled the population or used standardized surveys (Table 3; Bewley 2002). This method was appropriate for our study sites given the results of our initial interviews, which suggested that a low percentage of the population engages in hunting.

Our respondents were representative of the five main ethnic groups, Javanese, Malay, Batak, Chinese and Minangkabau, as well as of the primary religious groups, Islam, Christianity, Buddhism and Confucianism found in Jambi City and the neighboring regencies (Table 3). Of the 73 interviewees, 14 worked in oil palm plantations (wage

laborers), eight worked in rubber plantations (wage laborers), ten were smallholder farmers (often growing oil palm or rubber), eight were professional hunters, ten were wild meat vendors and 23 worked other non-agricultural jobs.

From each interviewee, we collected a diverse range of quantitative and qualitative data encompassing demographics and livelihood strategies, hunting practices and harvest rates as well as wildlife consumption and trade. We recorded each respondent's background information (i.e. ethnicity, religion, cultural practices, immigration history) and economic information (i.e., employment, earnings, family status, and farming activities). To avoid potential biases stemming from closely related "circles of influence," we also inquired about relationships among our subjects to other groups to triangulate and corroborate inferences about how and why different groups hunted. This included stratified sampling across different hunting groups, and when hunters were part of larger organizations (e.g., PORBBI), we interviewed people from chapters in different cities and regencies.

Interviewees were asked about their hunting effort (frequency, duration, hunting sites, distance traveled and hunting group size), locations and habitat (forest, oil palm, rubber, etc.), methods (weapons, traps, strategies), motivations (cultural, subsistence, commercial), and wildlife species harvested (quantity and frequency). We also directly observed hunts by accompanying hunters and hunting groups on hunts. We informally interviewed leaders of two hunting organizations (PERBAKIN and PORBBI) as well as local police, and officials at the forestry, agriculture, and conservation/resource management authorities (Dinas Kehutanan Jambi, Dinas Perkebunan, Dinas Pertanian dan Pangan, and Balai Konservasi dan Sumber Daya Alam).

Interviewees were also asked about their domestic and wild meat consumption (the frequency with which they had consumed different wildlife or domestic meat over the past week, month or year), wildlife trade (what was sold, for how much, to whom, and for what purpose), and agricultural pests (i.e., to rank species by damage incurred). In addition to respondents' perceptions of agricultural pests, we analyzed accounts of pest species' damage from government reports obtained from the agricultural department in Jambi (Dinas Perkebunan Provinsi Jambi 2012). These reports quantified the types of losses and associated costs caused by wildlife pest species in plantations from January-March, 2011. The reports were compiled from 471 km² of oil palm and 740 km² of rubber plantations monitored within Jambi province. Finally, respondents were asked about their perceptions of short and long-term wildlife population trends (what animals were increasing or decreasing, when, where, and why), as well as to speculate about other people's practices, which yielded reports of poaching of protected animals

Table 3 Respondents' self-identified ethnicity and religion. The Minangkabau are indigenous to West Sumatra, the Malay are indigenous to East Sumatra, including Jambi province, and the Batak are indigenous to North Sumatra

Religion	Ethnicity					Totals
	Javanese	Minangkabau	Chinese	Malay	Batak	
Muslim	17	18	1	9	1	46
Buddhist	0	0	16	0	0	16
Christian	1	0	2	1	6	10
None	0	1	0	0	0	1
Totals	18	19	19	10	7	73

that respondents may have avoided describing in their personal practices.

Wild meat vendors were asked about the species they sold, quantities sold per week (animals and weight), price, customers, and trends in demand. We also asked about the source of meat including characteristics about the hunter and method of hunting, when possible. Regional wild meat off-take was calculated from the number of animals sold in markets per week multiplied over the year, but this was only possible for wild boar (*Sus scrofa*) due to low frequency and highly variable presence of other wildlife species in meat markets. Of the 10 wild meat dealers interviewed, nine were located in Jambi City and were visited multiple times, and one was located in Muara Tebo, 200 km east in the Tebo Regency, and only visited a single time. Regardless, our four-month study period was too short to capture potential seasonal variations. This study also concentrated on hunting for wild meat, not the illicit wildlife trade; however, poaching is known to an issue in Jambi, often undertaken for international export of pets, exotic foods and Chinese traditional medicines (Corlett 2007; Nijman 2010).

Results

Hunting Motivations, Methods, and Harvest Rates

Hunting methods and motivations corresponded closely to specific ethnic groups. Acquiring meat for personal consumption (“subsistence” hereafter) was reported as the primary motivation for hunting by 12.2 % of respondents (primarily Javanese immigrants and Malays) followed by 40.8 % hunting primarily for sale (primarily Chinese and Batak) and 46.9 % hunting for social/cultural reason (primarily Minangkabau). The five hunting methods commonly employed (in order of total number of estimated annual hunter-days) were (1) weekly large social day hunts by ethnic Minangkabau’s that primarily utilized dogs, (2) herding wild boar (*Sus scrofa*) from within oil palm plantations into wire net traps, done by professional Chinese hunters at night twice-weekly, (3) snare hunting, usually done by Malay smallholder farmers in forest fragments and unkempt rubber plantations, (4) air rifles used by Malays primarily seeking mouse deer (*Tragulus spp.*) in rubber plantations or forest, and (5) vehicular hunts using firearms, conducted by wealthy members of the sport hunting group, PERBAKIN.

The Minangkabau dog-hunts were comprised of 10–300 people hunting together for social reasons and were organized through the PORRBI hunting association. Large dog-hunts occurred each Sunday in areas containing a mix of forest, rubber and oil palm plantations and covered an area ~15 km². The atmosphere at these hunts was leisurely and

hunts lasted the entire day. There were even mobile vendors who accompanied the hunters to sell food and drink along the road. The Minangkabau sought deer, but primarily killed wild boar, which were then given to Batak helpers who sold the meat. Dogs also rounded up a wide variety of other animals that were killed but not always eaten (for example, a gibbon (*Hylobates agilis*) was killed but not eaten or sold).

Professional Chinese hunters targeted wild boar within oil palm plantations and sold the meat. They hunted in groups of four to six people at night, herding wild boar from oil palm plantations into wire net traps, locally called *lapun babi*, which were placed at the plantation edge. *Lapun babi* wire traps are a type of circular snare approximately 1–2 m in diameter that entangle passing animals until they can barely move. A team of hunters set 50 to 150 traps on oil palm plantation borders late at night (~02:00) after wild boars had entered the plantations to forage on fallen palm fruits. At ~04:00 the hunters chase the wild boar out of the oil palm plantations and into the traps. An entire hunt can take 10–24 h when travel time, trap set up and break down are included and thus only one to three hunts were undertaken per week.

Malay farmers and plantation managers hunted with air guns, often carrying the guns throughout the work day. They reported most often shooting macaques (*Macaca nemestrina*) from within plantations, with the purpose of reducing crop damage, and wild boar for both pest control and for sale. Farmers with air guns would sometimes hunt mouse deer (*Tragulus spp.*) in rubber plantations or nearby forests at night for personal consumption (less than one hunt per week). Air guns are relatively expensive (more than USD 100) and are often modified to kill large animals such as wild boar, thus partially substituting for firearms.

Malay farmers and some Batak snared in forests patches (often selectively logged or secondary forests) or rubber plantations with undergrowth. They targeted wild boar for pest control and sale as well as deer species for personal consumption. However, snares also captured a variety of other wildlife (“by-catch” hereafter). Snares were usually set close to homes or farms where they could be conveniently checked. There were also commercial hunters who placed snares in forests along rural roads, primarily to catch and sell wild boar to prearranged vendors.

Wealthy hunters (those making more than 5 million IDR per month) who could afford the cost of guns and licenses used firearms and were most often also members of the PERBAKIN hunting association. Firearms were then used to hunt by shooting animals out of the back of pick-up trucks at night for sport. Hunters kept preferred species for personal consumption (e.g., deer) and gave wild boar to hired helpers who most often sold the meat.

The Batak often hunted with other groups, accompanying Muslim hunters (e.g., the Minangkabau) to collect wild boar

and sometimes set snares in forests along rural roads. Javanese were the least involved in hunting, but would occasionally kill and consume macaques and porcupines.

Among the methods, snares and Minangkabau dog hunts were the most non-discriminate with the highest levels of by-catch (non-pig or deer species). Both practices occasionally led to the capture of all deer species, sun bears (*Helarctos malayanus*), tapirs (*Tapirus indicus*), pangolins (*Manis javanica*), bearded pigs (*Sus barbatus*; which were only locally present seasonally), and porcupines (Hystricidae spp.). Even arboreal species like binturong (*Arctictis binturong*), and primates such as gibbons (Hylobatidae spp.) and macaques (*Macaca nemestrina* and *Macaca fascicularis*) were sometimes captured in snares or by dogs. However, hunters reported that only wild boar was captured in oil palm plantations at night. Further, only wild boar – the target species of several hunting methods – was harvested consistently enough across different methods to estimate harvest rates for different methods (Fig. 2).

Wild Meat Trade and Consumption

The majority of hunters preferred deer meat for their personal consumption, but took other animals for commercial purposes, pest control or sport. Wild boar was the most harvested species (both numerically and in terms of biomass). Deer species were the second most harvested (mouse deer (*Tragulus* spp.), muntjak (*Muntiacus muntjak*), and sambar (*Cervus unicolor*), respectively). Deer species were unanimously reported to have declined in the area while respondents reported that wild boar populations were stable or increasing. People were broadly aware that some species'

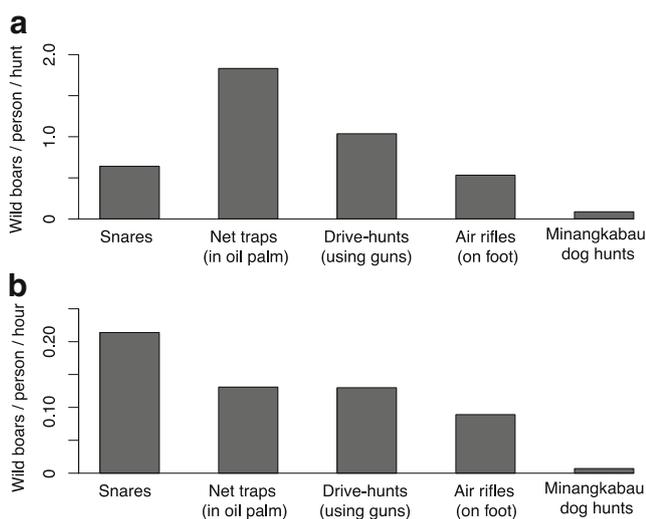


Fig. 2 Wild boar harvest rates by hunting method ($n=48$). **a** Mean wild boar harvest per person per hunt. **b** Mean wild boar harvest rates per person per hour (affected by hours spent hunting)

were protected, which might have affected whether they reported hunting protected species.

Data from wild meat vendors showed that wild boar was often the only wild meat routinely sold at local rural and urban markets, although deer (usually sambar, which are too large for one family to consume) was occasionally available and cost twice as much as wild boar per kg. Wild boar meat was sold in two ways: “raw” and “pumped.” The latter involves pumping water through the animal pre-butchered to add weight to the meat and turn it a lighter pink color, which was reported to more closely resemble domestic pork. This “pumped” wild boar meat is sold at a ~25 % lower price by weight than “raw” wild boar meat. Hunters earned ~5,000 Rp/kg (0.58 USD/kg) on average for selling dressed wild boar, which generally weighed between 30 and 50 kg per dressed carcass.

Each wild meat dealer sold 400 kg to 1,100 kg of wild boar meat per week (10–30 wild boars). Together, the nine wild meat dealers in Jambi City sold more than 7500 wild boars and 250 tonnes of wild boar meat in 2011, while a single dealer in Maura Tebo (one of many) sold another 1400–1500 wild boars and 50 tonnes of wild boar meat. This equates to a minimum harvest density of 0.71 wild boar/km²/year for the three regencies surrounding Jambi City. Wild boar is also personally consumed by hunters or traded outside of markets. Further, we did not speak with every dealer in the area (e.g. there were export meat dealers, other wild meat dealers in Maura Tebo, as well as dealers in many smaller towns). Thus, the true harvest density is likely more than double our minimum estimate of 0.71 wild boar/km²/year.

Wild meat dealers reported that their largest customers were local Batak or Chinese restaurant owners who frequently purchased wild boar. However, wild meat dealers outside urban areas also exported their meat, primarily via refrigerated trucks that regularly travel to Medan, a city in North Sumatra that is home to a large Batak population. Wild meat exporters also reported selling meat to Jakarta where there is a demand from Chinese, and Batam Island in Riau to meet demand from Batak there. Dealers and other interviewees reported that the wild boar meat export trade was expanding, made possible by improved road infrastructure associated with the development of the timber and agricultural sectors. However, except for wild boar, trade in wild meat was reported as declining; supplanted by an increasing availability of cheap domestic meat, which is also often preferred for taste.

The meal recall data showed 71 % of respondents reported eating wild meat over the past year. Domestic meat consumption (including domestically raised meats, eggs and seafood) was present in 55.1 % of meals across all respondents based on three meals per day, with little variance between ethnic groups. Wild meat was present in 3.9 % of

meals, representing 6.7 % of all meat servings. Across all respondents, 82 % of all wild meat servings were wild boar, but this was almost exclusively consumed by non-Muslim Batak and Chinese. Muslim Javanese and Malay inhabitants were the only groups that frequently consumed other wildlife, primarily macaques, mouse deer, and porcupines (Javanese 19.7 times per year, Malay 8 times per year).

Crop Raiding Perceptions and Damage

The reports from the Jambi government's agricultural department (Dinas Perkebunan Provinsi Jambi 2012) showed that in 2011, wild boar caused the most damage to oil palm (4.5 million Rp/ha; 526 USD/ha), rubber (7.6 million Rp/ha; 889 USD/ha) and coconut plantations (0.8 million Rp/ha; 94 USD). Corroborating these statistics, 100 % of respondents listed wild boar as causing the most damage to farms when explicitly asked about wildlife pests. Oil palm and rubber crop damage by wild boar was primarily due to their destruction of young trees. Farmers and hunters reported that wild boar practice a diurnal habitat shift, living and nesting in forest fragments or unkempt rubber plantations during the day and feeding in oil palm plantations at night. Corroborating this, hunters only reported to have captured wild boar within oil palm plantations at night and farmers only reported damages from wild boar at night. Further, when questioned, hunters reported that the stomach contents of the wild boar caught in all habitat types, including forest, often contained oil palm fruit. This indicates that wild boar are obtaining an important food source from oil palm plantations and are freely moving between habitats. To minimize damage, it was common for smallholder farmers to hunt in and around their property and for oil palm plantation managers to request hunting in their area, occasionally even paying hunters per boar killed.

Perceptions of the second most significant source of farm damage from wildlife species differed between rubber and oil palm plantations. Rats (*Muridae* spp.) were ranked second for oil palm and indeed caused the second most costly damage in government reports (2.2 million Rp/ha; 257 USD/ha). Macaques (primarily *Macaca fascicularis*, but also *Macaca nemestrina*) were perceived as the second-most damaging pest in rubber plantations, but their damage was not significant enough to be included in any agricultural reports. Elephants (*Elephas maximus sumatrensis*) were never listed by our respondents, but accounted for the third most costly source of damage to oil palm plantations in the agricultural reports (0.8 million Rp/ha; 94 USD/ha); while elephant damage is rare it is severe when it occurs (WWF 2004; Alfred *et al.* 2012). Porcupines and squirrels were reported as occasional but insignificant pests in both oil palm and rubber. Deer were never mentioned as pests.

Discussion

Jambi's 85 % increase in oil palm plantation land from 2000 to 2010 has been accompanied by a 17 % decline in forest cover, 28 % rise in total population, new immigrant populations representing 15–20 % of population growth, and widespread infrastructural improvements and a growing market economy with cheap domestic meats (Tomich *et al.* 2000; Angelsen and Kaimowitz 2001; Hirawan 2011; Margono *et al.* 2012). Our data suggest that these new socio-ecological conditions are shaping hunting strategies and wildlife harvest. First, commercial and cultural hunting were more common within Jambi than subsistence hunting, with wild meat present in just 3.9 % of our respondents' meals. Second, a relatively small proportion of Jambi's rural and urban residents were engaged in hunting; this was indicated by interviewees' responses as well as by the difficulty we faced in locating people who hunted. Third, our results demonstrate that different ethnic groups consistently practiced distinct forms of hunting, preferred different types of wild meat, and consumed different quantities of wild meat. Fourth, our results showed that hunters are overwhelmingly harvesting one species, wild boar, and there is a thriving local and export trade in wild boar meat. Fifth, demand for wild boar has emerged among non-Muslim Chinese and Batak immigrant groups both locally and outside Jambi. Finally, hunting motivations were multiple and interconnected. For example, farmers hunted themselves and also requested that commercial hunters visit their plantations to remove wild boar in order to reduce crop damage. Farmers and commercial hunters then consumed harvested deer meat and usually sold wild boar meat. Thus, hunting within plantations was simultaneously undertaken for pest control, subsistence, and economic gain.

Muslim groups (e.g., Javanese, Minangkabau, and Malay) did not consume wild boar for religious reasons, but would hunt and sell it. Batak prefer wild boar to domestic pork for cultural dishes while Chinese prefer the taste of domestic pork. Chinese people reported using wild boar as a cheaper alternative to domestic pork, particularly in restaurants. Demand from Chinese and Batak populations in other Sumatran provinces was reported as the reason underlying a substantial export of wild boar meat from Jambi, particularly to Batak in Medan. Clayton and Milner-Gulland (2000) describe a similar situation among adjacent but religiously distinct districts in Sulawesi where Christians hunted more actively and consumed more wildlife than their Muslim neighbors, instigating a cross-district wildlife trade.

The low proportion of wildlife consumption by respondents (just 3.9 % of meals) indicates that wild meat is not a critical component of people's diets in the study area. This finding is interesting since hunters may be expected to eat more wildlife than the general population. One explanation

for apparently low levels of engagement in hunting and wild meat consumption may be the widespread availability of domestic meat in Jambi's rural and urban areas, since this constituted the vast majority of meat consumed across all ethnic groups. This mirrors development trends from other studies in region; for example, in remote forested areas of Malaysian Borneo, Bennett *et al.* (2000) found that between 67.1 % and 90.0 % of meals contained wild meat. As they sampled in increasingly market-connected areas, the same study reported that 49.1 % of loggers' and 36.8 % of traditional hunter-cultivators' meals contained wild meat, while only 4.1 % of plantation workers meals contained wild meat. Bennett *et al.* (2000) also found that all communities hunted primarily for subsistence, only also engaging in commercial or sport hunting in areas with oil palm plantations. An important distinction however is that Borneo's Dayak groups are not predominantly Muslim, and thus do not face the same religious restrictions against consuming wild or domesticated pork. In Papua, where oil palm plantations are a recent addition to the landscape, more than half of meals still contained wild meat and 26 % of hunters primarily sought subsistence (Pangau-Adam *et al.* 2012). In comparison to results from these studies, it seems that the low levels of subsistence hunting and wild meat consumption we observed in Jambi reflect a decreasing reliance on forest products in developed plantation landscapes. This hypothesis is consistent with broad development trends in the region and elsewhere (Shively 1997; Angelsen and Kaimowitz 2001; Brashares *et al.* 2011).

Among the hunters we interviewed, those from different ethnic groups used different hunting methods with appreciably different harvest efficiencies. Malays most often hunted with snares for wild meat, which was the most efficient method because it only takes a single hunter a few hours daily to check snares. Minangkabau dog hunts in contrast were the least efficient because they were comprised of 10–300 men hunting all day for social and cultural reasons rather than meat harvest. Full-time Chinese hunters who sold the meat as their primary income source consistently harvested the most wild boar, although their method of herding animals from within oil palm required a substantial total time investment (12–24 h). The Javanese immigrants we interviewed who primarily worked in plantations seemed the least involved with hunting and consumed the least wildlife. This mirrors Bennett *et al.*'s (2000) finding that oil palm laborers in Borneo (also often immigrants) were the least involved in hunting. Our results may also indicate a modernization of hunting technologies since some historical methods, such as blowguns, which are commonly used in Malaysian Borneo (Bennett *et al.* 2000), and bows and arrows, which were still the most common hunting method used in Papua, were never reported by our respondents (Pangau-Adam *et al.* 2012). Shotguns were the primary method used by Malaysian

hunters in Borneo, but air rifles were more common in Jambi (Bennett *et al.* 2000). This is due to firearms being more strictly regulated in Indonesia, causing their usage to be limited to the military or wealthy sport hunters that can afford to obtain guns and licenses (Corlett 2007).

Respondents reported that the novel ecological conditions in Jambi's oil palm plantation landscapes affected the contemporary wildlife community. Specifically, wild boar was reported to be the most abundant large wildlife species in plantation landscapes and the primary source of crop damage to plantations. This result is corroborated by camera trapping study from Jambi, which reported that wild boar accounted for 42 % of wildlife photographs in forests adjacent to oil palm plantations and 82 % of photographs within plantations (Maddox *et al.* 2007). Similarly, high wild boar densities were also reported in Peninsular Malaysia where a forest fragment surrounded by oil palm plantations had 27 boars/km² and 47 boars/km² in two different estimates (Ickes 2001), while natural densities ranged from 3 to 5 pigs/km² (Kawanishi and Sunquist 2004). Such facts are consonant with what might be expected from the feeding habits and reproductive strategies of wild boar; unlike strict herbivores, wild boar are generalists that consume palm fruits and their reproductive rate is higher than other large mammals (e.g. wild boar sexually mature as early as 8 months old and give birth to 1 or 2 litters per year, each with 4–12 piglets; Bieber and Ruf 2005).

Related to the increase in wild boars near oil palm, our data capture how the shift in wildlife is informing farming practices, hunting practices, and livelihood strategies. Oil palm farmers reported that they have adapted their management in response to the new wildlife conditions by more actively hunting wild boar to reduce crop damage as well as investing significant resources in digging trenches and erecting fences (even electric fences; WWF 2004; Alfred *et al.* 2012). In Jambi, oil palm plantation owners have also encouraged hunting around their property and even paid hunters to kill wild boar. Likewise, hunters have developed novel methods tailored towards hunting within oil palm plantations, namely by herding wild boar into nets. The demand for wild boar meat has enabled hunting to be a full-time commercial enterprise. Finally, hunting wild boar can provide an alternative "safety net" resource for communities during crop failures or employment shortages (Brashares *et al.* 2011). In this vein, we wonder if hunting increases when large oil palm and rubber estates replant plantations and there is a temporary (3–5 year) loss in harvesting jobs.

Changing wildlife populations and hunting practices in oil palm landscapes also affects the ecology of remaining forests. For example, wild boar disturb the soil when grubbing, rooting and wallowing, and also consume a large percentage

of the seed bank and kill seedlings to build nests (Ickes *et al.* 2005). In excess, these disturbances are associated with the establishment of invasive species and suppressed tree recruitment (Curran and Webb 2000; Ickes *et al.* 2005; Fujinuma and Harrison 2012). At the other extreme, in Borneo, excessive hunting led to defaunation and instigated dramatic changes in tree recruitment dynamics, likely largely due to the loss of wild pigs (Harrison *et al.* 2013). At the same time, hunting within plantations can potentially serve as a “buffer zone” to core natural areas (Wilkie and Lee 2004). Similarly, hunting pigs may divert hunting pressure from more threatened wildlife species (Naughton-Treves *et al.* 2003). Thus, from a conservation perspective, managing for a natural density of native wild boar is advantageous to maintaining healthy forest ecosystems.

We found that the different hunting methods and locations resulted in different species captured and harvest rates. In particular, hunting wild boar within plantations resulted in the capture of few threatened species. This method may thus be preferable to more indiscriminate methods used in forests, such as snares or dogs. To better identify specific causes and impacts of changing hunting practices, we recommend research that quantifies hunting intensities across forest-plantation landscapes, longitudinal studies, and research in a variety of different locations with different ethnic groups.

Conclusion

Our findings show how changing biophysical and demographic conditions in plantation-dominated landscapes influence contemporary hunting practices and wildlife harvest. First, oil palm development has led to better road networks, increasing access to forests and the potential to bring wild meat to market. Then, the influx of non-Muslim groups has created a substantial rural and urban demand for wild boar meat and thus the ability to earn income from hunting. Hunting motivations, methods and wildlife consumption were closely tied to different ethnic groups and thus affected by immigration. Overall, we found that hunting is no longer primarily a subsistence activity, but done to commercially trade wild boar meat inside and outside Jambi province, as well as to reduce crop damage, and as a cultural activity by the Minangkabau and social or sport activity by wealthy hunters.

In the wake of widespread deforestation, hunting poses a serious threat to wildlife in Southeast Asia’s remaining forests (Sodhi *et al.* 2004; Corlett 2007). Promisingly however, our results demonstrate that the specific hunting methods and locations being used in Jambi may offer clear management opportunities. With many wild boars (*Sus scrofa*) but few threatened wildlife species utilizing oil palm plantations, policies that limit hunting to within plantations may

minimize the harvest of threatened wildlife while maximizing the benefits obtained via hunting. If sustainably managed, hunting wild boar in plantations may satisfy cultural practices, provide meat and income to local people, and reduce damage to crops.

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