

IL242 Ecology of the top mammalian predator in the forests of Sulawesi, Indonesia

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The Malay civet *Viverra zibellina* is one of 35 species of small to medium sized carnivores in the family Viverridae (Nowak 1999). This family, along with the mongooses which some authorities now include within the Viverridae, consists of mostly omnivorous tropical forest-dwelling animals that are often the most numerous members of mammalian rainforest predator communities in Asia and Africa (Charles-Dominique 1978, Rabinowitz 1991, Heydon & Bulloh 1996, Ray 1997, Colón 2002). However, despite their potential importance in Old World rainforest ecosystems as predators, frugivores and pollinators, very little is known about their ecology, largely due to their secretive nature and the inaccessibility of their jungle habitats.

This project explores two crucial elements of Malay civet ecology: 1) population dynamics (the study of how and why populations change over time) and 2) spatial organisation and social behaviour (a long-standing hot topic in carnivore ecology because of the great range of social behaviours displayed within the order Carnivora e.g. Macdonald 1983, Bekoff et al. 1984). Each of these two topics including the findings of the project up to date will be discussed separately in sections below. But first the study needs to be put into geographical context – the project study site on Buton Island, southeast Sulawesi, is out the Malay civet's original range and is ecologically quite different.

The Malay civet on Buton

The Malay civet is found on the Malay Peninsula, Sumatra, Borneo, Sulawesi, the Moluccas and the Philippines. On Buton Island, Sulawesi and nearby islands both the plants and animals are quite different to those in other parts of the Malay civet's range. Notably, on Buton the Malay civet shares its range with a much more limited community of mammalian predators. This is potentially important, because in other habitat types, including many temperate habitats and tropical savannahs, intraguild predation and competition has been shown to be very important in affecting the ecology of mammalian carnivores (e.g. Palomares et al. 1997, Palomares & Caro, 1999, Fedriani et al. 2000). On Buton Island the Malay civet is one of probably only two species of wild mammalian carnivores: although the presence of a second species, the endemic Sulawesi palm civet *Macrogalidia musschenbroekii* has not yet been confirmed, many of the people living around the forest

have a name for a second species of civet matching the description of the Sulawesi endemic, and so it is likely that the elusive Sulawesi palm civet is indeed present in the forests of Buton Island. Feral domestic carnivores including both dogs *Canis familiaris* and cats *Felis catus* are also present in parts of the forest near villages and roads. In contrast, west of the Wallace line on Borneo, Sumatra and the Malay Peninsula the Malay civet shares its habitat with a much bigger suite of mammalian predators. On Borneo, for example, the Malay civet shares its rainforest habitat with 22 other species of mammalian carnivore including eight species of civet (Nowak 1999).

Not only do conditions on Sulawesi and Buton differ ecologically from elsewhere in the Malay civets range, because of their isolation the civets themselves may be genetically distinct from elsewhere in their range. Unlike the big islands of Borneo, Java and Sumatra which were attached to mainland Southeast Asia via the Sunda shelf during the last ice ages, Sulawesi and surrounding islands including Buton remained separated from both the Asian and Australian continents by deep ocean. The Malay civet was introduced to the Wallacea region including Sulawesi and the Molluccas from Borneo by human agency. It's not known when they first arrived on Buton; it could have been as far back as prehistoric times, brought along with the expansion of humans into Sulawesi, as early as 7000 BC (Whitten et al. 1987) or as recently as the seventeenth century when European demand for civet musk for the medical and perfume industries may have triggered the transport of Malay civets to new islands including Sulawesi (Dannenfeldt 1985). Either way, there are perceptible differences in the sizes of Malay civets on Buton from those on Borneo and the Malay Peninsula (Jennings et al. 2006, Jennings et al. 2009), but whether or not these differences have a genetic component is unknown.

Population dynamics of mammalian carnivores

Probably the most famous and long-running of any published time-series of a mammalian carnivore is Elton and Nicholson's (1942) data on the number of pelts of Canadian lynx *Lynx canadensis* obtained by the Hudson's Bay Company each year between 1821 and 1912. These data revealed a dramatic ten-year cycle in the fluctuation of lynx numbers, which were seen to track the abundance of snowshoe hares *Lepus americanus*. Population cycling is easily generated in model predator-prey systems and arises due to "delayed density dependence", the time lag between the effect of the predator abundance on prey

populations and vice versa (e.g. Begon et al. 1990). The lynx population was tracking the abundance of their main prey, the snowshoe hares, though it seems the hares themselves were being affected by the quality and availability of their plant food supply (Sinclair et al. 1988) rather than predation by lynx. Populations of mammalian carnivores are likely to track prey abundance when they specialise on particular prey species and if those prey themselves are prone to fluctuations. This situation is common for specialist predators such as stoats and weasels in boreal regions (e.g. Hanski et al. 1991, Hellstedt et al. 2006). The situation for generalist mammalian Carnivores is less clear, since generalist species can easily switch to other prey types one prey type becomes scarce. This is especially true of omnivorous members of the order Carnivora such as foxes, raccoons, badgers, and many species of civet including the Malay civet, as they may even switch from animal to plant material such as fruit when animal food becomes scarce. For these carnivores, other factors are likely to play an important role in shaping population dynamics.

Disease has shown to be an important factor influencing the abundance of mammalian carnivores. Red fox *Vulpes vulpes* populations in Europe have been shown to crash dramatically in response to outbreaks of sarcoptic mange *Sarcoptes scabiei* infection (Lindström, 1994; Soulsbury et al. 2007). The populations of a range of mammalian carnivores in the Serengeti-Masai Mara ecosystem including lions *Panthera leo* and spotted hyenas *Crocuta crocuta* have been shown to be profoundly affected by an outbreak of the canine distemper virus in 1994 (Roelke-Parker et al. 1996). Civets may be affected by a number of diseases including canine distemper (Ikuyo et al. 2009) and the SARS coronavirus (Bell et al. 2004), though it is not known what roles these pathogens play on civet population dynamics.

Population dynamics of Malay civets on Buton

The numbers of adult Malay civets caught each year has fluctuated from 9 in 2004 to 17 in 2008 (Figs. 1 and 2).

Fig. 1. Minimum number alive count of civets caught in the Buton study area by year

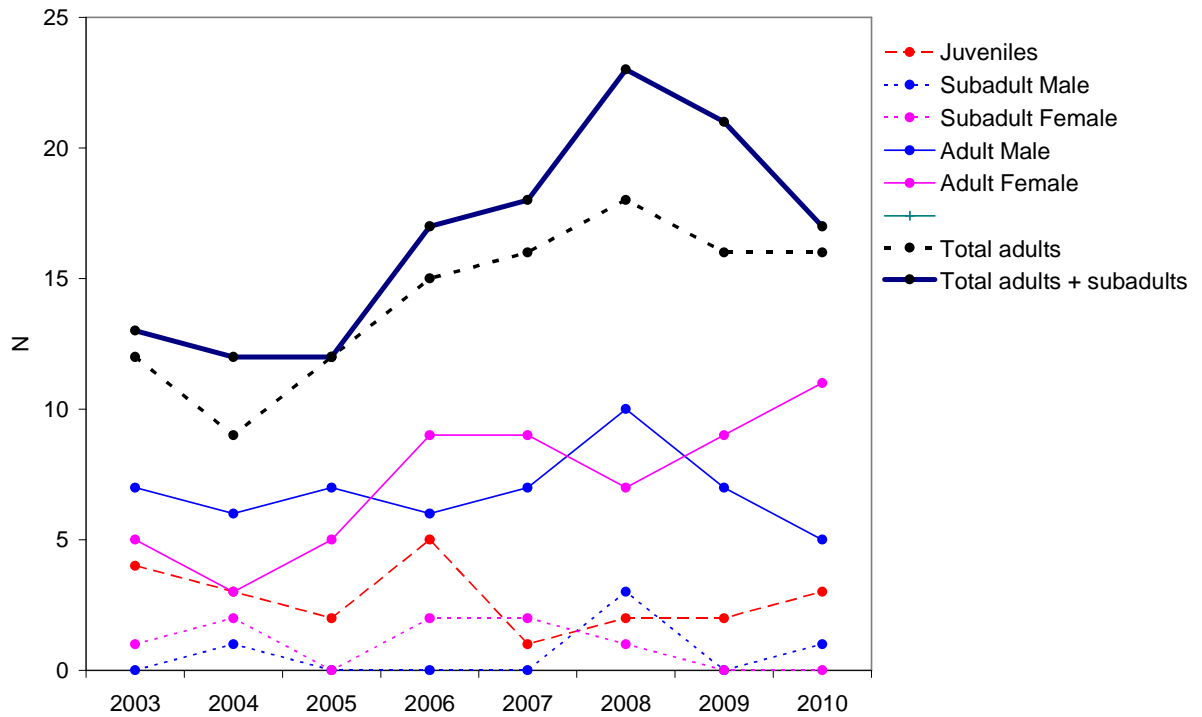
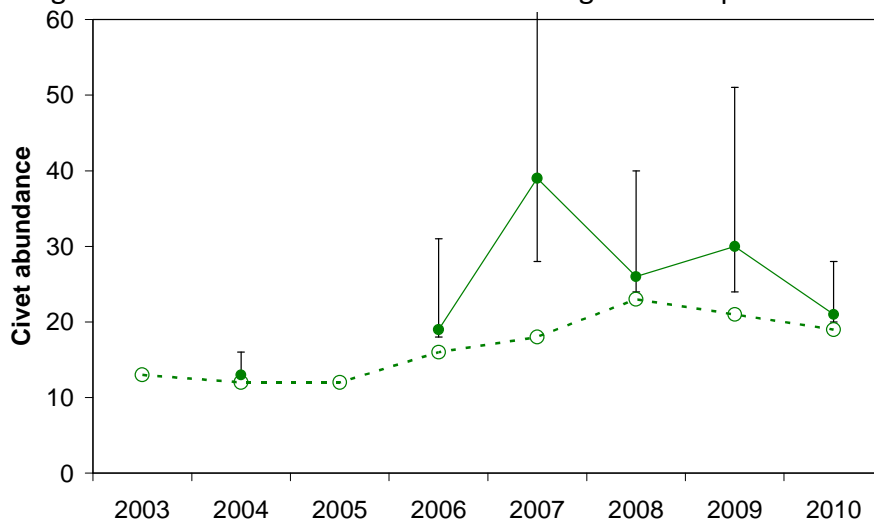


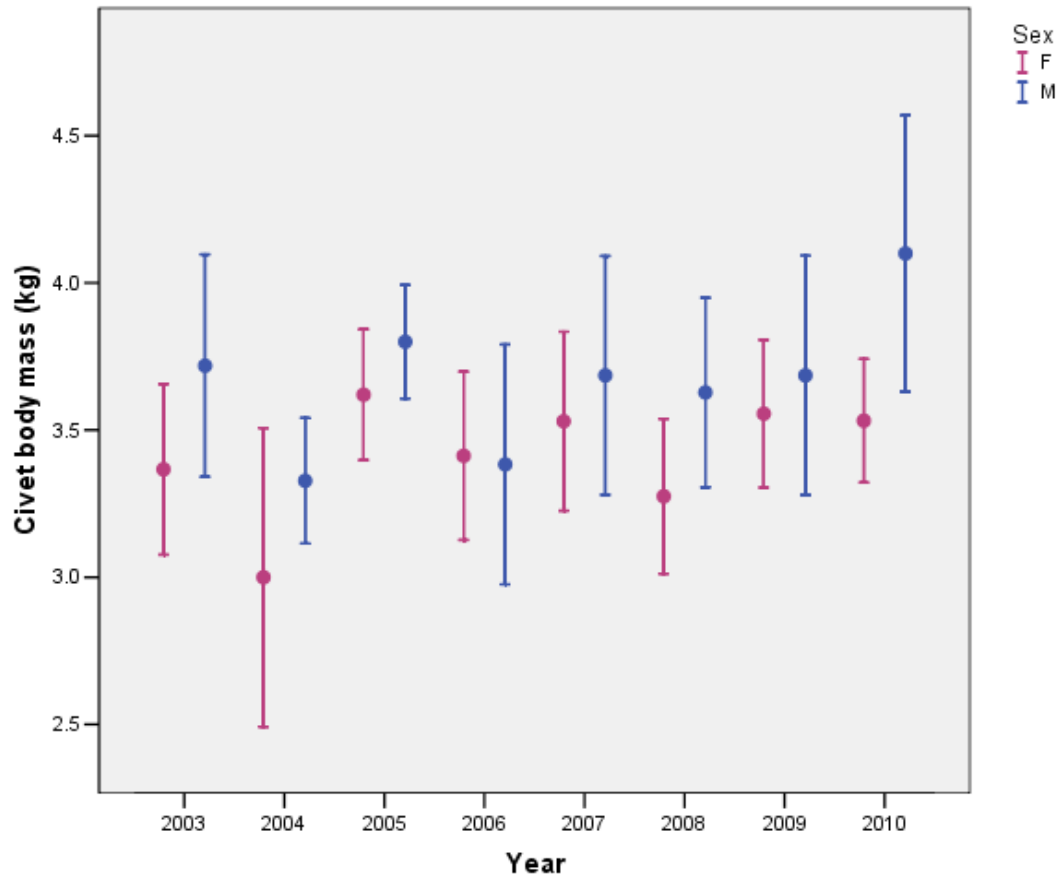
Fig. 2. Abundance estimates \pm 95% CL using closed capture-mark-recapture models



The low abundance of civets in 2004 coincided with behavioural signs of disease (unsteadiness on feet, and slow and erratic departure when released from traps), and low adult body mass (Fig. 3). Although data from the civets caught in 2011 has not yet been processed, initial indications suggest that abundance is again low and adults also show low body masses and signs of disease. Further investigation clearly needs to examine blood tissues for signs of disease including canine distemper. It is interesting that the first signs of

disease since 2004 are happening in 2011 after a sustained run of high civet abundance from 2007-2010. Could it be possible that a disease and civets are showing host-pathogen cycles?

Fig. 3. Mean civet body mass (kg) \pm 95% CI



One of the clearest observations from the capture-mark-recapture is that females are much more likely to be recaptured between years than males (Fig. 4). It is not clear whether this is due to higher female survival or increased female philopatry, but either way, females remain in the study site for longer. Between year recapture rates are much higher in females than males for young age classes (Juvenile, Subadult, Young adult), but this pattern is reversed in the adult age class (Fig. 5).

Fig. 4. Capture history for male and female civets from 2003 to 2010.

Males

Females

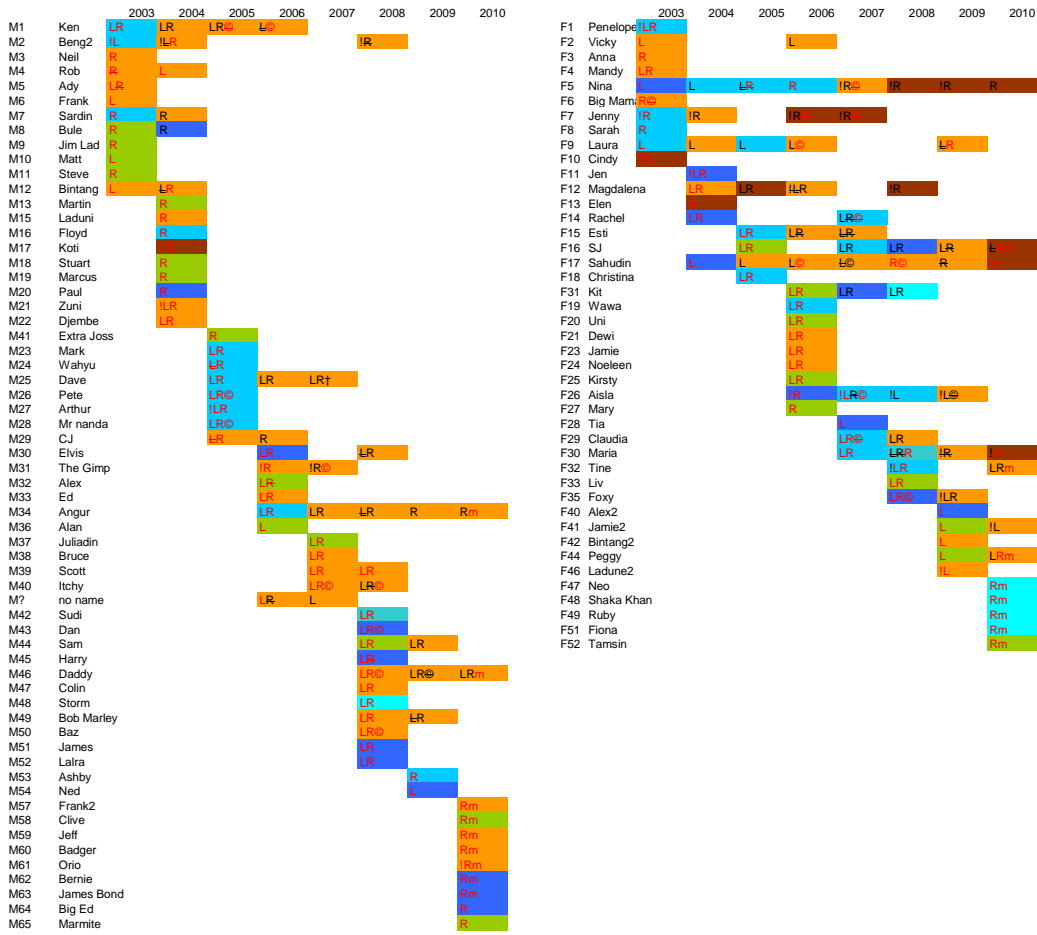
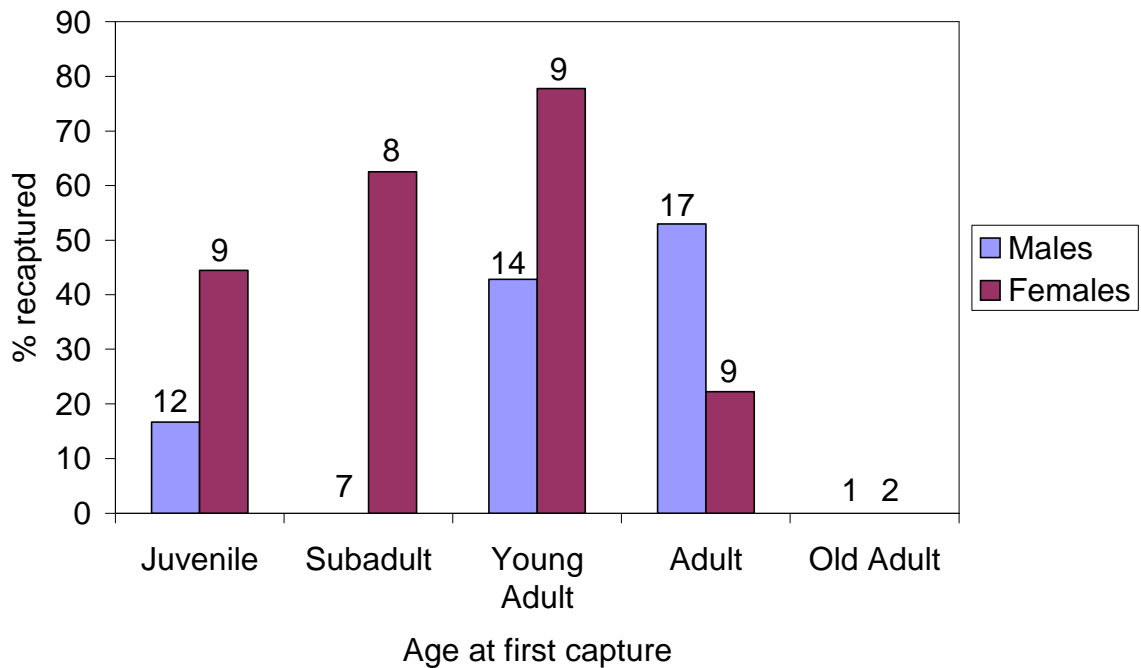


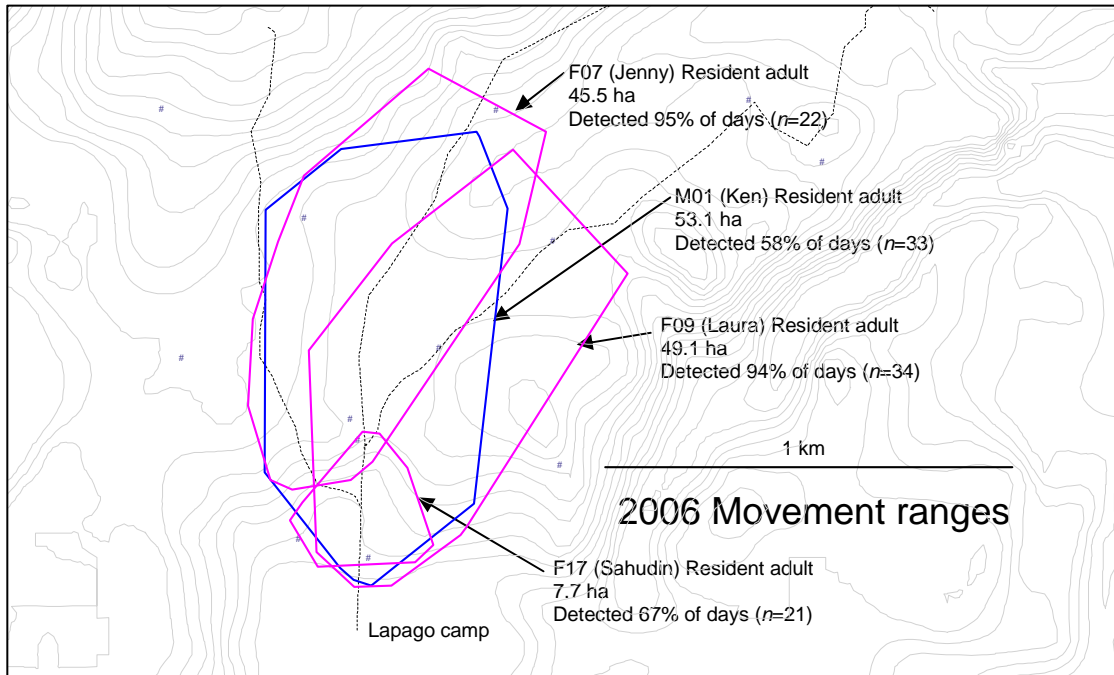
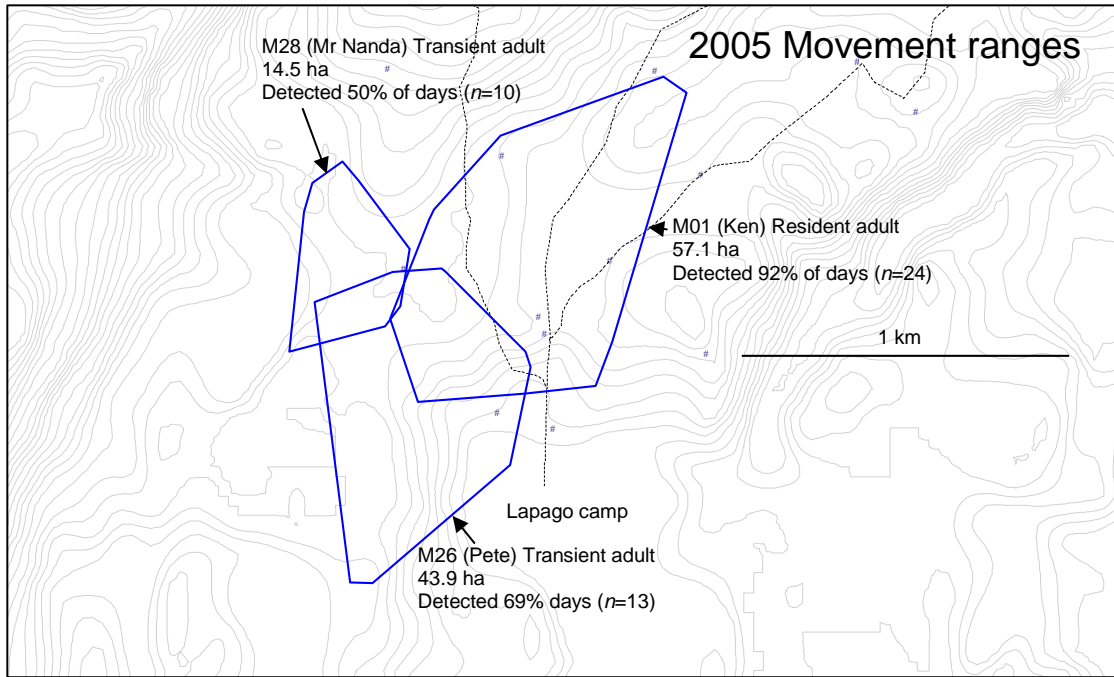
Fig. 5. Percentage between year recapture for male and female civets.

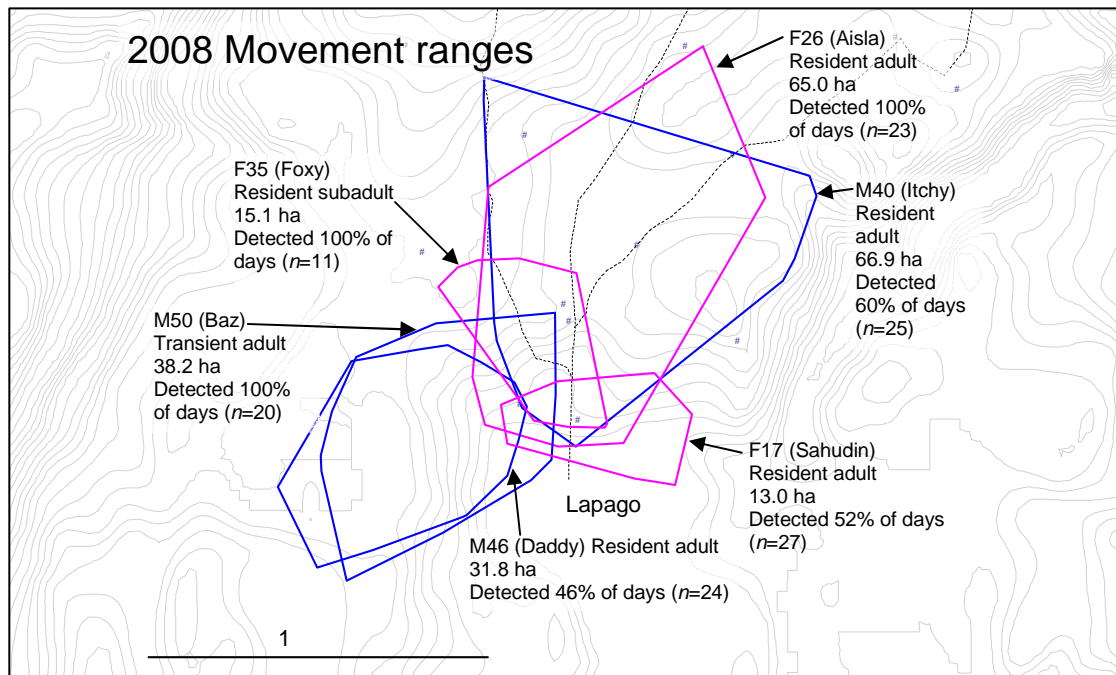
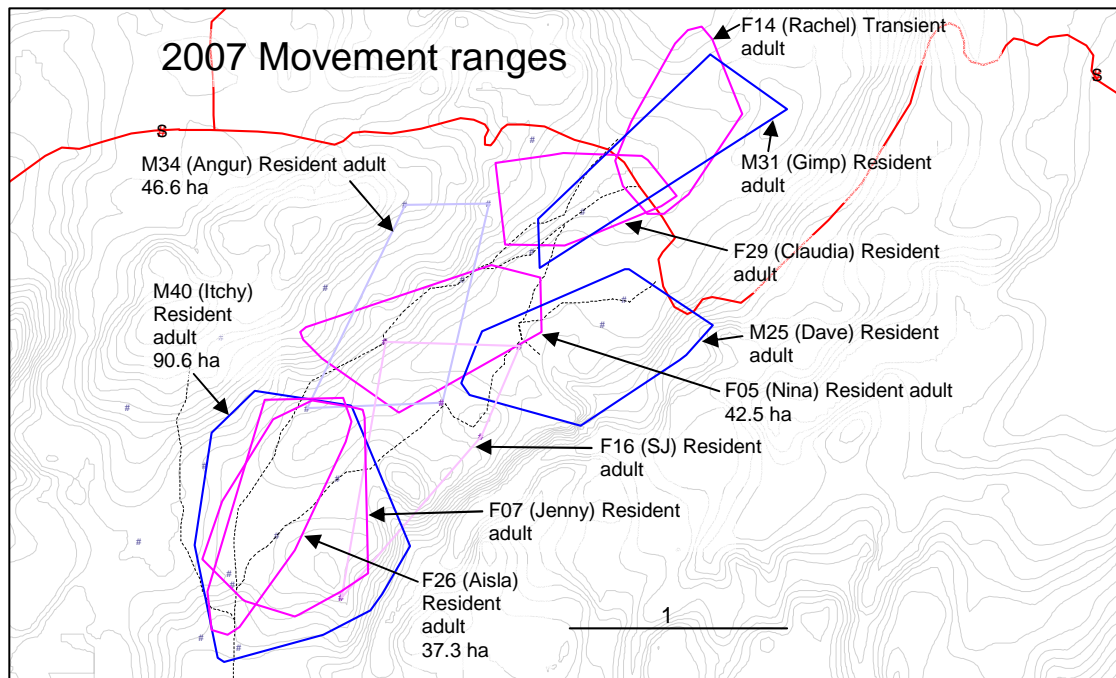


Social organisation of carnivores

Many members of the order Carnivora form complex social groups showing cooperative behaviour, with large species such as wolves *Canis lupus* and lions *Panthera leo* clearly benefiting from living in groups by cooperative hunting and in the case of lions by cooperative defence (female defence of cubs from infanticidal males), and other species such as meerkats *Suricata suricata* and banded mongooses *Mungos mungo* benefiting from group vigilance and alloparental care (Macdonald 1983, Bekoff et al. 1984). But there are many other species from other Carnivoran families, including Canids (e.g. red fox *Vulpes vulpes*), Mustelids (e.g. European badgers *Meles meles*), Procyonids (e.g. Kinkajou *Potos flavus*) and Viverrids (e.g. African palm civet *Nandinia binotata*), where the adaptive significance of group living is much less clear, since these species usually hunt alone, but will often form groups at other times (Charles-Dominique 1978, Baker et al. 1998, Kays & Gittleman 2001). Explaining why these groups are formed has been much harder, and many theories have been put forward. These include the resource dispersion hypothesis (the passive tolerance of additional group members due to the abundance and distribution of food resources: Macdonald 1983, Johnson et al. 2002), the territory inheritance hypothesis (inclusive fitness benefits from allowing offspring to stay in the natal territory when dispersal costs are high: Lindström 1986) and the “anti-kleptogamy” hypothesis (males space themselves to monopolise as many females as possible, defending these territories to ensure exclusive access to several females: Roper et al. 1986). Understanding the ecological conditions that allow multiple stable territories to overlap thus opening the possibility of repeated interaction between individuals is a crucial step in understanding how group living and sociality may have evolved.

Most rainforest Viverrids are considered to be solitary animals, who only come together to mate or when mothers are raising young offspring (Nowak 1999). However, our radio tracking research has shown that the Malay civets on our study site have frequently overlapping ranges (both within and between sexes: Fig.6), and that meetings between collared civets occur quite frequently – any given civet is likely to meet a neighbour at least once per night. Sometimes civets spend long periods in close proximity to each other. Females being the more sedentary, may form long-lasting relationships, however, there seems to be no difference in the frequency or duration of male-male, male-female or female-female interactions, though more analysis needs to be done.





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