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RESEARCH ARTICLE

Long-Term Population Survey of the Sulawesi Black Macaques (*Macaca nigra*) at Tangkoko Nature Reserve, North Sulawesi, Indonesia

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The Sulawesi black macaque (*Macaca nigra*) population at Tangkoko Nature Reserve in North Sulawesi, Indonesia has been the focus of periodic study for over 30 years. The population has shown considerable decline during much of that time. Here we present the results of a long-term population survey of the Tangkoko *M. nigra*, conducted over the past decade, to provide updated information and on-going assessment of the population. Line-transect sampling was conducted annually from 1999 to 2002 and 2005 to 2011 along the same transect during a 2- to 3-week survey period. Although further decline in the population was observed at the outset of the survey, over the subsequent 12-year period we have seen stability in the population parameters with evidence of modest increases in both group and population density. During the 1999–2002 survey periods, there was a mean group density of 3.6 groups/km^2 and a mean population density of 39.8 individuals/km^2. During 2005–2011, mean group density increased to 3.8 groups/km^2 and mean population density was 51.4 individuals/km^2. The 2011 survey data indicated an estimated group density of 4.3 groups/km^2 and a population density of 61.5 individuals/km^2. Given that our transect was located in the core of the Tangkoko reserve, our density estimates should be limited to that area of the reserve. One explanation for the apparent stabilization of the population may be tied to the increasing and sustained number of training and research programs being conducted at the reserve. This collective effort by local and international groups may be helping to reduce illegal activity in the reserve (i.e., hunting and habitat destruction) and generate greater awareness of this critically endangered species. Without the continued vigilance afforded by the existing research and training programs and the support and involvement of the local people, the *M. nigra* at the Tangkoko Nature Reserve will likely face further decline. Am. J. Primatol. 00:1–7, 2012.

Key words: Sulawesi black macaque; *Macaca nigra*; population survey; Indonesia

INTRODUCTION

The Sulawesi black macaque (*Macaca nigra*) population at the Tangkoko Nature Reserve in North Sulawesi, Indonesia has been the focus of periodic study and assessment for over 30 years. Like so many primate populations around the world, the Tangkoko *M. nigra* have suffered the effects of hunting and habitat loss [Lee, 1997; O'Brien & Kinnaird, 1996; Rosenbaum et al., 1998; Sugardjito et al., 1989]. While the decline of many primate populations often goes undetected, the decline in *M. nigra* population at Tangkoko has been well documented. As such, this population has become an important marker in assessing the long-term effects of anthropogenic pressures on the local ecosystem. Continued investigation of this population will provide critical information about future population trends and conservation priorities.

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The extensive survey work of John MacKinnon and Kathy MacKinnon in the late 1970s [see MacKinnon, 1983; WWF, 1980] provided the first estimates of abundance for the *M. nigra* population at Tangkoko and an important baseline for future comparison. Subsequent population surveys in the late 1980s [Sugardjito et al., 1989] and early 1990s [Rosenbaum et al., 1998, and see O'Brien & Kinnaird, 1996] indicated a considerable and progressive decline in this critically endangered macaque population. The primary cause for the decline was thought to be largely the result of hunting for meat and pets [see O'Brien & Kinnaird, 1996, 1997 for more extensive reviews of the *M. nigra* ecology and behavior at Tangkoko].

This report describes the results of a decade-long population survey project conducted annually from 1999 through 2002 and 2005 through 2011 at the Tangkoko Nature Reserve. The annual surveys were conducted to provide updated information and on-going assessment of the *M. nigra* population, especially in light of continued hunting and habitat destruction in and around the reserve. This project is part of an ongoing collaborative program established in 1996 between Sam Ratulangi University, the University of Washington, and the Primate Research Center of Bogor Agricultural University that has helped to facilitate field research, training, and community outreach education programs in primate conservation biology, and to promote the conservation of biodiversity at the Tangkoko and Duasudara Nature Reserves.

METHODS

Study Area

Tangkoko Nature Reserve (Cagar Alam Tangkoko) is located at the northern tip of the Minahasa Peninsula in North Sulawesi, Indonesia (Fig. 1). The reserve covers an area of 3,196 ha and is part of an extended protected area system consisting of the adjacent Duasudara Nature Reserve (4,299 ha) and two recreation parks (Taman Wisata), the Batuputih Recreation Park (615 ha) and Batuangus Recreation Park (635 ha) [Sub Balai KSDA, 1998].

Collectively, the reserves and parks comprise a total protected area of approximately 8,745 ha and are situated around three dormant volcanoes, Mt. Tangkoko (1,109 m), Mt. Batuangus (450 m), and Mt. Duasudara (1,361 m). Once part of an extended forest track, the reserve system is now effectively isolated as a forest fragment, the result of forest conversion of the surrounding area for agricultural use [O'Brien & Kinnaird, 1996]. The Tangkoko reserve is considered the central core of the protected area and has received the greatest level of protection. Although the entire reserve system is often referred to simply as "Tangkoko," for the purpose of this report, we will be referring specifically to the area designated as the Tangkoko Nature Reserve.

The Tangkoko Nature Reserve supports a number of endemic animal species including the red-knobbed hornbill (*Aceros cassidix*), Sulawesi tarictic hornbill (*Penelopides exarhatus*), maleo (*Macrocephalon maleo*), spectral tarsier (*Tarsier spectrum*), and the Sulawesi black macaque (*M. nigra*). The *M. nigra* population at Tangkoko represents one of the largest remaining black macaque populations in the wild. The conservation status of the *M. nigra* is currently categorized as critically endangered by the IUCN Red List [Supriatna & Andayani, 2008]. They were first categorized as Endangered in 1996.

Data Collection

Population surveys were conducted annually from 1999 through 2002 and 2005 through 2011 during a 2- to 3-week survey period (April–May) that coincided with our annual Field Course in Conservation Biology & Global Health held at the Tangkoko Nature Reserve [Kyes et al., 1998, 2008]. The surveys were conducted following line-transect sampling methods outlined by the National Research Council [1981], and similar to those reported in previous studies at the reserve [MacKinnons see WWF, 1980; Sugardjito et al., 1989; Rosenbaum et al., 1998, and see O'Brien & Kinnaird, 1996]. Sampling was conducted along a 3.6-km transect that began near POS 3 and ran up the north slope of Mt. Tangkoko, beginning at an elevation of 8 m asl and climbing to 425 m asl (coordinates: N01° 33′ 44.5″, E125° 10′ 27.8″ to N01° 32′ 01.2″, E125° 10′ 29.4″; see Fig. 1). During 2005–2011, sampling was conducted along the same transect (beginning at the same location near POS 3) continuing up to a distance of 3.2 km. The transect was located in the core of the Tangkoko reserve and in the same area as some of the transects used by the MacKinnons [WWF, 1980]; Rosenbaum et al. [1998, and see OO'Brien & Kinnaird, 1996]; and Sugardjito et al. [1989] in earlier survey work.

The transect was sampled twice a day in a single direction (N to S) during early morning (beginning at ~6:00 a.m.) and late afternoon (beginning at ~2:00 p.m.). Sampling was postponed during periods of rain or high wind. Sampling was conducted by the first two authors, RK and EI, who were joined by three to four field course participants. Individuals walked at a rate of approximately 1.5 km/hr with frequent stops to scan the forest and listen for the macaques. Upon detection, the following data were recorded: time of detection, approximate location along the transect (based on transect number/global positioning system coordinates), perpendicular distance from the transect to the first animal observed (via rangefinder), number of animals observed (and age/sex class), vertical location, general behavior, and direction of

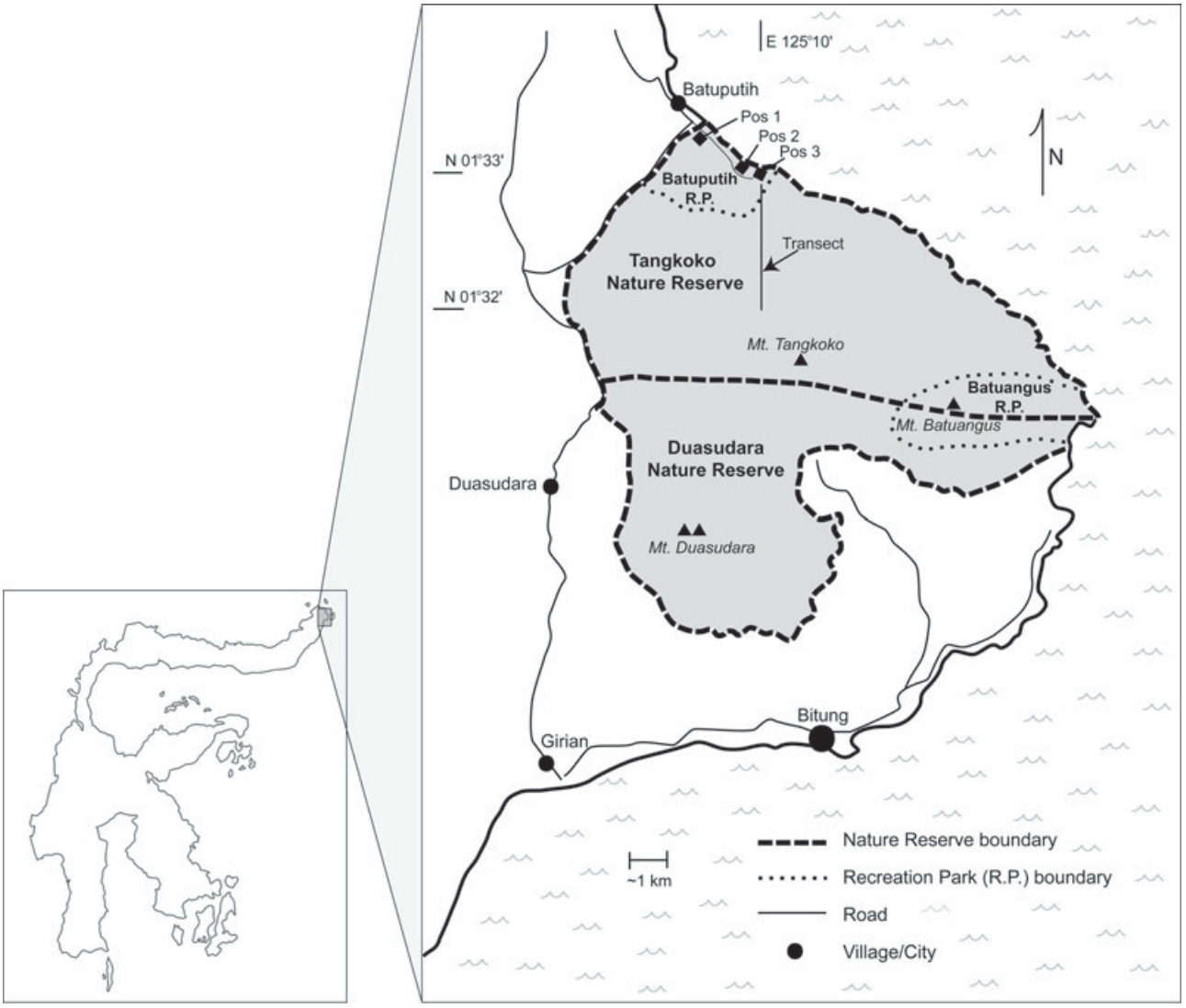

Fig. 1. Sulawesi, Indonesia and the location of the Tangkoko Nature Reserve and study area (boxed cutaway). Adapted from Sub Balai KSDA [1998].

movement. Groups/animals detected were observed for a maximum of 10 min. A detection distance of 50 m was used for this survey project, thereby covering a strip width of 100 m. This was the same detection distance reportedly used by Sugardjito et al. [1989], and Rosenbaum et al. [1998]. Only data involving visual sightings were used for analysis. For the purpose of distinguishing individual groups, we defined a group as two or more individuals separated by no more than 50 m from one another and separated by at least 100 m from members of another "group" [Kyes, 1993]. Only groups of two or more individuals were included in the analyses [a procedural point also noted by Rosenbaum et al., 1998].

To permit comparison of the data with those from earlier studies [i.e., Rosenbaum et al., 1998; Sugardjito et al., 1989; WWF, 1980], density estimates were calculated following methods outlined by the National Research Council [1981]. Additionally, estimates of group density were calculated (by co-author FH) using the software program DISTANCE [Buckland et al., 2001; Thomas et al., 2010], a contemporary standard for analyzing line-transect data. We note however, that some researchers have raised concerns that DISTANCE often overestimates densities of forest primate groups [Lwanga et al., 2011]. Nevertheless, the DISTANCE values were generated to provide baseline comparison for subsequent population surveys at the Tangkoko reserve.

We also calculated the precision of our estimate of the mean number of primate groups encountered for each survey period [as described by the National Research Council, 1981]. The precision of group encounters is the 95% confidence limits of estimated means expressed as the percentage of those means [Mitani et al., 2000]. When the precision values of group encounters reach asymptote, it may be concluded that a sufficient number of survey

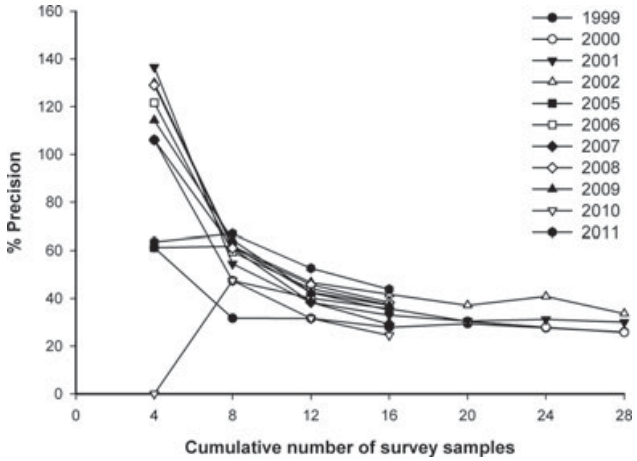

Fig. 2. Precision of estimated mean number of primate groups as a function of the cumulative number of completed survey samples: 1999–2002 (28 survey samples) and 2005–2011 (16 survey samples).

samples have been completed to provide a representative sampling of the transect for a given period of time [Lwanga et al., 2011]. Our research complied with the animal care protocols approved by the Institutional Animal Care and Use Committee at the University of Washington and adhered to the legal requirements and applicable laws of Indonesia, and to the American Society of Primatologists (ASP) Principles for the Ethical Treatment of Nonhuman Primates.

RESULTS

A total of 28 survey samples (representing 100.8 km, 28 samples × 3.6 km) were completed during each annual survey (survey period) for years 1999–2002, and 16 survey samples (representing 51.2 km, 16 samples × 3.2 km) during each annual survey for years 2005–2011. An average of 16 morning and 12 afternoon samples were completed during each annual survey, 1999–2002, and 8.7 morning and 7.3 afternoon samples during 2005–2011. No significant differences in frequency of group encounters (via independent t-test, $P > .05$) were associated with time of day; therefore, morning and afternoon samples were combined for each survey period. Additionally, calculations of precision of our estimate of the mean number of primate groups encountered for each survey period indicated that the number of survey samples conducted was sufficient to generate reliable density estimates (see Fig. 2).

Throughout the entire 12-year period, groups were encountered at various locations along the entire transect, from beginning to end. Single animals were rarely encountered (on average 3.0 times per survey period [range 0–6]) and, as noted above, these data were not included in the density calculations.

During the 1999–2002 survey periods, there was an average of 35.8 group encounters for a mean group density of 3.6 groups/km^2 (see Table I). Group size averaged 11.1 individuals (±SD 1.4; range 2–46). Mean population density was estimated at 39.8 individuals/km^2. During 2005–2011, there was an average of 19.6 group encounters for a mean group density of 3.8 groups/km^2. Group size averaged 13.4 individuals (±SD 1.7; range 2–71) with an estimated mean population density of 51.4 individuals/km^2.

Although the group density estimates are considered true estimates, group size may be underestimated. Group size counts of two habituated groups at the Tangkoko reserve ("Rambo satu" and "Rambo dua") indicated group sizes of approximately 50 animals per group in 1999, increasing to 70+ animals per group by 2009. These two groups frequently traveled on the ground in open areas (e.g., along the beach) thus permitting relatively accurate counts of group members.

Comparison of the data with those from earlier studies (Fig. 3) indicates further decline of the Tangkoko population by 1999. This decline, however, appears to have stabilized with some evidence of modest population growth over the subsequent 12-year period.

DISCUSSION

The results of our long-term survey suggest that the *M. nigra* population at the Tangkoko Nature Reserve is beginning to show evidence of stabilization and modest recovery following years of documented decline [Rosenbaum et al., 1998; Sugardjito et al., 1989; WWF, 1980]. Although we observed a further decline in the population at the outset of our survey project, beginning in 1999, during the subsequent 12-year period, we have seen numeric stability in the population parameters with evidence of modest increases in both individual and group density. For example, the maximum number of groups encountered during a single survey sample per survey period averaged 3.5 (±SD 0.7, range 3–5 groups) with the greatest number of groups/survey sample ($N = 5$) encountered during 2011. We do want to note however, as is often the case in population surveys of forest primates, that our estimates of individual abundance may be conservative underestimates. We believe that the group density estimates are considered a reliable measure of abundance in this study.

Documentation of this positive trend in the *M. nigra* population at Tangkoko illustrates the value and importance of long-term, annual monitoring in helping to understand population dynamics and evaluate potential variables that may be influencing population change [also see Lwanga et al., 2011]. A single-year survey conducted at any point over the past 12-year period would offer differing interpretations of the population status compared to what has been observed via annual monitoring.

TABLE I. Abundance Estimates of the Sulawesi Black Macaques at Tangkoko Nature Reserve, 1999–2002 and 2005–2011

Year	km surveyed	km^2 surveyed	Group encounters	Groups/km^2	Mean group size	Individuals/km^2
1999	100.8	10.08	36	3.6	9.0	32.4
2000	100.8	10.08	36	3.6	11.9	42.8
2001	100.8	10.08	35	3.5	11.9	41.7
2002	100.8	10.08	36	3.6	11.7	42.1
≈						
2005	51.2	5.12	20	3.9	13.8	53.8
2006	51.2	5.12	19	3.7	10.9	40.3
2007	51.2	5.12	18	3.5	11.7	41.0
2008	51.2	5.12	18	3.5	12.5	43.8
2009	51.2	5.12	19	3.7	15.3	56.6
2010	51.2	5.12	21	4.1	15.2	62.5
2011	51.2	5.12	22	4.3	14.3	61.5

Note: Respective group density estimates from DISTANCE (ver. 6.0, release 2) are presented below. Values represented include GD (group density estimate or groups/km^2); CI (95% confidence interval of the GD); %CV (coefficient of variation of the density estimate expressed as a percentage); and ESW (effective strip width). The number of repeats (survey samples) for each survey period is noted in the text. Estimates were obtained using the half-normal model with a cosine adjustment [Buckland et al., 2001].

Year	GD	CI	%CV	ESW
1999	4.3	3.2–5.9	15.73	44.7 m
2000	4.5	3.3–6.1	15.71	43.3 m
2001	4.5	3.1–6.5	18.64	42.0 m
2002	4.6	3.1–6.7	19.54	41.2 m
2005	6.4	3.9–10.4	24.30	33.8 m
2006	4.6	2.9–7.1	21.96	51.3 m
2007	3.9	2.6–6.1	21.05	49.3 m
2008	4.1	2.6–6.6	23.21	47.2 m
2009	5.2	3.2–8.3	23.98	41.7 m
2010	7.1	4.5–11.2	22.62	36.9 m
2011	5.8	3.4–9.9	26.20	43.6 m

While the strength of our data set lies in the long-term sampling over a 12-year period, the ability to generalize or extrapolate our findings to the entire reserve system is weakened due to sampling along a single transect [see Buckland et al., 2010]. Given that our transect was located in the core of the Tangkoko reserve, our density estimates should be limited only to that area of the reserve. It is important to note that the previous studies to which we have drawn comparisons [i.e., Rosenbaum et al., 1998; Sugardjito et al., 1989; WWF, 1980] also sampled along one or more transects in the same area of the reserve.

In an effort to broaden the survey area and provide more representative density estimates, we plan to establish additional transects in other areas of the reserve system for annual sampling, including the Duasudara Nature Reserve and Batuangus Recreation Park. While the Tangkoko Nature Reserve continues to suffer from hunting and illegal logging, the situation in other parts of the reserve system is much worse. Based on reports from reserve rangers and our own observations during a preliminary population survey in the Duasudara Nature Reserve [Laatung et al., 2006], the pressures in that reserve pose a serious threat to the *M. nigra* population. Traps and snares were frequently observed throughout the survey area. Although these capture techniques ostensibly target other animals such as forest pigs [Rosenbaum et al., 1998], the risks to the macaques are considerable. We have even observed two juvenile macaques at the Tangkoko reserve with amputated limbs (at the wrist and ankle) likely the result of being caught in a snare.

Given the on-going anthropogenic pressures at the reserve system, what might account for the increasing stability of the *M. nigra* population at Tangkoko over the past decade? Although this study did not address the factors underlying the apparent stabilization of the population, possible explanations would include a decline in hunting pressure or possibly an increase in food abundance.

Another explanation for the apparent recovery may be tied, in part, to the increasing number and sustained presence of training, research and community outreach education programs being conducted at the reserve. A number of conservation organization such as the World Wildlife Fund and the Wildlife Conservation Society have worked at Tangkoko over the years conducting important research and

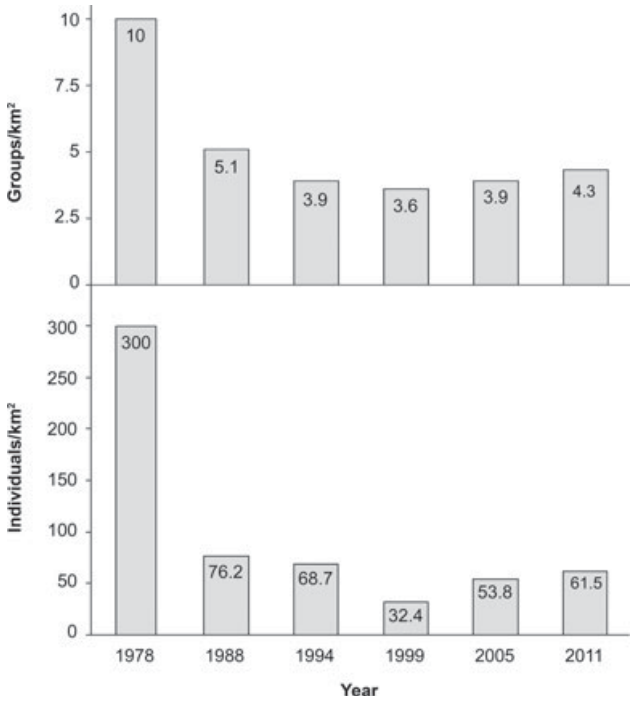

Fig. 3. Estimated group and population (individuals/km^2) densities of *Macaca nigra* at Tangkoko Nature Reserve: 1978–2011. 1978 data from Mackinnon & Mackinnon [see WWF, 1980]. 1988 data from Sugardjito et al. [1989]. 1994 data from Rosenbaum et al. [1998]. 1999, 2005, and 2011 data, from current study. Adapted from Sugardjito et al. [1989] and Rosenbaum et al. [1998].

conservation programs in and around the reserve. These efforts, however, typically have been cyclic without a long-term presence at the reserve. In 1996, our institutional partnership involving Sam Ratulangi University, the University of Washington and the Primate Research Center of Bogor Agricultural University lead to the establishment of the Tangkoko Conservation Foundation (Yayasan Tangkoko Lestari); an organization dedicated to promoting field research, training, and community outreach education as well as support for the management and conservation of the local biodiversity. Although the foundation is no longer active, the associated programs have continued to flourish. For example, we have conducted an annual field training program (field course) at the Tangkoko reserve for local university students and professionals since 1998 [Kyes et al., 1998, 2008], recently completing our 15th annual field course. This 2-week program, titled "Field Course in Conservation Biology & Global Health: At the Human Environment Interface" (formerly Field Course in Primate Behavior and Ecology), has provided training for more than 200 participants to date. The participants have included undergraduate and graduate students and faculty from five local universities, government Forestry Department staff, reserve rangers, conservation NGO staff, local tour guides, and members of local conservation groups in the region.

We also have conducted conservation-related community outreach education programs annually since 2001 for children in the local elementary schools in Batu Putih, a village located at the entrance to the Tangkoko reserve. To date, we have completed 21 outreach programs for more than 500 children. These programs are intended to help promote environmental awareness, an understanding of the relationship with global health, and a sense of commitment to the conservation of biodiversity.

In addition to our on-going research, training and outreach programs, a number of other research groups [Engelhardt & Perwitasari-Farajallah, 2008] and local organizations such as the Tangkoko Ecotourism Guides Club (KONTAK, since 1998) and KPA Tarantula (a regional Nature Group, since 2005) have become active at the Tangkoko reserve helping to provide a better understanding of the *M. nigra* population and improve management and conservation practices. This collective presence may be helping to both reduce the level of illegal activity in the reserve (i.e., hunting and habitat destruction) and generate greater awareness and appreciation of these indigenous macaques. Indeed, over the past few years, there does appear to be growing interest among the youth in the local community to take a more proactive role in the conservation and management of the reserve. Interestingly, it was recently discovered that several of the participants in our annual field course (who are members of the local conservation group KPA Tarantula in Batu Putih) had participated in our educational outreach programs several years earlier when they were children in the local elementary schools [Kyes, 2011].

Although the results of our survey provide reason for optimism, the future of the Tangkoko *M. nigra* remains tenuous. There exists a fragile balance between this critically endangered macaque population and an expanding human presence that requires constant monitoring. In addition to our annual population surveys, we also have begun to address issues of genetic variability and pathogen risk within the macaque population [Kyes et al., 2004, 2007; Paulsen et al., 2006] in an effort to provide a more comprehensive assessment of the population status and long-term viability. Without the continued vigilance afforded by the existing research and training programs and the support and involvement of the local people, the *M. nigra* at the Tangkoko Nature Reserve will likely face further decline.

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Cover Photo: Juvenile Sulawesi black macaques (*Macaca nigra*) foraging in the Tangkoko Nature Reserve, North Sulawesi, Indonesia.

Courtesy of: Randall C. Kyes

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