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Research Article

Water-body use by Asian elephants in Southern Sri Lanka

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Abstract
We assessed water-body use by elephants through monitoring elephant signs around them. Elephant footprints and dung piles were recorded at 25 water bodies fortnightly for one year. Elephants preferred perennial water bodies and avoided those with temporary human dwellings. Human activities did not significantly affect elephant use of water bodies, suggesting low incidence of activities and behavioral adaptation to them by elephants. Elephant signs at perennial water bodies increased in the dry season. The monitoring technique was able to detect differences in elephant densities in two areas and establish the presence of herds even at low densities. We conclude that outside protected areas, large perennial water bodies represent a preferred resource for elephants, and that assessing elephant signs around water bodies is a useful technique for monitoring elephant presence for management and research purposes.

Keywords: Asian elephant, *Elephas maximus*, Water body, Wildlife monitoring, Elephant drive

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Introduction

Water availability may have a strong influence on the ranging behavior and distribution of wildlife in general and elephants in particular [1-3]. As water bodies draw elephants from the surroundings, their survey could provide an easy and reliable method of detecting elephant presence in an area. In the dry zone of Sri Lanka, the landscape is dotted with innumerable water bodies (tanks) built for irrigated cultivation [4]. The main method of creating tanks consists of building earth dams to collect surface runoff or damming a watercourse. Tanks range in size from small seasonal ponds to large perennial reservoirs thousands of hectares in surface area. Elephants regularly use such tanks both within and outside protected areas. Increasing water availability is one of the main methods of habitat enrichment for elephants, and considerable conservation funds are spent in the development of water bodies within protected areas in Sri Lanka (pers. obs., PF). However, no information is available on whether elephants preferentially use particular types of water bodies.

Asian elephants (*Elephas maximus*) mostly inhabit low-visibility forest habitats [3] similar to those used by African forest elephants (*Loxodonta cyclotis*) [5]. Thus, Asian and African forest elephants are likely to have a closer ecological affinity to each other than either has to African savannah elephants (*Loxodonta africana*), which inhabit open savannah grasslands. The majority of Asian elephant range has been densely populated by humans for millennia, and elephants frequently come into contact and conflict with people. As a result most Asian elephants are behaviorally adapted to avoid humans [3]. Unlike in open African savannahs, direct observations of elephants are of limited applicability in assessing elephant presence and densities in forests [5]. In consequence, distribution maps for Asian elephants are few, and available information is mostly based on “expert opinion” of elephant occurrence (for example, see [6]) and do not provide any information on their relative abundance, seasonality, or demography.

Indirect techniques such as dung counting on line transects [7], genetic-mark-recapture [5], photographic identification [8], and camera trapping [9] can provide detailed information. However, their laboriousness, technical complexity, and high cost preclude wide application, making them of limited relevance for wildlife management. Therefore, a simple technique that provides reliable information on elephant presence would be of great value for the management and conservation of Asian elephants.

One of the key techniques in Asian elephant management in Sri Lanka and other range countries is the “elephant drive,” used to remove elephants from extensive areas, usually as a prelude to development [10]. Elephant drives consist of coordinated action by a large group of people who chase the elephants by shouting, lighting firecrackers, and shooting. In July 2005 an elephant drive was conducted to remove all elephants from areas adjacent to the Yala National Park. An electric fence on the park boundary subsequently prevented the elephants from back-tracking. Anecdotal evidence suggested that the drive only decreased the density of elephants from the drive area outside the park. The situation provided us with an opportunity for testing whether “monitoring water bodies for elephant signs” could detect the presence of elephants at low densities, distinguish differences in densities, and provide basic demographic information on whether only adult males or both adult males and herds remained in the drive area.

The objectives of this study are to investigate patterns and determinants of water-body use by elephants, and to evaluate monitoring water bodies for elephant signs as a technique for assessing elephant presence, basic demography, and relative densities.

Methods

The study area covers a strip of land approximately 50 km^2 in extent along the Southwest boundary of the Yala National Park and an adjacent area of approximately 10 km^2 inside the park. Outside the park the vegetation consists of secondary scrub forest and shifting agriculture fields, while on the inside it is dominated by mature scrub forest. At the time of the study, 24 tanks were present in the outside area, of which 21 were monitored. Within the park four tanks [Bandu Wewa (#1), Bembawa Wewa (#2), Palatupana Wewa (#4), and Aliolu Wewa (#13)] situated along the park boundary were selected (Fig. 1). There were additional tanks inside the park, at distances of over 500 m from the boundary, which were not monitored.

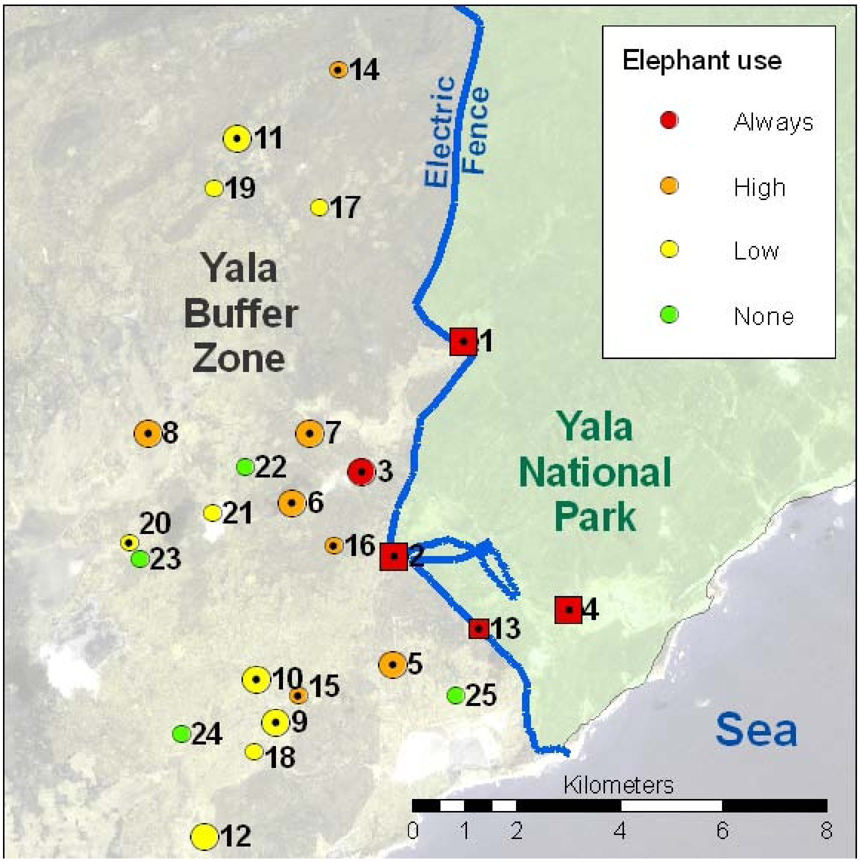

Fig. 1. Locations of the 25 tanks monitored. Tanks marked with a square are in the Yala National Park. The size of the marker reflects the tank size category (large or small). Presence of juveniles is indicated with a black dot.

From October 23, 2005, to October 12, 2006, the 25 tanks were monitored twice a month. The tanks were classified into “large” (N=12; >50 ha when full) and “small” (N=13; <50 ha when full; Table 1). A tank was designated “seasonal” if it dried up for at least 1.5 months (N=15) and “perennial” (N=10) otherwise (Table 1). Based on rainfall data we defined the dry season as the period from the beginning of May to September 20, 2006, and the rainy season for the rest of the year. Consequently nine visits (#14-22) were conducted during the rainy season.

Tanks were also categorized according to indicators of human disturbance, including presence of permanent buildings or temporary huts on the tank perimeter, paddy or vegetable cultivation adjacent to the tank, fishing, lotus flower collection, presence of livestock, and poaching (Table 1). Fishing was defined as the use of nets to catch fish by wading or by boat, and excluding occasional fishing by rod and line; presence of livestock as the herding or corralling of cattle or water buffalo on the tank bed or perimeter and excluding the presence of livestock without such activity; and poaching as the presence of constructed pits/hides on the tank perimeter or tank bed, for lying in wait to shoot animals.

Table 1. Characteristics and results (number of visits) of the 25 tanks monitored 24 times from Oct. 2005 to Oct. 2006.

No.	Tank name	Tank characteristics										Tank status			Elephant signs	
		Size	Perennial	Permanent	Temporary	Paddy	Vegetable	Fishing	Lotus	Buffalos	Poaching	Full[d]	Dry	None	Elephants	Juveniles
1[a]	Bandu Wewa	Large	yes	yes	no	yes	yes	yes	yes	yes	yes	1	0	0	23	18
2[a]	Bembawa Wewa	Large	yes	no	no	no	no	yes	yes	yes	yes	0	0	0	24	18
3	Rotawala Wewa	Large	yes	no	no	no	no	no	no	yes	yes	4	0	0	20	12
4[a]	Palatupana Wewa	Large	yes	yes	no	no	no	no	no	yes	no	1	0	0	23	11
5	Orukema Wewa	Large	no	no	yes	no	yes	yes	no	yes	yes	9	6	1	8	2
6	Divulpathana Wewa	Large	yes	no	no	yes	yes	yes	yes	yes	yes	0	1	5	18	9
7	Thabarawa Wewa	Large	no	no	no	yes	yes	yes	yes	yes	yes	0	7	6	11	5
8	Gonapattiya	Large	yes	yes	yes	yes	yes	yes	yes	yes	yes	13	0	4	7	2
9	Nimalawa	Large	yes	no	yes	yes	yes	yes	no	yes	yes	0	2	13	9	2
10	Lolugas Wala	Large	no	yes	yes	yes	yes	no	no	yes	no	0	5	14	5	3
11	Amara Wewa	Large	no	no	no	no	no	no	no	yes	yes	0	10	11	3	2
12	Kattadi Wewa	Large	yes	yes	yes	yes	yes	yes	no	yes	no	0	0	22	2	0
13[a]	Aliolu Wewa	Small	no	no	no	no	yes	no	no	yes	yes	0	7	0	17	13
14	Dalukkema Wewa[b]	Small	yes	no	no	yes	yes	no	no	yes	yes	0	1	1	7	5
15	Nimalawa 2[c]	Small	no	no	no	yes	no	no	no	yes	no	0	6	2	6	3
16	Muwan Wewa	Small	no	no	yes	no	no	no	no	yes	yes	0	8	4	12	3
17	Galara Wewa	Small	no	no	no	no	no	no	no	yes	yes	0	15	6	3	0
18	Punchi Wewa 1	Small	yes	no	yes	yes	yes	no	no	no	yes	14	1	6	3	0
19	Aluth Wewa	Small	no	no	no	yes	yes	no	no	yes	yes	7	10	5	2	0
20	Ruwan Wewa	Small	no	no	yes	no	no	no	no	yes	yes	0	7	14	3	1
21	Punchi Wewa 2	Small	no	no	no	no	yes	no	no	no	yes	2	9	12	1	0
22	Karabudange Wewa	Small	no	no	yes	yes	yes	no	no	yes	yes	9	10	5	0	0
23	Punchi Wewa 3	Small	no	no	yes	no	yes	no	no	yes	yes	0	18	6	0	0
24	Debaragas Wala	Small	no	no	yes	yes	yes	no	no	yes	yes	9	6	9	0	0
25	Robiyal Wewa[c]	Small	no	no	yes	no	yes	no	no	yes	no	0	5	9	0	0

[a]Located inside the Yala National Park; [b]Could not be monitored during the cultivation period (October to May); [c]Tank newly built during the study, monitoring started mid-March; [d]No data collected because the tank was too full to walk around it

The tanks were monitored by walking around them at a distance of 10 m from the waterline. The presence of elephant footprints at the edge of water and the number of dung piles up to 30 m from the observer (40 m from the water line) were recorded. At a few water bodies it was not always possible to walk around the entire perimeter due to dense vegetation when they were completely filled.

For each dung pile, the distance from the water's edge was recorded and the circumference of up to 3 boli was measured. Piles with dung boli of > 45 cm circumference were assigned to adult males, of 35-45 cm to adult females/subadult males and of < 35 cm to juveniles. Dung piles were broken up after recording to prevent recounting at the next visit. Additionally, footprints were assessed to indicate presence or absence of elephants and estimate the number of animals. Prints of < 75 cm circumference were assigned to juveniles. For any visit, elephant presence was affirmed if either dung piles or footprints or both were found.

Over the whole study period, an index of elephant use of each tank was defined as the ratio between the number of visits where elephant signs were observed and the total number of visits to this tank (excluding the visits when there was no water). The index of juvenile elephant use was calculated analogously. We tested the relationship of elephant use to 10 categorical tank variables using JMP 8. As many of the potential explanatory variables are strongly correlated with each other, we used a principal-components analysis (on correlations, varimax rotation of principal components with eigenvalues larger than 1) to find an orthogonal set of variables. Then, a generalized linear model was built with elephant-use index as dependent variable, and the four principal components as independent variables. Alternatively, we applied a stepwise forward regression procedure including all 10 independent variables to find the most influential effects. The two resulting effects were then additionally subjected to a nonparametric test (Wilcoxon signed rank, two-sided). Annual variation in use was studied based on dung data from the three tanks in the park that held water throughout the year.

Results

Elephant presence was detected at water bodies in the study area throughout the year (Table 1). Signs from juveniles were observed at 12 out of 21 tanks outside the park and all four tanks within the park (Table 1). In total, 364 dung piles were sampled in the outside area and 2,036 within the park. The total number of dung piles per tank over the study period was 17.3±23.9 (N=21) in the outside area and 509.0±204.6 (N=4) in the park. The average number of dung piles detected per visit per tank was 1.3±3.2 (N=275) in the outside area and 23.7±24.7 (N=86) in the park.

Elephant use of water bodies could be categorized into four groups, “none,” “low,” “high,” and “always,” with low use represented by elephant signs observed during less than 50% of visits and high use during more than 50% of visits.

Four tanks (#22-25) were not used by elephants at all. These four tanks were small and completely dried up during the dry season (Table 1). One of them was constructed during the study period. Nine tanks were in the “low-use” category, of which four were large (#9-12) and five were small (#17-21). Eight of them dried up during the dry season; only #12 held water throughout the year. At five of these tanks no signs of juveniles were found (Table 1). Seven tanks were in the “high-use” category, of which four were large (#5-8) and three were small (#14-16). Six of them dried up in the dry season. All “high-use” tanks showed signs of juveniles.

For five tanks, elephant use was detected on all visits, of which four were large (#1-4) and one (#13) was small (Table 1). Only the small one dried up in the dry season. Four of the tanks in the “always’”category were located in the park (Fig. 1). Signs of juveniles were found on more than 50% of the visits to four of the tanks and 47.8% of visits to the other (#4).

Table 2. Factor loadings of the principal-components analysis, rotated factors with eigenvalues larger than 1. Loadings > 0.4 are indicated in bold face.

Factor	1	2	3	4
Percent variance explained	32.452	17.219	16.158	10.256
Variable				
Size	**0.796**	-0.078	-0.315	0.217
Seasonality	**0.705**	-0.009	-0.274	-0.361
Permanent dwellings	**0.402**	0.171	***-0.780***	0.019
Temporary dwellings	-0.321	**0.648**	-0.177	0.266
Paddy cultivation	0.322	**0.684**	-0.132	-0.148
Vegetable cultivation	0.102	**0.869**	0.103	-0.163
Fishing	**0.851**	0.279	0.054	0.206
Lotus flower collection	**0.855**	0.053	0.206	0.063
Livestock presence	0.182	-0.114	-0.115	**0.882**
Poaching	0.178	0.010	**0.880**	-0.099

Table 3. General linear model of factors influencing elephant use. A) Elephant use and B) juvenile use index as response, principal components (cf. Table 2) as effects.

Response	Term	Estimate	t ratio	Prob> |t|
Elephants	Factor 1	21.188	3.51	0.002*
	Factor 2	-16.670	-2.76	0.012*
	Factor 3	0.563	0.09	0.927
	Factor 4	0.019	0.00	0.998
Juveniles	Factor 1	14.482	3.32	0.004*
	Factor 2	-11.823	-2.64	0.016*
	Factor 3	0.274	0.06	0.952
	Factor 4	-0.496	-0.11	0.913

To assess the effect of potential correlates of elephant use, we subjected the 10 highly intercorrelated variables (size of tank, seasonal or perennial, presence of permanent buildings or temporary huts, paddy or vegetable cultivation, fishing, lotus flower collection, livestock presence, and poaching) to a principal components analysis (Table 2). The first factor, explaining 32% of the variation, indicates the overall tank quality, loading on size and perennial water content, and at the same time preference of humans (permanent settlements, fishing, and lotus-collecting activities).

The second factor accounts for 17% of total variation and is mainly loading on temporary settlements and human cultivation (paddy or vegetables). The third factor represents poaching activities and the absence of permanent settlements, whereas the fourth represents the presence of livestock. Both elephant use and presence of juveniles are positively correlated with factor 1 and negatively with factor 2 (Table 3), whereas factors 3 and 4 do not show an effect. Using a stepwise regression procedure to explain elephant use, a model with two effects was selected: temporary human dwellings exert a negative effect (p=0.008), and perennial water content is a positive correlate (p=0.021). For the presence of juveniles, the same two effects were selected (temporary settlements: p=0.001, negative; perennial water content: p=0.013, positive), but additionally the presence of buffalos and cattle showed a positive trend (p=0.057). These two effects were also confirmed in a nonparametric test (Fig. 2).

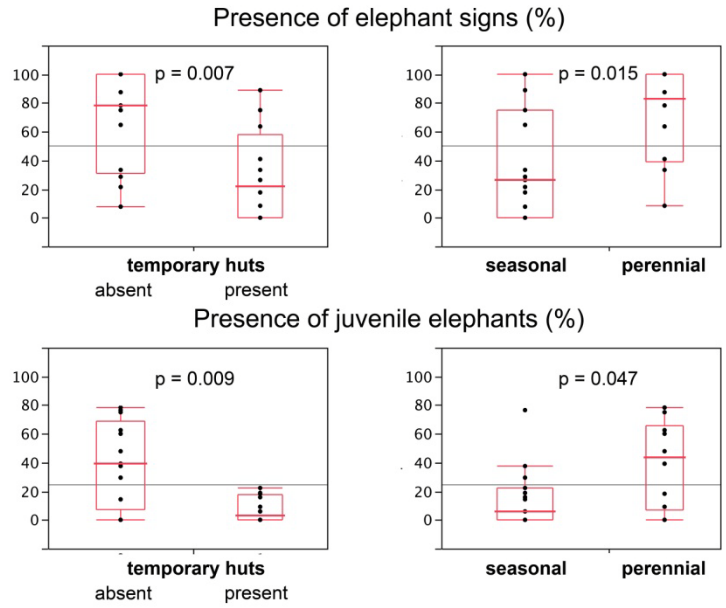

Fig. 2. Correlates of elephant presence. Perennial tanks are more frequently visited by elephants and exhibit more signs of juvenile elephants. The presence of temporary huts affects the presence of elephants negatively. The p-values indicate the results of Wilcoxon signed-rank tests.

The seasonal intensity of tank use by elephants was assessed based on data from the three perennial tanks inside the park where elephant presence was detected on all visits. The intensity of elephant use as indicated by the number of dung piles was low in the wet season and increased in the dry season (Fig. 3). The number of dung piles found at each of the three tanks during the dry season was significantly higher than during the wet season (Mann-Whitney U test, $\alpha < 0.05$).

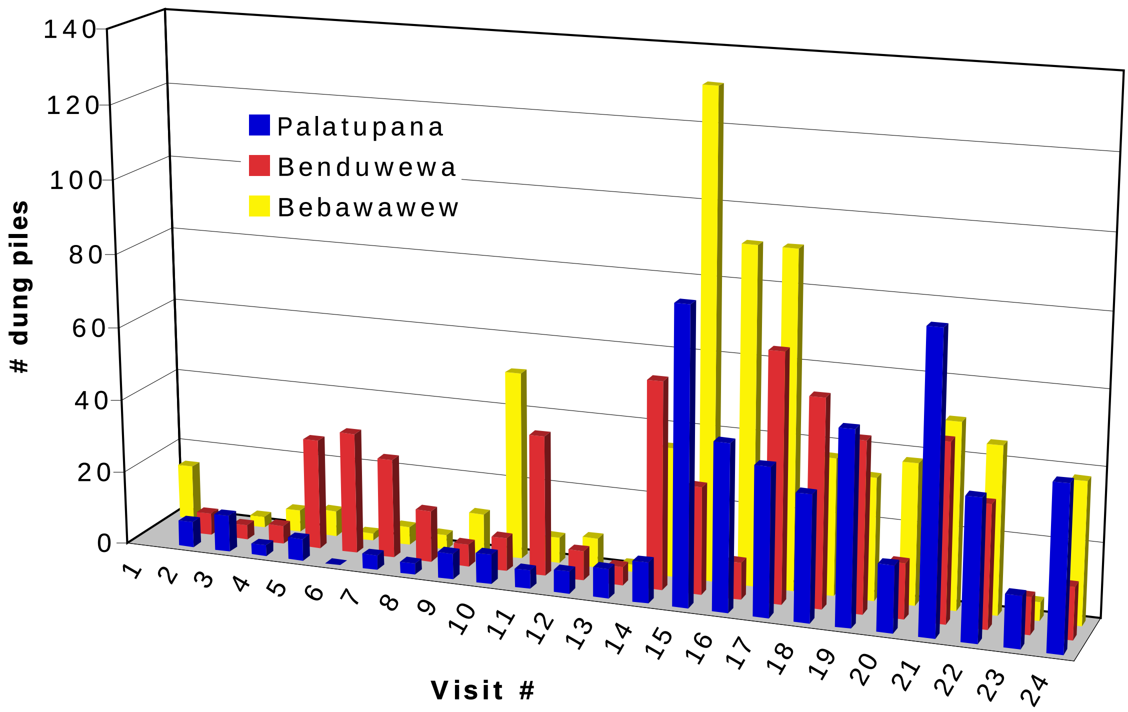

Fig. 3. Number of dung piles found per visit (Oct. 2005 to Oct. 2006) at three tanks inside the Park. Visits #14-22 were during the dry season.

Discussion

Patterns and Determinants of Water Body Use

Our results indicate that elephants do not use all available water bodies evenly. Overall, elephants use perennial tanks more frequently and show a preference for tanks without temporary human settlements. As elephants have a sexually dimorphic social structure with females and young forming herds and largely solitary adult males, signs of juveniles indicate the presence of herds (Fig. 4a). Thus, our results show that herds exhibit largely the same pattern of tank use as single individuals.

Elephants showed a preference for perennial tanks (Fig. 4b). As visits where a tank was found to be dried out were not included in our calculation of the elephant-use index, the preference of perennial tanks is not biased by seasonal water content. On the other hand, our finding of greater use of perennial tanks is consistent with a conservative preference of elephants to stick with a source rather than switch between sources. A perennial tank could be used throughout the year, whereas use of seasonal tanks would necessitate switching to another source in the dry season. Continuation with a single source has obvious advantages in greater familiarity and knowledge of surroundings and human activities at the location, which may influence elephant preferences.

Further, elephants showed a preference for tanks without temporary human dwellings. Such dwellings are erected by seasonal cultivators during the growing season, are fairly numerous, and commonly situated all around the tanks (Fig. 4c). Seasonal cultivators chase away elephants coming to water because they fear elephants would raid their crops and because some view elephant consumption of water as a significant cause of water loss, especially from seasonal tanks. Therefore, hostile human presence as indicated by temporary dwellings deterred elephants from using such tanks.

The cluster of five co-related characteristics denoted by factor 1 in our principal-components analysis (water-body size, seasonality, presence of permanent dwellings, fishing, and lotus collection) had a positive effect on elephant use of water bodies. In contrast, factor 2 composed of temporary dwellings and paddy and vegetable cultivation showed a negative influence on elephant use of water bodies.

As water-body size is strongly correlated with perennial water content, elephants also prefer larger over smaller tanks by using perennial tanks more frequently. Although tank size does not show up in a multivariate analysis as an independent effect, there are reasons why elephants prefer larger tanks. The longer perimeter in large tanks could provide greater security for elephants in accessing water, wherein some parts of the tank are likely to be secluded and free from human presence and disturbance. With smaller tanks, approaches for accessing water would be more limited and more likely to be subject to human influence. Furthermore, water quality could have a bearing on elephant use and also be correlated with size and seasonality. In our study, although not assessed in any chemical analyses, no obvious differences in water quality were observed, with all tanks apparently containing good-quality fresh water.

In contrast to temporary human dwellings, presence of permanent buildings did not deter elephants from using a tank. This result is not as unexpected as it may seem, because permanent buildings in two of the four cases were within the park and were constructed as animal-viewing lodges and/or housing for park personnel. The two instances of permanent buildings on tanks outside the park were houses whose owners are not directly associated with cultivation. Although not relevant to elephant use, our results also showed that presence of permanent buildings decreases poaching.

In contrast to cultivation, other human activities such as lotus collection and fishing at the tanks did not affect elephant use negatively (Fig. 4d). Rather, as these activities are most frequent at large, perennial water bodies, they correlate positively overall with elephant use, although they don't show an independent effect. In any case the assessed activities occurred at low intensity in the study area. Fishing and lotus collection may not disturb elephants because they occur during the day, whereas elephants have adapted to being more active nocturnally [3], including visiting tanks mainly during the night.

The presence of cattle or buffalos and poaching activities did not affect elephant use of tanks at all. While poaching is more a nocturnal activity, it was at a very low intensity and since elephants were never the target its impact on elephant use may be low.

Two small tanks were newly built during the study period. One already had elephant signs the first time it was monitored in March 2006 and in June there were also footprints of juveniles, indicating that elephants including herds are quick to discover and use new water sources.

Elephant Drive

The results showed that elephants were still present in the drive area throughout the year after the drive, including both single males and herds. Therefore our findings confirm that the drive failed to eliminate elephants from the drive area. Drives tend to remove only a fraction of elephants from an area, as they cannot remove aggressive individuals used to conflict [10]. In the study area, crop raiding is almost exclusively by males, and herds raid rarely if at all. Therefore the failure of the drive to remove some herds points out the inability of drives to even remove all non-conflictive elephants. However, by exposing them to a high level of confrontation it is possible that drives make even such elephants more accustomed to conflict, leading to increased human-elephant conflict.

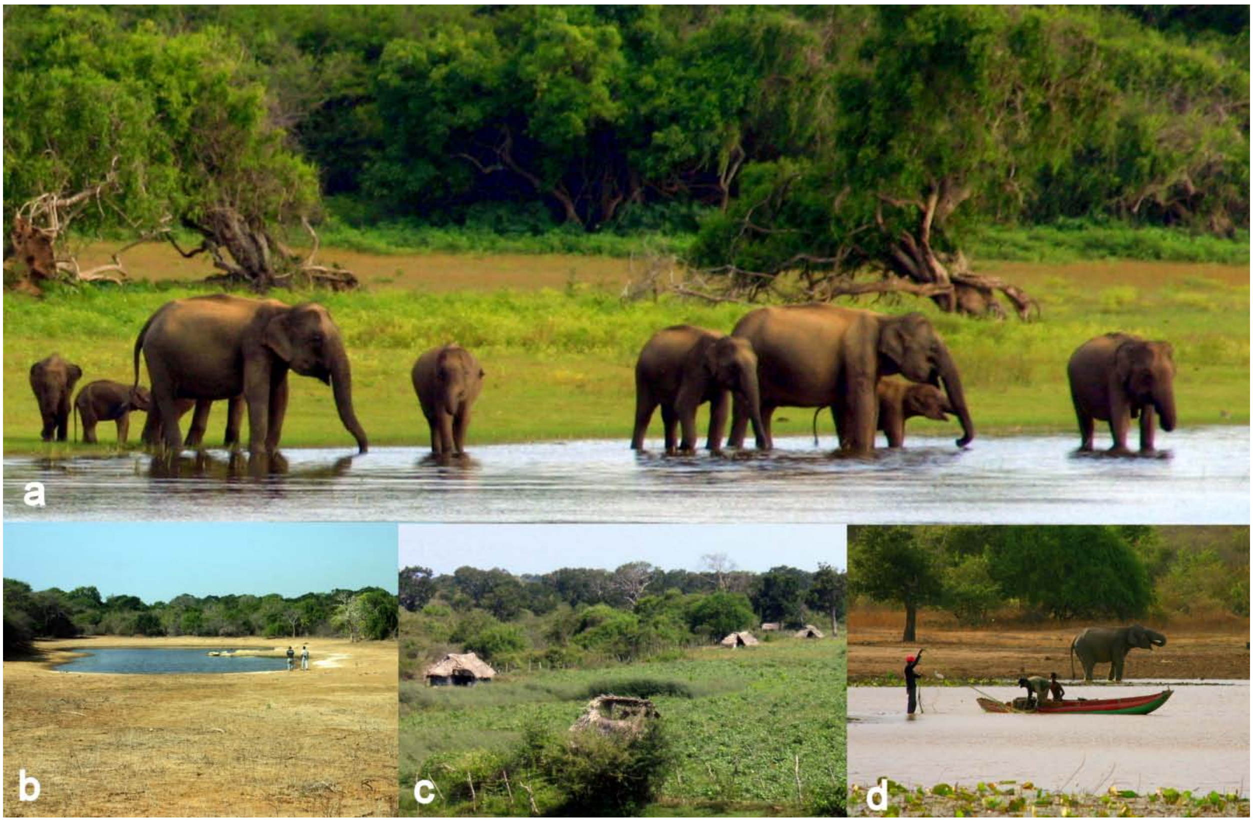

Fig. 4. a) Elephant herd at a tank inside Yala National Park. b) Monitoring a tank that is drying out as the dry season progresses. c) Temporary huts of farmers in close proximity to Bandu Wewa. d) A rare daytime visit to the Divulpathana Wewa by an elephant male while people are engaged in fishing. Photos by authors.

Implications for conservation

The number of elephant dung piles increased markedly at the tanks in the park with progression of the dry season. This could be a result of greater use of water sources by elephants in the dry season as well as a concentration at perennial water sources when the seasonal ones dried up. Therefore, in constructing water bodies as a habitat enrichment measure for elephants, it is more useful to construct tanks that are perennial. Since the presence of temporary habitations appeared to deter elephants from using tanks, ensuring that tanks have secluded areas where elephants can access water without hindrance or disturbance is of importance outside protected areas.

Suitability as a Monitoring Technique
In comparing the outside area with the park, the total number of dung piles (364 vs. 2036), dung-piles-per-tank (17.3±23.9 vs. 509.0±204.6), and dung-piles-per-tank-per-visit (1.3±3.2 vs. 23.7±24.7) all provided a clear distinction between the two areas, consistently detecting a difference in relative abundance. The higher abundance of elephants in the park indicated by our results was consistent with the history of the elephant drive and anecdotal observations. The area assessed in the park was smaller than the area outside, which could be expected to bias towards a greater number of total dung piles outside. On the other hand, the total extent of elephant habitat within the park was much larger than the area surveyed and the surveyed water bodies could potentially draw elephants from a greater area than outside. However, the presence of other water bodies not surveyed deeper within the park could be assumed to negate any such effect. The density of water bodies in the surveyed area of the park was somewhat less than outside, which could show a bias towards showing higher number of dung piles per tank and dung piles per visit per tank in the park. However, the results showed a marked difference in the indicators of elephant presence, suggesting that the technique was robust enough to overcome such biases.

The technique also established the presence of herds with young outside the park, where elephants were at low densities. Therefore this method can provide reliable information on presence/absence and relative abundance of elephants. As there was a significantly greater use of water bodies by elephants in the dry season, the method is more appropriate for surveying for elephant presence in areas with restricted water availability. For the same reason, the technique is not suitable for monitoring seasonal variation of elephant densities in a given area.

We suggest that the method is useful in surveying for elephant presence/absence as well as for comparing relative elephant abundance in different areas within the same season and in the same area in different years. It has the advantage of simplicity and of not requiring highly technical equipment or trained personnel; hence it can be conducted in most range-country situations. We conclude that it is a valid and useful technique that can be used by managers and researchers alike to monitor elephants and to obtain distribution data.

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