DEPARTMENT OF LAND RESOURCE MANAGEMENT

Feral buffalo (*Bubalus bubalis*): distribution and abundance in Arnhem Land, Northern Territory

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Photograph: R Edmonds

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Summary

Populations of feral buffalo *Bubulas bubalis* in Arnhem Land provide both an economic opportunity and a source of significant environmental damage. There has been no consistent management of feral buffalo in the Northern Territory since the Brucellosis and Tuberculosis Eradication Campaign (BTEC) of the late 1980s and early 1990s. Local control programs have been undertaken in response to concern about buffalo impacts, but these programs have not been coordinated or integrated at the regional level. The development of a strategic management program for feral buffalo in Arnhem Land requires adequate baseline data on the distribution and abundance of buffalo across the region.

From 9 June to 23 June 2014, an aerial survey was conducted to determine the distribution and abundance of feral buffalo (and other large feral vertebrates) in Arnhem Land, Northern Territory. The total survey area of 91,658 km^2 was surveyed at a sampling intensity of 3.6%. Species counted were buffalo, cattle, donkey, horse and pig. Buffalo counts were corrected for perception (observer) bias, but uncorrected for availability (habitat) bias.

The corrected population estimate for feral buffalo in Arnhem Land was 97,923 ± 9,327, a density of 1.07 ± 0.10 buffalo per km^2. This estimate has a precision of 9%, which is considered good for such broad-scale aerial survey. Population estimates for other feral species were not calculated as sightings were too few for estimation with an acceptable level of precision.

The 2014 survey recorded relatively high buffalo densities in a number of areas:

- a large area to the north-west of Bulman and south-east of the Arnhem Land Plateau;
- the floodplains of the Blyth and Cadell Rivers;
- the coastal floodplains between the Blyth and Glyde River mouths;
- the floodplains and wetlands to the south-west of Buckingham Bay;
- the floodplains and wetlands north of the Roper River, downstream from Ngukurr;
- the south-west corner of the survey area.

Previous (1985 and 1998) surveys also recorded high buffalo densities in the Bulman area, but these surveys showed moderate to low buffalo density throughout the rest of Arnhem Land.

Introduction

Water buffalo *Bubula bubalis* were brought to Australia between 1824 and 1886 as a source of meat (Letts 1962). They were first introduced to Melville Island and Cobourg Peninsula and wild herds were observed post 1843 (Letts 1962). Over the past 130 years, Buffalo in the Northern Territory have been utilised as an economic resource (both hides and meat) and intensively managed as feral wildlife and as a reservoir for exotic disease (Letts *et al.* 1979, Graham *et al.* 1982b, Bayliss & Yeomans 1989b, Freeland & Boulton 1990, Boulton & Freeland 1991).

The Brucellosis and Tuberculosis Eradication Program (BTEC) of the late 1980s and early 1990s sought to eradicate all ‘domestic’ and feral Buffalo that tested positive to these diseases (Anon, undated). Prior to this, management through utilisation was extensive in the western Top End (Graham *et al*. 1982b). There has been a major decline in the utilisation of Buffalo post-BTEC, primarily as a result of destocking within pastoral areas during the BTEC program.

With the conclusion of the BTEC program in 1995, coordinated and integrated management of feral buffalo in the Northern Territory ceased. Since 1995, smaller-scale (property or part catchment) control of feral buffalo has been undertaken on both pastoral and Indigenous lands, but these programs have not been coordinated or integrated at the broader regional scale. These control programs were generally undertaken in response to concerns about specific identified buffalo impacts at the property or catchment scale.

Arnhem Land (Figure 1) has long supported a large population of feral Buffalo (Graham *et al*. 1984, Bayliss & Yeomans 1989b, Saalfeld 1998). Major population surveys were undertaken in 1985 (Bayliss & Yeomans 1989b), 1989 (Bayliss & Yeomans 1989b) and most recently in 1998 (Saalfeld 1998). The 1985 and 1989 surveys were undertaken to monitor population changes arising from culling operations undertaken under BTEC. Prior to these surveys, Graham *et al*. (1984) conducted aerial surveys of feral buffalo distribution and abundance in Arnhem Land in 1981 and 1983.

These surveys demonstrated a clear increase in the buffalo population in Arnhem Land from 1981 through to 1985 (Figure 2), followed by a marked decline in the buffalo population from 1985 through to 1998 (Figure 2) attributed to the BTEC program (Bayliss & Yeomans 1989b, Saalfeld 1998).

The 2014 aerial survey was carried out to estimate the current distribution and abundance of Buffalo in Arnhem Land. The survey area (Figure 1) was selected to cover the same area as previous surveys and to encompass known areas of major feral Buffalo concentrations. Estimates of population size and density and mapped density distributions have been derived for use in management planning.

Figure 1: Map of Arnhem Land showing the extent of the 2014 survey area.

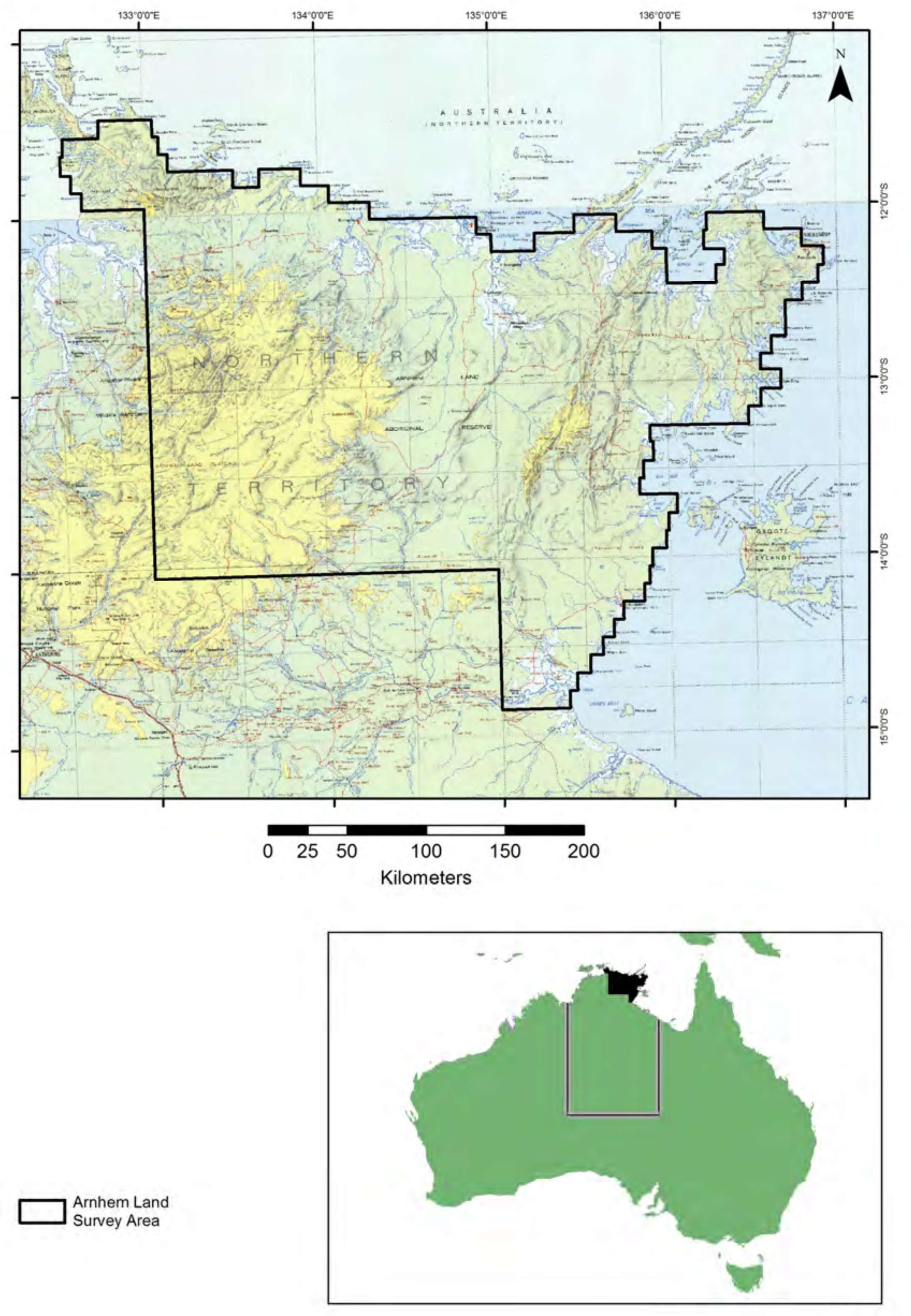
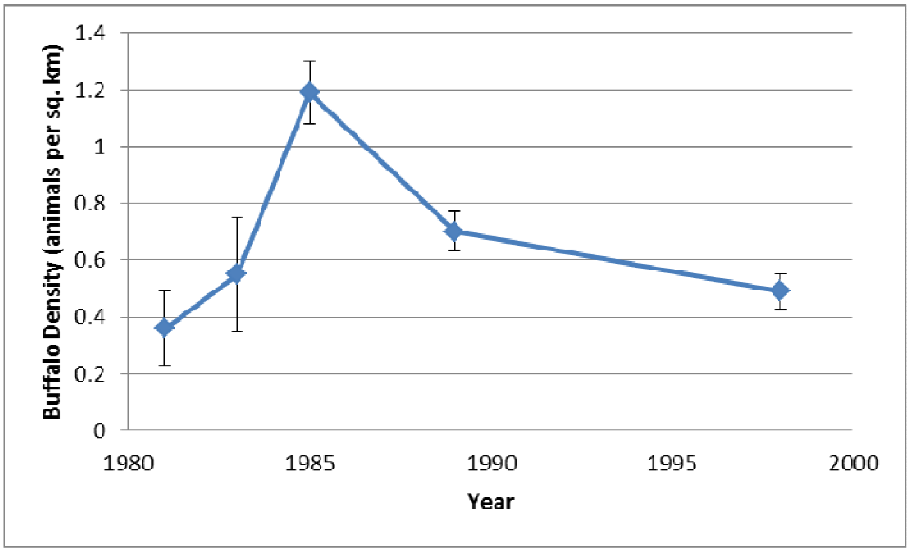


Figure 2: Estimated buffalo density from aerial surveys conducted across Arnhem Land from 1981 to 1998.



Methods

This 2014 survey was flown in the early dry season between 9 June and 23 June 2014.

The method for broad-scale aerial surveys in the Northern Territory has become relatively standardised over the past two decades (Graham *et al.* 1982a, Graham *et al.* 1982b, Graham *et al.* 1984, Choquenot 1988a, Choquenot 1988b, Bayliss & Yeomans 1989a, Bayliss & Yeomans 1989b, Bayliss & Yeomans 1989c, Saalfeld 1997, Scott & Saalfeld 1999), with minor modification of the methodology in data recording and estimation of observer correction factors.

Study Area

The survey area (Figure 1) had a total area of 91,658 km^2 and was systematically sampled by east-west transects (Figure 3) of 400m width at an 11.112 km (6' latitude) separation, giving a sampling intensity of 3.6%. A total of 152 transects of a mean length of 54 km was flown. For analysis purposes, the survey area w divided into survey blocks (Figure 3) encompassing either ten transects (blocks 2-11 & 13), twelve transects (blocks 1, 12 & 14) or 6 transects (block 15).

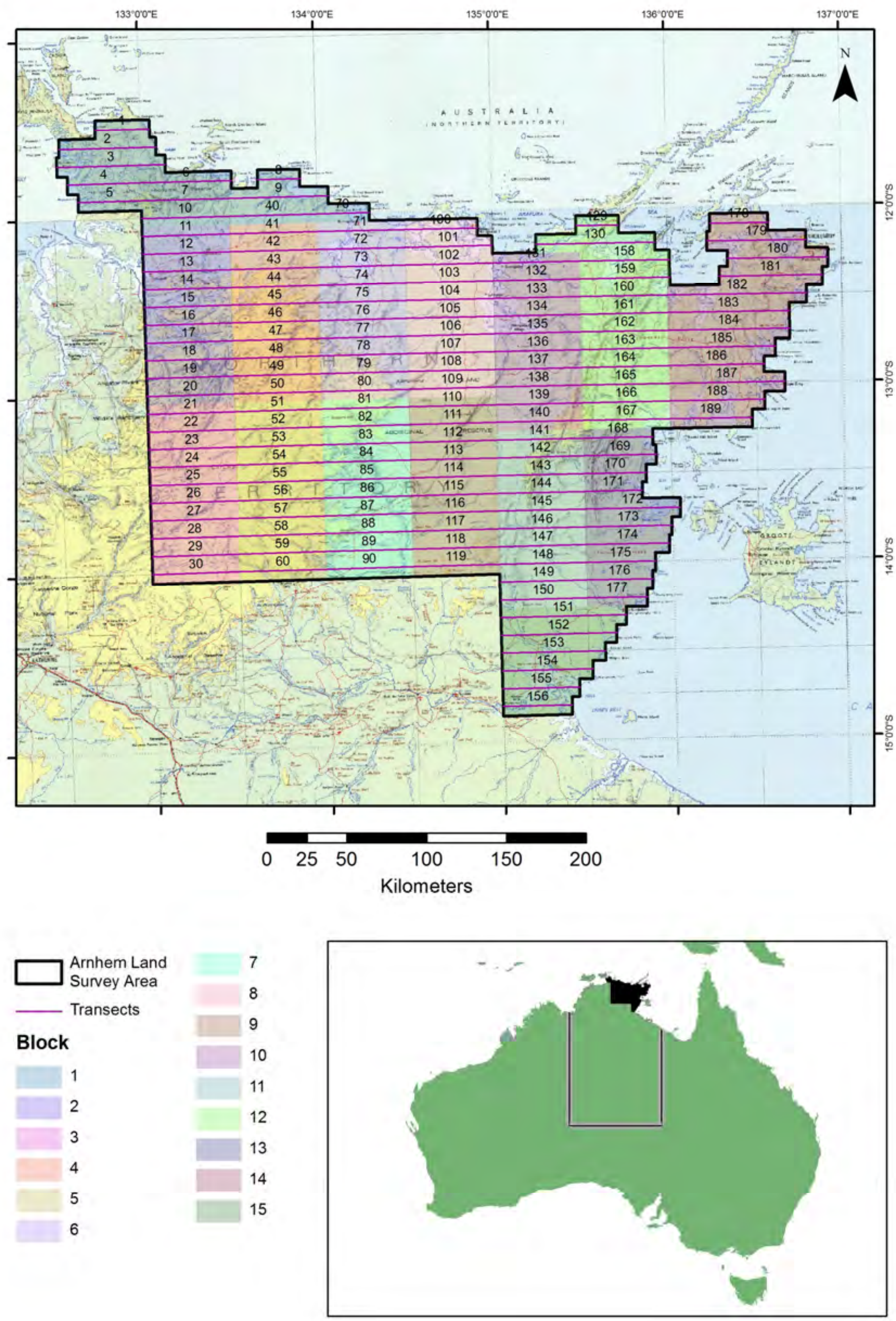
Survey Method

The sampling platform was a Cessna 206 high-wing aircraft equipped with radar altimeter and Global Positioning System (GPS). The aircraft was flown at a mean altitude of 76 m (250 ft) above ground level and at an average ground speed of 185 km/h (100 kts). The transect width of 200 m on each side of the aircraft (at survey altitude) was delineated by rods attached to the aircraft wing struts.

Three observers – two to starboard and one to port – recorded sightings, with the two starboard observers functioning as an observer team; the tandem starboard observers counted the same transect independently and without collusion. Observers rotated position in a clockwise direction on successive flights.

Buffalo, cattle, donkey, horse and pig were counted in groups. Groups typically were aggregations of animals within about 360 metres of each other rather than biologically meaningful associations of animals (Choquenot 1995). Sightings were recorded by each observer using proprietary data logging hardware and software (EcoKnowledge Pty Ltd, Adelaide, SA, Australia). Data recorded for each sighting were species, group size, date, time, easting (UTM), northing (UTM), observer and position in aircraft. Survey transects were navigated and flight path recorded using a Samsung Tablet (Galaxy Tab 2, 7 inch) with internal GPS unit and running OziExplorer moving map software (OziExplorer Pty Ltd, Brisbane, Queensland, Australia).

Figure 3: Map of survey area showing the transects and blocks



Data Analysis

Aerial survey data incorporate two types of bias that lead to underestimates of the true population size: availability bias and perception bias. Perception bias is a result of observers missing animals that are potentially visible, while availability bias arises because some animals are concealed from the observers (Marsh and Sinclair 1989). We used the observations of the tandem starboard observers to assess perception bias and variance following Marsh and Sinclair (1989). Groups of buffalo seen by the starboard front and starboard rear observers were classified as either (a) seen by the front observer, missed by the rear (S_f), (b) seen by the rear observer, missed by the front (S_r), or (c) seen by both observers (S_b). Groups that were recorded by both observers less than 6 seconds apart were considered to be the same animals and placed in category (c). Groups seen by the port observer were classified as seen by rear observer only (P_r).

The method of Marsh and Sinclair (1989) was used to convert counts of groups of buffalo to population estimates. The steps were:

1. Calculate the mean group size for the whole survey area and the associated SE.
2. Calculate for each transect the total number of groups sighted by the single port observer and the combined number for the starboard tandem team (ie. $S_f + S_r + S_b$).
3. Multiply the values from step (2) by the mean group size obtained in step (1) to obtain the number of animals seen on the port and starboard sides for each transect.
4. Calculate the perception bias correction factor for the combined starboard observations on each transect (C_s) as follows:

   $C_s = (S_f + S_b)\ (S_r + S_b)/(S_b(S_f + S_r + S_b))$
5. Calculate the perception bias correction factor for the port observations on each transect (C_p) as follows:

   $C_p = (S_f + S_b)/(S_f + S_r + S_b)$

   i.e, the starboard rear-seat perception bias.
6. Apply the appropriate correction factor to the values from step (3) to account for perception bias.
7. Sum the two values from step (6) to obtain the corrected (for perception bias) number of animals for each transect.
8. Apply the ratio method (Jolly 1969; Caughley 1979) for unequal transects to the values from step (7) to obtain the corrected (for perception bias) estimate of population size and its associated sampling variability.
9. Calculate the total variance of the population estimate by adding the errors for mean group size [step (1)] and the correction factor [step (5)] to that due to sampling variability [step (8)].

Parallel calculations to those in steps (7) and (8) were performed to estimate the population density and its variance. Estimates were calculated for each survey block and added to obtain the overall estimate and standard error for the total survey area. Precision of the estimate for each survey block and for the overall estimate was calculated. Precision is a measure of the uncertainty in the estimate and its standard error –; the greater the precision the greater the uncertainty in the estimate.

We were unable to assess availability bias in this study as it was not possible to conduct a post-survey culling operation (*sensu* Bayliss & Yeomans 1989b). Consequently, population size or density will be underestimated if availability bias is significant. .

Density distribution maps were generated for the survey area from the spatial distribution of the raw sightings and Kernel Density interpolation using the Spatial Analyst Extension in ArcGIS 10.2 (ESRI, Redlands, California, USA).. Two density distributions were generated using the sighting data: a smoothed distribution which provides a good overview of the broad density distribution across all of Arnhem Land; and a minimally smoothed distribution which provides a finer scale density resolution suitable for planning local management actions. The smoothed distribution was generated using a search radius in the Kernel Density interpolation set to three times the spacing between transects, which allows sightings on the immediate and two adjacent transects to strongly influence the density interpolation. The finer resolution distribution was generated using a search radius in the Kernel Density interpolation set to the spacing between transects, which limits the influence of sightings on adjacent transects on density interpolation.

The raw data for the 1998 survey were available and used to generate a smoothed density distribution using the same method. This distribution was then subtracted from the 2014 smoothed density distribution to produce a map showing change in density distribution between 1998 and 2014.

Results

2014 Survey

Mean group size and perception bias correction factors used to calculate corrected feral buffalo population size and density for the 2014 survey area are shown in Table 1.

Table 1: Mean group size and perception correction factors for buffalo for 2014 Arnhem Land aerial survey (c.v. is the Coefficient of Variation).

Species	Mean Group Size (c.v.)	Perception Bias Correction Factor	
		Port (c.v.)	Starboard (c.v.)
Buffalo	4.54 (0.0638)	1.50 (0.0021)	1.14 (0.0021)

Estimates of feral buffalo population size and density for each survey block and the total survey area are shown in Table 2.

Table 2: Feral buffalo population size and density for each survey block and the total survey area for the 2014 Arnhem Land aerial survey. The standard error of each estimate is shown; values in parentheses are the precision of the estimate expressed as a percentage. These estimates have been corrected for perception bias, but not for availability bias.

Survey Block	Area (km^2)	Population Estimate	Density (buffalo per km^2)
1	6,511	524 ± 371 (71%)	0.08 ± 0.06
2	6,038	954 ± 488 (51%)	0.16 ± 0.08
3	6,014	10,357 ± 2,896 (28%)	1.72 ± 0.48
4	6,037	2,527 ± 633 (25%)	0.42 ± 0.10
5	6,013	11,020 ± 3,278 (30%)	1.83 ± 0.55
6	6,036	10,078 ± 1,698 (17%)	1.67 ± 0.28
7	6,012	17,071 ± 4,342 (25%)	2.84 ± 0.72
8	5,935	11,832 ± 5,424 (46%)	1.99 ± 0.91
9	6,011	7,779 ± 1,946 (25%)	1.29 ± 0.32
10	6,031	5,062 ± 1,047 (21%)	0.84± 0.17
11	6,006	2,054 ± 540 (26%)	0.34 ± 0.09
12	7,187	8,738 ± 2,371 (27%)	1.22 ± 0.33
13	5,014	3,964 ± 1,325 (33%)	0.79 ± 0.26
14	8,600	1,623 ± 659 (41%)	0.19 ± 0.08
15	4,211	4,340 ± 1,715 (40%)	1.03 ± 0.41
Total	**91,658**	**97,923 ± 9,327 (9%)**	**1.07 ± 0.10**

The distribution of feral buffalo sightings is shown in Figure 4, and the resulting Kernel Density distributions are shown in Figure 5 (smoothed density distribution) and Figure 6 (minimally smoothed distribution). Density is number of buffalo per square kilometre.

Figures 5 & 6 show five distinct areas of high buffalo density (greater than five animals per square kilometre):

- the Blyth and Cadell River floodplains and wetlands to the east of Maningrida and the floodplains and wetlands between the mouth of the Blyth and Glyde Rivers (area **A** in Figure 5);
- the floodplains and wetlands of the Woolen and Buckingham Rivers to the south-west of Buckingham Bay (area **B** in Figure 5);
- the area around Bulman and to the north-west of Bulman covering the headwaters of Liverpool, Mann and Wilton Rivers (area **C** in Figure 5);
- the south-west corner of Arnhem Land on the Arnhem Land Plateau covering the headwaters of the Katherine River north of Eva Valley (area **D** in Figure 5); and
- the floodplains and wetlands north of the Roper River covering the headwaters of the Phelps River (area **E** in Figure 5).

Comparison of 1998 and 2014 surveys

The 2014 survey completely covered the area of the 1998 survey. The change in feral buffalo density between 1998 and 2014 is shown in Figure 7. The change in density is presented for the smoothed distribution only, in order to reduce the effect of local scale variability on the broad-scale pattern of change. Across much of Arnhem Land, feral buffalo density had increased substantially between 1998 and 2014, and there are no areas where density has decreased from that estimated in 1998.

Figure 4: Distribution of feral buffalo sightings in the 2014 Arnhem Land survey area.

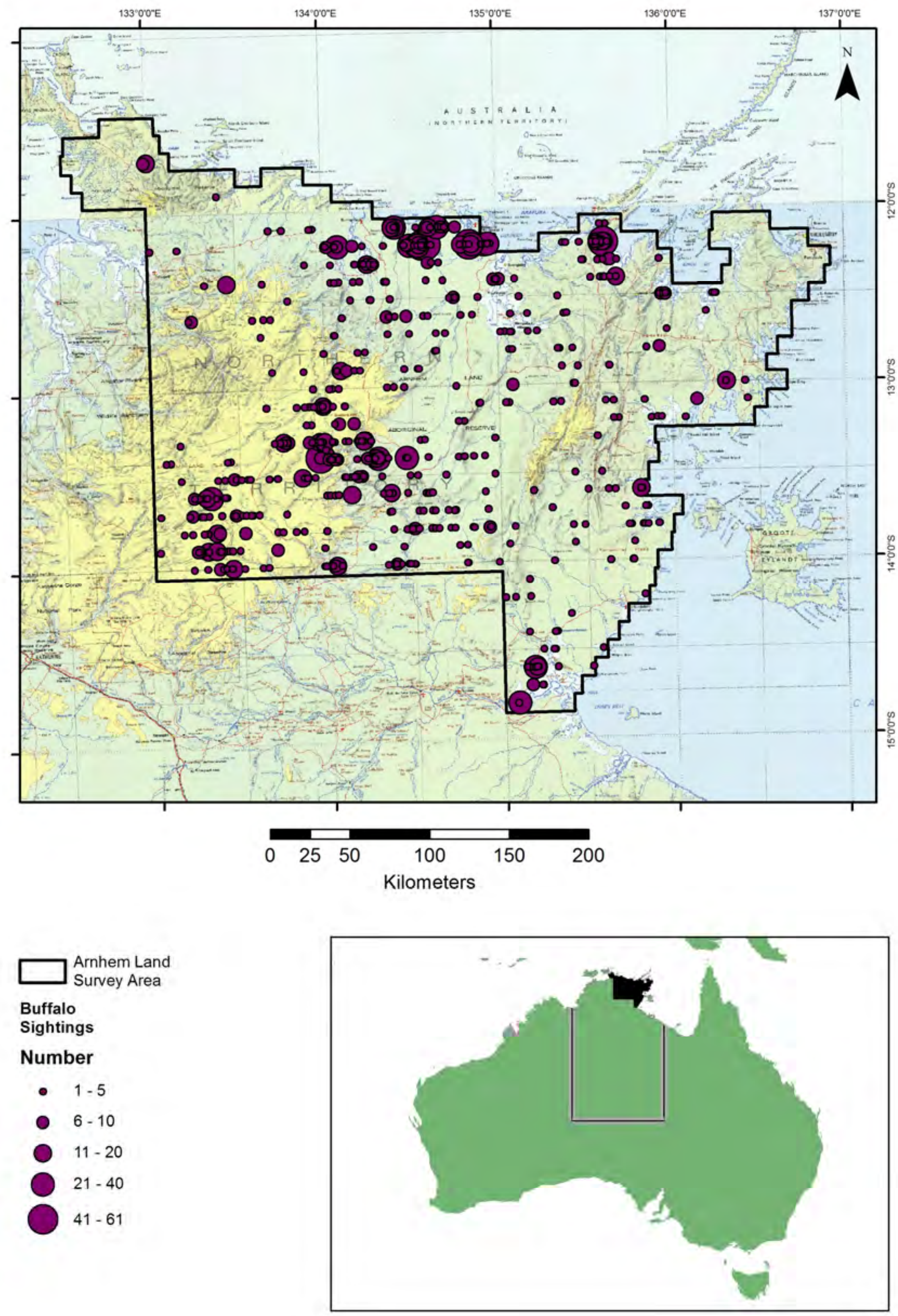


Figure 5: Smoothed density (individuals/km^2) distribution of feral buffalo in the 2014 Arnhem Land survey area showing broad pattern of buffalo distribution.

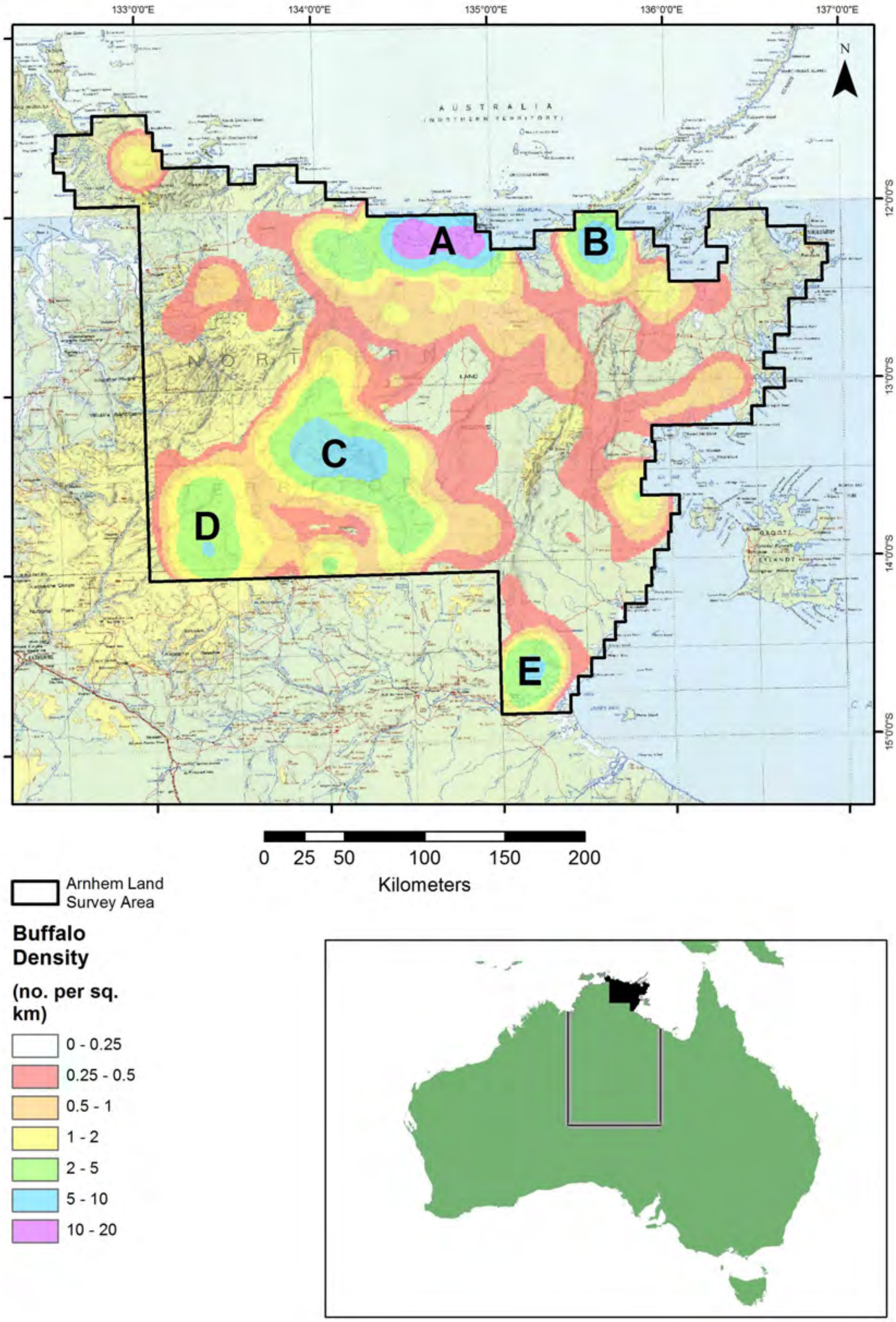


Figure 6: Non-smoothed density (individuals/km^2) distribution of feral buffalo in the 2014 Arnhem Land survey area showing local high density peaks in buffalo density.

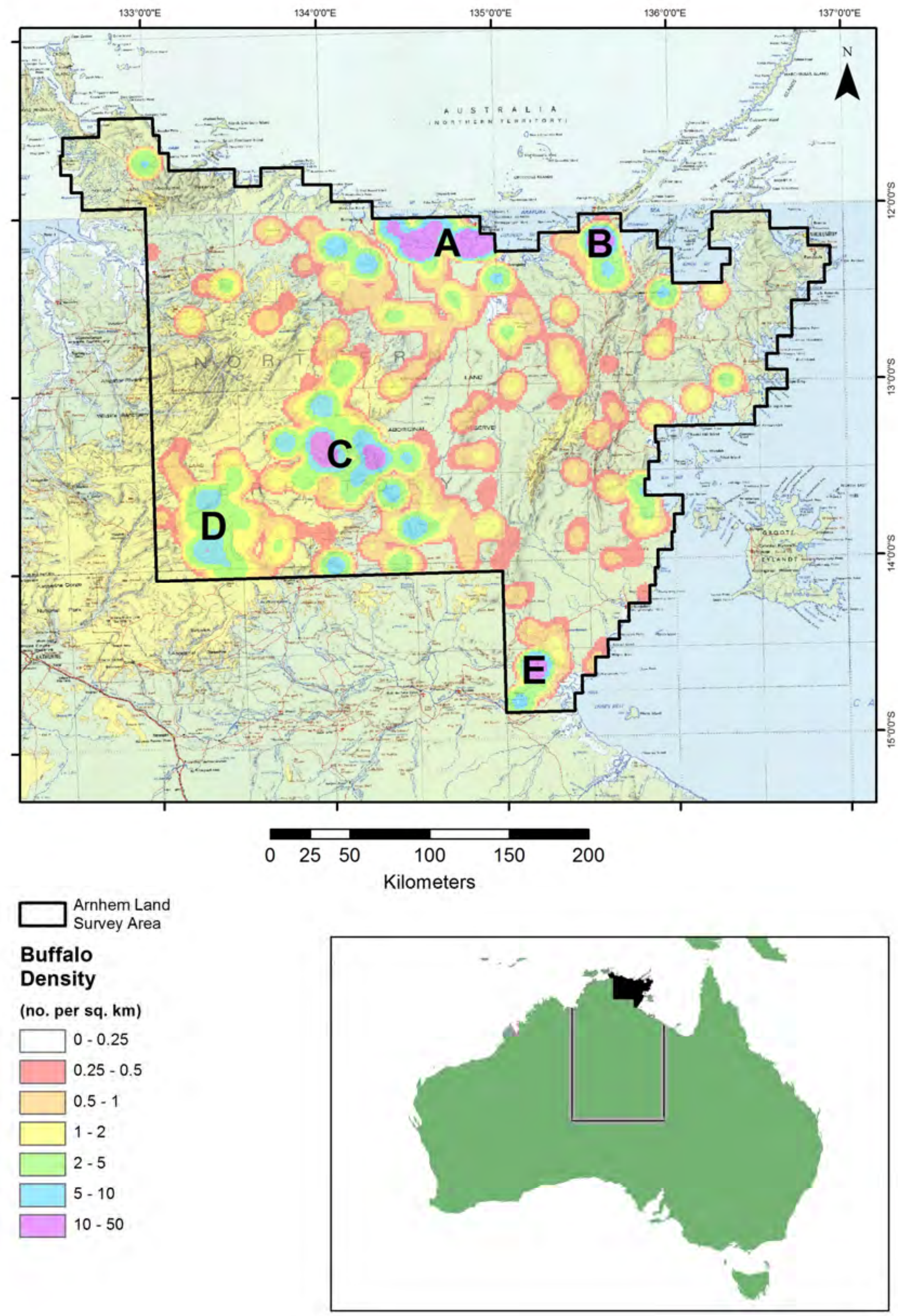
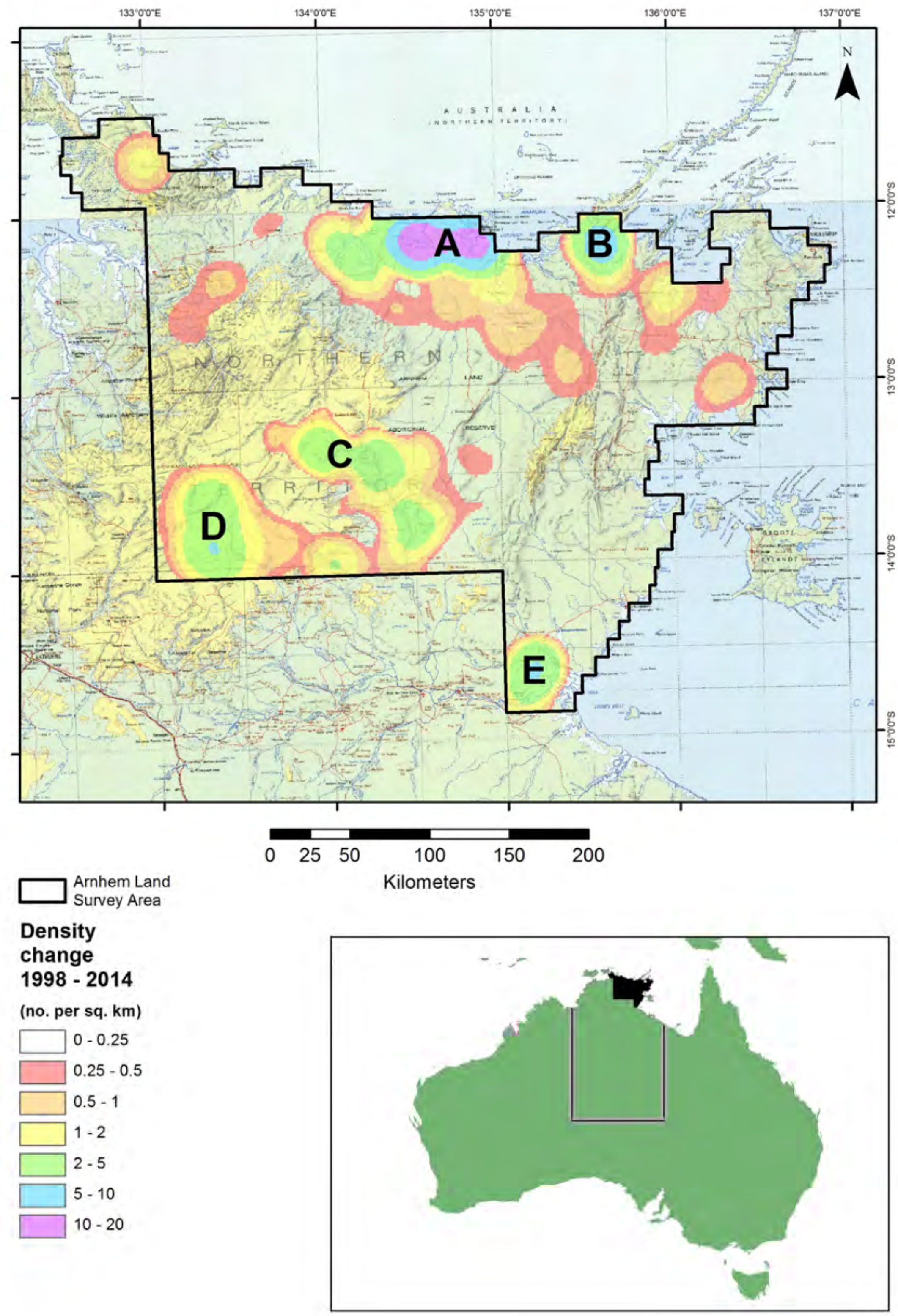


Figure 7: Change in smoothed density (individuals/km^2) distribution of feral buffalo in the Arnhem Land survey area between 1998 and 2014.



Discussion

The 2014 survey indicated that there is currently a minimum of 97,923 feral buffalo within the Arnhem Land survey area. This figure is a minimum because it does not include a correction for availability bias, and available information suggests the availability bias for buffalo may be significant (Graham *et al.* 1984, Bayliss & Yeomans 1989b).

A comparison between population estimates in 1998 and 2014 shows that the population of feral buffalo in Arnhem Land increased at a mean annual exponential rate (*r)* of 0.0512. This represents an increase of about 5.25% per year or an approximate doubling of population size every 14 years, and is consistent with the rate of increase reported by Freeland & Boulton (1990). The ecological carrying capacity (*K*) of Arnhem Land for feral buffalo is not known. Recent anecdotal reports by indigenous land managers identify severe land degradation from the impact of feral buffalo across much of Arnhem Land, both in lowland and some upland habitats.

The density distribution maps indicate that feral buffalo are broadly distributed across a large area of Arnhem Land and that the density of feral buffalo has increased substantially since 1998. Saalfeld (1998) estimated that the population of feral buffalo across Arnhem Land in 1998 was a minimum 43,000 buffalo, with the highest concentrations found in the area to the north-west of Bulman. This was a substantial reduction from the estimated population of 110,000 in 1985 (Bayliss & Yeomans 1989b), with that reduction attributed to the BTEC program (Bayliss & Yeomans 1989b, Anon undated, Saalfeld 1998). The population increase from 1998 to 2014 indicates that the current estimated minimum population is approaching that in 1985, prior to the BTEC program.

Of the five areas of high density identified from the 2014 survey, only the area north-west of Bulman similarly showed relatively high densities in 1998. The other four areas of high density in 2014 all represent large density increases compared with 1998.

In the area of the Blyth and Cadell River floodplains and wetlands to the east of Maningrida and the floodplains and wetlands between the mouth of the Blyth and Glyde Rivers, density has increased by up to ten times 1998 values. Similar increases have occurred in the area of the floodplains and wetlands of the Woolen and Buckingham Rivers to the south-west of Buckingham Bay; the south-west corner of Arnhem Land on the Arnhem Land Plateau covering the headwaters of the Katherine River north of Eva Valley; and the floodplains and wetlands north of the Roper River covering the headwaters of the Phelps River.

In some of these high-density zones, densities of up to 47 buffalo per sq. km were estimated in the 2014 survey. Given that there was no correction for availability bias, true densities may be considerably higher (Graham *et al.* 1984, Short *et al*. 1988, Bayliss & Yeomans 1989b, Choquenot 1995) and in this case localised densities exceeding 50 animals per square kilometre may be occurring. This is likely to be associated with very severe environmental impact.

Current management of feral buffalo is largely *ad hoc* and has little impact on overall population growth. Individual control programs have been undertaken at a number of locations across Arnhem Land and have achieved substantial localised population reductions (Arafura Swamp and Blue Mud Bay). However these programs have not been coordinated or integrated at the regional level, and maintaining low densities is likely to be difficult if management is not also undertaken in adjoining country.

Acknowledgements

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