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Turning Pests into Profits: Introduced Buffalo Provide Multiple Benefits to Indigenous People of Northern Australia

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Abstract Introduced species are a major driver of negative ecological change, but some introduced species can potentially offer positive benefits to society. Asian swamp buffalo (*Bubalus bubalis*) were introduced to the northern Australian mainland in 1827 and have since become a serious pest. However, buffalo have also supported various profitable industries, including harvesting for hides, meat, and live export. We investigate an indigenous wildlife-based enterprise that harvests wild buffalo from indigenous-held lands in remote northern Australia. We used ecological modelling and social research techniques to quantify the buffalo dynamics and to examine their contributions to sustainable livelihoods in a remote Aboriginal community. Results suggest that the current harvest rate will not drive the species to extinction and it is thus unlikely that the population size of buffalo will be reduced enough to alleviate ecological damage. This enterprise is profitable and provides regular royalty payments to traditional land owners and wage income for employees, along with several additional non-financial capital assets. We demonstrate that the commercial exploitation of introduced species can provide additional or alternative sources of protein and income to promote economic development for indigenous people. This type of enterprise could be expanded to more communities using harvest rates above maximum sustainable yield to provide greater positive social and ecological outcomes for indigenous communities.

Keywords Feral introduced species · Asian swamp buffalo (Bubalus bubalis) · Sustainable wildlife harvest · Economic development · Australia

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Introduction

Major global initiatives such as Millennium Development Goals (United Nations 2009) aiming to improve the quality of people's lives through economic development while simultaneously reducing environmental degradation and biodiversity loss face serious challenges (Sachs *et al.* 2009; Tilman *et al.* 2001) from an expanding human population (Bongaarts 2009), climate change, economic volatility and reduced food security (Gregory *et al.* 2005). Increased rates of consumption associated with population growth and growing affluence will place ever greater stress on already over-exploited natural resources such as fresh water (Vorosmarty *et al.* 2000), arable land (Foley *et al.*, 2005), forests (Bradshaw *et al.* 2009a, 2009b), and fisheries (Hilborn *et al.* 2005; Pauly *et al.* 2005). Synergistic effects among these factors (Brook *et al.* 2008) will present challenges to global sustainability but will also force local communities to adapt, innovate (Howden *et al.* 2007) and use natural resources more efficiently.

Challenges for human society such as alleviating poverty, increasing food security, and protecting the environment are high priorities in the developing world; however, these concerns also extend to indigenous peoples in developed nations like Australia, New Zealand and Canada, who similarly face serious issues of poverty, service inaccessibility and relatively lower life expectancy (Young 1995). Economic development, along with health, education and housing, are seen as the cornerstones of creating healthy and prosperous indigenous communities in remote northern Australia. Consequently, in recent decades Australian Governments have encouraged economic development to improve this sector's quality of life. However, many of these programmes have failed despite active government engagement (FaHCSIA 2009).

Indigenous Australians commonly supplement their income through the consumptive use of native and non-native wildlife (Wilson *et al.* 2010), particularly when engaging in traditional and customary activity on their native lands (Altman 1987). Accordingly, what needs to be investigated are the ways in which indigenous people can use their current skills and the natural capital assets on their lands for economic benefit and financial independence.

Wildlife-based enterprises offer potential for social, economic and environmentally sustainable development for indigenous people living in remote northern Australia (Brook *et al.* 2006). The use of naturally occurring wild flora and fauna for commercial purposes represents an alternative land use (to that of contemporary agricultural practices such as broad-scale cropping, irrigated agriculture and intensive livestock grazing) that does not require substantial initial landscape transformation. Such enterprises include the manufacture of didgeridoos (an Aboriginal musical wind instrument) from native trees (Forner 2006), supply of long-neck turtle to the pet-trade (Fordham *et al.* 2007) and the harvest of crocodile eggs for sale to commercial farms (Cochrane and Doulman 2005). However, wildlife-based enterprises need not be restricted to the use of native species. Using feral animals living in the same landscapes can be seen as restorative rather than destructive, and therefore beneficial for natural resource management and biodiversity conservation (Bradshaw and Brook 2007). Indeed, wildlife-based enterprise offers the opportunity to reward land owners financially for their management and conservation of landscapes. Furthermore, wildlife-based enterprises that exploit environmentally destructive introduced species can provide financial benefits to indigenous people and provide a long-term solution to the management of introduced species, thus providing better biodiversity conservation outcomes. One such wildlife-based enterprise in northern Australia illustrates how the use of an introduced mammal, the swamp buffalo (*Bubalus bubalis*), can benefit local indigenous communities while potentially having a positive ecological outcome.

The first Asian swamp buffalo introduced to Australia was a shipment of 16 animals onto Melville Island (Fig. 1) to the north of Darwin in 1826 (Letts 1962). Buffalo were first introduced to mainland Australia from Kupang (now West Timor, Indonesia) a year later as livestock for the Raffles Bay military settlement on the Cobourg Peninsula (Fig. 1). Another 18 buffalo were obtained from Kisar Island (northeast of modern Timor-Leste) and introduced to Victoria Settlement in Port Essington on the Cobourg Peninsula, (Letts 1962). In 1843, another 49 buffalo were introduced to Port Essington from Raffles Bay (Letts 1962). When the Port Essington settlement was abandoned in 1849, all the buffalo were released and spread rapidly throughout the Northern Territory.

Buffalo numbers increased to approximately 350,000 animals by the early 1970s to cover most of northern Australia (Fig. 1). A major eradication campaign of buffalo (and wild cattle) to control brucellosis and tuberculosis undertaken during the 1980s and 1990s resulted in large declines in densities over parts of their range. However, given that there were no sustained density-reduction programmes in place after the initial culls, populations of buffalo rebounded strongly and now number around 150,000 animals (Bradshaw *et al.* 2007). At higher densities, swamp buffalo cause major environmental damage such as saltwater intrusion into sensitive wetlands through the trampling of sensitive vegetation and browsing on remnant monsoon forest during the harsh late dry season when native pasture quantity and quality is declining (Bowman *et al.* 2008; Braithwaite *et al.* 1984; Petty *et al.* 2007; Werner 2005; Werner *et al.* 2006). Economically, buffalo are a major threat to Australia's livestock industry as hosts and vectors for diseases such as foot-and-mouth (Cousins and Roberts 2001; Ward *et al.* 2007), and their broad dietary niche allows them to compete with cattle for pasture during the dry season (Bowman *et al.* 2010). Socially, they pose a danger to human safety, especially for indigenous Australians in rural and remote areas (Albrecht *et al.* 2009).

Despite the many problems associated with swamp buffalo, they are also a valuable natural resource that has sustained a range of small-scale industries for over 100 years, including harvesting hides, meat production and a lucrative live-export trade (Petty *et al.* 2007), such as the one currently in operation at Bulman, Northern Territory. Bulman is a remote indigenous community in Arnhem Land (Fig. 1). The Gulin Gulin Buffalo Company musters wild buffalo from a 10,000-km^2 area of unimproved rangelands surrounding Bulman. This land is communally owned by various indigenous clan groups

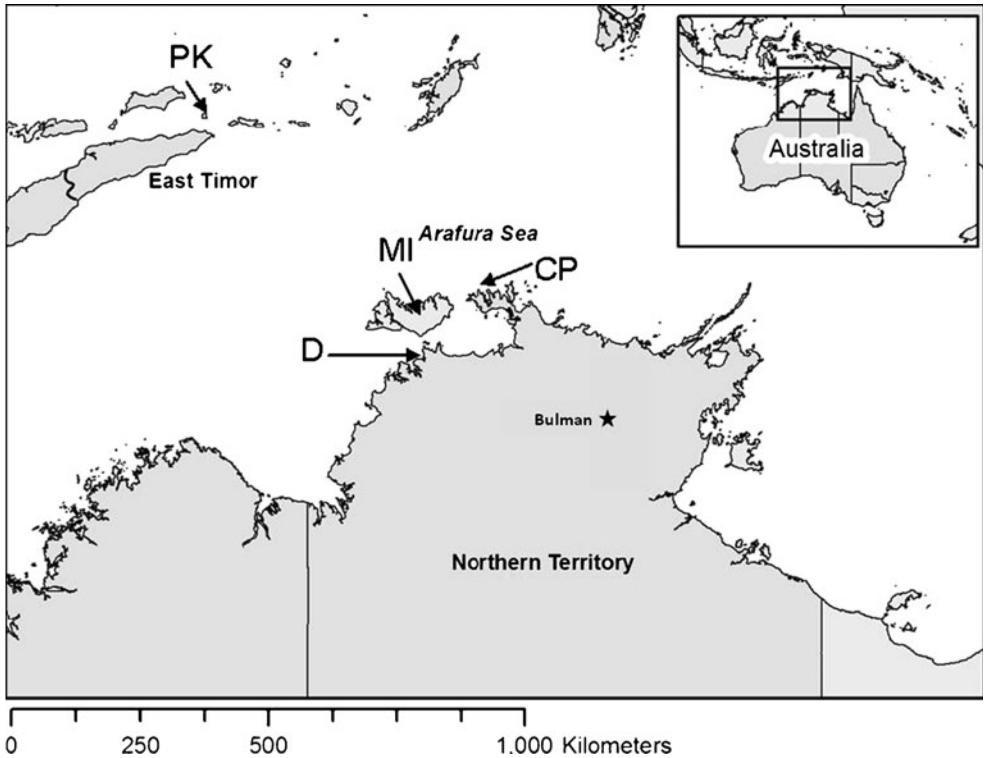

Fig. 1 Map of Australia and northern Australia (*inset*) showing the Northern Territory and the location of Bulman station where the buffalo mustering occurs. PK, Pulau Kisar; D, Darwin; MI, Melville Island; CP, Cobourg Peninsula

who have granted the buffalo company exclusive rights to muster on their property. According to company records, mustering activities have been consistently profitable for nearly 20 years.

We use a multidisciplinary approach that combines ecology, modelling and sustainable livelihoods research to (1) construct a population model to estimate the impact of the current harvest rate on the long-term population size of introduced buffalo at Bulman station, (2) explore the influence of the Company on the capital assets of the community using the sustainable livelihoods framework, and (3) highlight the potential economic-conservation synergies that can arise when a wildlife-based enterprise is developed based on the exploitation of an introduced species.

Methods

Buffalo Life Tables

Effectively managing animals, whether for harvest, conservation or control, relies on sound demographic information (du Toit 2002; Shea *et al.* 1998). Cross-sectional population data (Caughley 1977) based on tooth examinations were collected from the harvested population (Bulman, $n=520$ buffalo mustered) of swamp buffalo in Arnhem Land, northern Australia in July 2007 (McMahon *et al.* in press).

Life tables are used to characterize the survival properties of cohorts and provide insights into population persistence. However, accurate estimates of animal age are required to construct life tables (Caughley 1977; Sinclair *et al.* 2006). We estimated each sampled animal's age using established tooth eruption and wear patterns (Low and McTaggart Cowan 1963; Tulloch 1969; Moran 1992). Once ages were estimated, we constructed an age-specific frequency distribution with corresponding age-specific fertility rates for the female component of the population. We then constructed an age-specific life table using Caughley's Method 6 (McMahon *et al.* 2010a). The accuracy of this method is contingent on an unbiased sampling protocol; given that entire family groups were culled (i.e., eradication of all individuals from small patches of occupied habitat), it seems reasonable to assume that sampling was random. Age-specific female fertility (m_x) was determined by an examination for lactation and pregnancy in culled females. This information summarised the age-specific survival (l_x), mortality (d_x), fertility (m_x) and mortality rates (q_x) up to the maximum observed age of 17 years (McMahon *et al.* 2010a).

Population Model

We used the vital rates from the buffalo life table to construct and parameterise a system dynamics model of the Bulman buffalo population using the Stella modelling environment (Costanza and Voinov 2001). We chose to model our data using Stella because it is a user-friendly software package with icon-based graphic interfaces specifically designed for dynamic systems modelling that is flexible and can be easily modified and extended to suit different goals and case studies (Costanza and Voinov 2001). We did comparisons between simulated and observed data to infer the performance of the dynamic model, and different scenarios were tested (see below). The population model was structured by sex and age class and considered demographically closed. The female component of the population model consisted of 11 age classes and the male component had nine classes (Fig. 2). We used a simple density-feedback equation to estimate the annual reproductive rate of the population (i.e., the number of new individuals entering the population per unit time (B):

$$B = rN_t\left(1 - \frac{N_t}{K}\right) \quad (1)$$

where r is the intrinsic rate of population increase ($-1 < r > 1$), N_t is the population size at time t, and K is the carrying capacity. Maximum carrying capacity (K_m) was estimated at approximately 8.32 animals km^{-2}, an estimate based on previous observations of buffalo densities in other parts of the Northern Territory with similar environments (Bayliss and Yeomans 1989) and used for modelling feral animal management strategies in Kakadu National Park (McMahon *et al.* 2010b). However, it is unlikely that the population is at K_m because of heterogeneity in the landscape and variability in habitat quality associated with fluctuating environmental conditions. We made the assumption that the initial carrying capacity was 50% of K_m or approximately 43,000 animals for a mustering area of 10,000 km^2. The initial vectors of the age classes were derived using the assumption of initial population size and the smoothed frequencies (F_x) of each age class (Table 1). The number of individuals in each age class depends on the number of animals in the previous age class and the survival rate of that class. For example, the number of individuals in an age class is:

$$M_2 = M_1(1 - q_{x1}) \quad (2)$$

where M_2 = number of individuals in age class two, M_1 = number of individuals in age class one, q_{x1} = mortality rate of age class one derived from the life table calculations. Male buffalo are harvested for live export to Indonesia and Malaysia (meat), and for the safari trade; large bulls with good-quality horns are sold to 'safari' properties as trophy animals, sometimes selling for 3-4 times the price of live export animals (Markus Rathsmann, Gulin Gulin Buffalo Company, *personal communication*). Females are harvested for the live export market only. Animal welfare standards prohibit the export of pregnant females so harvesting occurs from age classes 1–4 only. The life table survival rates for these classes therefore represent a combination of natural and harvest mortality.

Harvest Simulations

We ran the model using a set of scenarios based on current and alternative harvest regimes, and modified buffalo rates of population increase (r). The maximum intrinsic rate of population growth (r_m) for swamp buffalo in the Northern Territory is approximately 0.3 (McMahon *et al.* 2010b). We therefore assumed that realised r for the Bulman sub-population was this maximum value. However, we investigated the potential impacts of lower rates of population increase by running simulations with r=0.15 and r=0.2. We ran 1,000 simulations for each scenario and plotted the mean and standard deviations of population size over a 100 year time horizon. For males, harvesting occurs across all of the age-classes. To compare the population size and sustainability of the harvested Bulman population, we also ran simulations with survival rates modified to reflect a

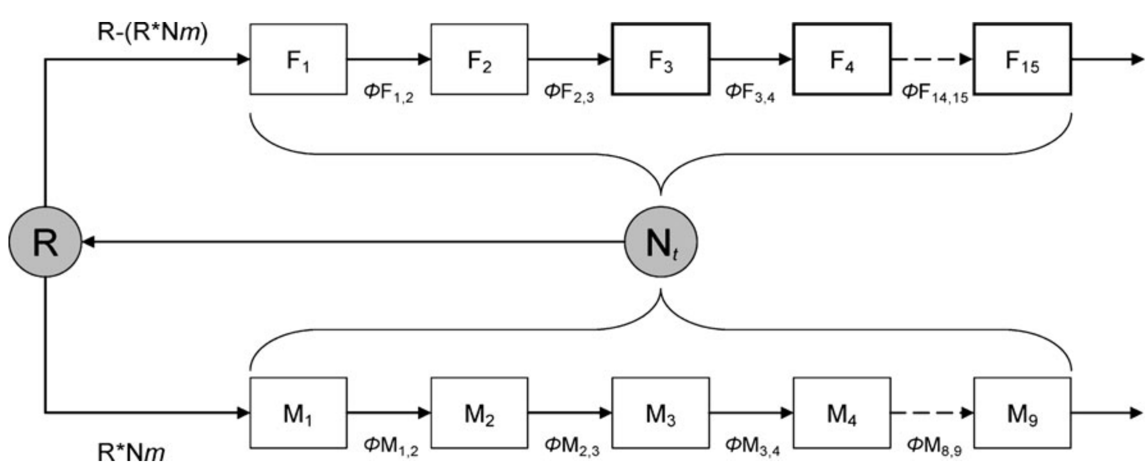

Fig. 2 Model structure of the Bulman swamp buffalo (*Bubalus bubalis*) population. The model is age structured for both male and females with vital rates (Φ) taken from life table. R is the reproduction of the population calculated using a simple logistic growth function (r* N_t)*(1–N_t/K). N_t = population size at time t. Model is closed assuming no migration

Table 1 Vital rates of swamp buffalo

		Females				Males			
Age (x)	Age-class	F_x	N_t=0	q_x[a]	q_x (harvested)	F_x	N_t=0	q_x[a]	q_x (harvested)
0	1	99.76	5,599	0.338	**0.248**	99.76	4,833	0.338	0.306
1	2	74.978	4,315	0.236	**0.255**	69.22	3,040	0.236	0.470
2	3	55.82	3,294	0.236	**0.262**	36.65	2,010	0.236	0.443
3	4	41.17	2,491	0.236	**0.269**	20.40	1,396	0.236	0.415
4	5	30.08	1,866	0.236	0.276	11.93	1,020	0.236	0.385
5	6	21.77	1,385	0.236	0.282	7.33	783	0.236	0.353
6	7	15.61	1,018	0.236	0.289	4.74	632	0.236	0.320
7	8	11.09	742	0.236	0.296	3.22	536	0.236	0.286
8[b]	9[b]	7.80	535	0.236	0.302	8.21	477	0.236	0.249
9	10	5.44	382	0.236	0.309	–	447	–	
10	11	6.77	271	0.236	0.315	–	440	–	
11	12		190				464		
12	13		132				551		
13	14		91				655		
14	15		62				777		

[a] Vital rates from Wilton River population used to produce 'no-cull' population projections

[b] Male population restricted to nine age classes

Bold number indicate age-classes from which female buffalo are harvested (i.e. some females in these classes are non-lactating)

Age (x) is the age of the animals in years; F_x is the percentage of the population in the adjacent Age-class; N_t=0 is the initial state vector of each age class; q_x is the mortality rate

non-harvested population. We used data from a life table constructed for a buffalo population at Wilton River with a similar age frequency distribution to that of the Bulman River population (Supplementary Material: Appendix 1). When the non-harvest model is selected for simulation, the vital rates from the Wilton River population are invoked in the model. When harvesting is simulated for Bulman, the model invokes the vital rates for the Bulman population (Table 1).

Sustainable Livelihoods Asset Analysis

We used qualitative research methods to ascertain the benefits of buffalo mustering operations for the Gulin Gulin Buffalo Company employees and wider community. We visited and participated in the Gulin Gulin mustering in southern Arnhem Land on two occasions in August 2008 and September 2009. We organised semi-structured, in-depth interviews and participant observations. We used the semi-structured interviews as a framework to guide discussions (Liamputtong 2009) and to obtain insight into the research question: What contributions does the Gulin Gulin Buffalo Company make to local livelihoods? Observations took place whilst mustering and socialising around camp, and were recorded daily (Angrosino 2007).

The data accumulated through interviews and observations were compiled and analysed using basic coding techniques. We used the sustainable livelihoods framework to organize and analyze the contributions made to the local livelihoods. We used the five asset categories of the sustainable livelihoods framework to describe the multiple benefits derived from the Gulin Gulin Buffalo Company enterprise.

A multi-disciplinary approach was essential for understanding the biological underpinnings of this operation. Specifically, we wanted to know if the enterprise was ecologically sustainable from a strict stock and harvest model of natural resource use, disregarding the potential environmental damage caused by buffalo. The sustainable livelihoods approach allows us to examine the multiple benefits (economic and otherwise) provided to the Bulman community.

Results

In the annually harvested population at Bulman, juvenile survival made a higher proportional contribution (0.516) to population growth than adult survival (0.23) or adult fertility (0.17) or juvenile fertility (0.08) (McMahon *et al.* 2010a). Most females of breeding age were reproductively active (0.83) and even those females in the oldest age classes sampled (17 years) were observed with calves. Age at primiparity was 3 years for this population.

Given the present conditions and the assumptions of the model, the buffalo population at Bulman is being harvested sustainably (Fig. 3). The harvests are also below the estimated maximum sustainable harvest of approximately 3,400 individuals: i.e., ~ 10% of the current total population, indicating that harvests could be increased without risk to the sustainability of the enterprise. The choice of the value for r had a large effect on the sustainability assessment. Simulations that used assumed values of $r=0.2$ and $r=0.3$ produced population projections that reached an asymptote. Using $r=0.15$ produced a population projection that declined throughout the projection.

The harvest of buffalo around Bulman by the Gulin Gulin Buffalo Company can be seen as activating the otherwise dormant (in terms of livelihoods) natural capital of the local wild buffalo stocks. We could not establish whether the use of buffalo in this manner represents a net gain in natural capital for livelihoods in the region because there is uncertainty around the negative effects on livelihoods caused by environmental degradation due to buffalo. Mustering of buffalo also provides ecological subsidies for other enterprise activities in the Bulman region, such as buffalo safari hunting and tourism.

We were able to identify numerous beneficial contributions to local livelihoods created by the buffalo enterprise (Table 2). Some of these benefits are directly attributable to the presence

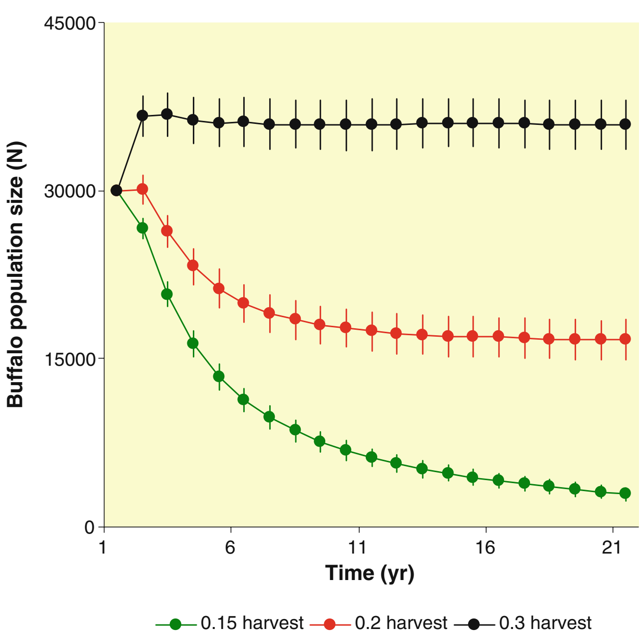

Fig. 3 Projections, at three different levels of population growth (0.15, 0.20 and 0.3), of swamp buffalo (*Bubalus bubalis*) population size at Bulman Station for the next 20 years, which is the same time period the mustering has been operating

of the company in the community, whilst others are indirect and cumulative. The buffalo operation contributes most to the financial assets of the local community. The most direct contribution to financial capital made was payment of wages to employees for their labour. In 2008, the total wages paid to employees was more than AU$83,116 (1 AUD ≅ 1 USD). The Gulin Gulin Buffalo Company also provides direct investment in the local Bulman economy through royalty payments to Traditional landowners. Since 1997, the Company has contributed at least AU$1.24 million of royalties to the local economy. Over the 11 years of royalty payment data made available from the Company, the average annual payment was AU$113,137 $year^{-1}$. However, this has steadily grown to AU$225,214 in 2008 (Table 3). These royalties are based on the number of buffalo extracted from each of their respective lands. In addition to these payments, the Gulin Gulin Buffalo Company also provides employees with small, zero-interest loans in the form of cash advances and cost-price diesel and oils for their motor vehicles. The repayments for these small loans are made by forgoing part of future wage and/or royalty payments.

Although data are not available on how much each individual employee earns, the wages they receive represent a boost to their personal income. When compared to the average annual income for indigenous employees in rural areas of the Northern Territory (AU$10,180 $year^{-1}$; Dillon and Westbury 2007), and considering that the mustering season usually lasts <6 months per year, this investment provides greater financial independence and less reliance on social security payments that are provided by the government. Combined with the royalty payments made to Traditional owners, the Gulin Gulin Buffalo Company is an important investor in the Bulman economy both socially and financially.

The Gulin Gulin Buffalo Company also provides a tool for local people to develop human capital. The company provides all training informally and on-the-job. Each season, employees are assessed based on their previous work experience and skills, and are assigned appropriate roles. As more skills are learned and confidence grows, employees are given more responsibility and higher-skilled roles to perform. Knowledge transfer occurs between the experienced operations coordinator (who works on contract for other pastoral properties outside the buffalo mustering season) and the company employees. Local traditional knowledge (in combination with other sources of information) was promoted and practiced through this work: for example, it is used for strategic decision making and navigation of the landscape (geographic and cultural) during the musters. The skills and knowledge developed by employees are likely transferable to other occupations in the pastoral industry and wider economy.

The Gulin Gulin Buffalo Company contributes to the physical capital of the Bulman community by maintaining

Table 2 Contributions to local livelihoods from buffalo mustering operations by the Gulin Gulin Buffalo Company in the Northern Territory, Australia

Livelihood assets	Livelihood contributions
Natural capital	• Introduced buffalo are a livelihood asset
	• Mustering 'subsidises' other buffalo-related activities (e.g. tourism and hunting)
	• Mustering is natural resource management
Financial capital	• Wage income
	• Royalty income
	• Small, zero-interest loans
Human capital	• Employment
	• Training
	• Knowledge and skill transfer
	• Improved diet and increased exercise
	• Overcome apparently overwhelming boredom
	• Spend time 'on country'
Physical capital	• Access roads used to outstations and culturally significant sites
	• Access to company tools and equipment for personal use
Social capital	• Employees can accrue social capital by creating wealth for the community

roads that are used for mustering operations and transport of stock. These roads are used *inter alia* by local people for vehicle access to their outstations: an outstation is a small indigenous Australian settlement, usually consisting of one family group, living in a geographically remote location within ancestral lands (Altman 2006). The Gulin Gulin Buffalo Company also allows access to producer goods that can be used by trusted employees for their own personal use, such as access to a workshop, tools and equipment, and restricted personal use of company vehicles.

We observed that buffalo were seen as a communally owned resource from which all community members are entitled to benefit (directly or indirectly). The Gulin Gulin Buffalo Company employees acknowledged their own wage income, but considered this to be a secondary benefit. For example, when questioned about what impacts the removal of buffalo might have locally, one employee responded that: "People would be sad, because it is part of making money for the community." Employees place greater emphasis on the communal income created by royalties, as opposed to the wage income accrued individually. This is important socially in accounting for the high expectation of reciprocity present in indigenous Australian societies (Schwab 1995). Whilst not exempting employees from these social arrangements, it does allow the individual to perceive himself, and to be perceived as working for the community as a whole. This is a mechanism by which individuals can potentially enhance their social capital and satisfy any requirements to contribute to their community, whilst realising personal livelihood gains.

Discussion

Feral swamp buffalo, while a serious environmental and occasional social pest (Albrecht *et al*. 2009), are also a valuable resource that can form the basis of an industry that

Table 3 A summary of the swamp buffalo harvest between 1997–2008 showing the number of buffalo mustered for sale, the royalty payments made to Indigenous land owners and the profit of the Gulin Gulin Buffalo Company

Year	Buffalo caught	Approx. value per head ($AUD)	Royalty costs ($AUD)	Profit ($AUD)
1997	451	417.47	39,837	77,564
1998	312	392.11	22,465	15,817
1999	455	454[a]	26,208	NA
2000	1,073	520.51	84,461	172,537
2001	841	550.94	84,864	144,958
2002	1,638	454[a]	167,671	NA
2003	1,091	468.55	109,059	123,260
2004	2,015	439.38	209,779	312,958
2005	2,057	432.78	106,733	142,193
2006	2,980	455.64	NA	NA
2007	2,675	454.46	168,220	134,329
2008	2,529	408.87	225,214	70,013

[a] Estimate of price per head based on a calculation of the mean price per head

NA No data available

supports indigenous people in northern Australia. Our population modelling simulations indicate that the buffalo enterprise operating at Bulman is being harvested below its maximum sustainable yield, and will, at present harvest rates, continue to provide livelihood benefits to indigenous people. Our simple approach of using a system dynamics model is not as sophisticated as matrix modelling approaches employed in predictive models of wild populations (Bradshaw and Brook 2007). Nevertheless, our model is populated with robust demographic data (McMahon *et al.* 2010a), obtained from seven populations of swamp buffalo across the Northern Territory, and is complemented by previous research (Boulton and Freeland 1991; Freeland and Boulton 1990). Indeed, our simulations give similar results to those obtained by Boulton and Freeland (1991) who developed a discrete-time model of extinction risk based on aerial control programs. They found that a consistent harvest of buffalo, using annual aerial culling campaigns, failed to eradicate a population of 10,000 animals after 150 years of simulation.

Northern Australia currently supports a vast cattle industry worth approximately AU$320 million *per annum*. Introduced buffalo are a potentially valuable resource that could aid rural development in disadvantaged aboriginal communities of northern Australia. The buffalo population is increasing and they are well-adapted to the monsoonal tropics (Bowman *et al.* 2010; Bradshaw and Brook 2007). Indeed buffalo are an excellent low-maintenance resource because unlike cattle, they can maintain body condition and positive growth during times of low food or quality (Ford 1978, 1982; Moran 1986, 1992). In addition to their ability to maintain good body condition under variable environmental situations, buffalo (unlike commercial cattle in northern Australia) have high annual reproductive rates (McCool 1992) and females continue to reproduce until their maximum age—approximately 17 years (McMahon *et al.* 2010a). Although buffalo are well-adapted to poor environments (Ford 1978, 1982; McMahon *et al.* 2010a; Moran 1986, 1992), their calves are vulnerable to extended periods of harsh conditions. For example, increased juvenile mortality has been linked to the delayed onset of the monsoon season because buffalo rely heavily on the drinking water and germinated forage produced by late dry season rains (Freeland and Choquenot 1990). These physiological advantages and low maintenance requirements make buffalo a valuable resource for remote indigenous communities of northern Australia.

Swamp buffalo in northern Australia are a valuable livelihood resource, but they will remain an ecological, social and biosecurity menace without greater controls to reduce their population size. The economic and livelihood gains associated with buffalo harvesting at rates that do not substantially reduce the population should not obscure their negative environmental and potential disease impacts (Cousins and Roberts 2001). Although a ten-year eradication program severely reduced the population size of buffalo in the Northern Territory in certain areas, it has had little impact on the buffalo population over the long-term. The lack of an ongoing maintenance control program has allowed the population to rebound to approximately 150,000 animals and once again environmental damage is increasingly evident across the landscape (Bradshaw *et al.* 2007). The expansion of the buffalo harvesting industry, and a higher harvest rate above replacement values, could thus provide ecological and biosecurity rewards in the long term. Consequently, buffalo could be transformed from a burden on the environment to a valuable resource that contributes substantially to peoples' livelihoods and their communities.

The Gulin Gulin Buffalo Company is a realization of one of the historic arguments for indigenous economic empowerment through land rights in Australia (Young 1988). That is, that ownership and control over land and resources would allow indigenous people to engage in economic development. Indeed, the Gulin Gulin employees take pride that their use of buffalo for commercial purposes allows them to demonstrate their capacity to engage in the wider economy. In comparison to other forms of enterprise development, wildlife-based enterprise is more closely aligned with and relevant to the livelihoods that are seen as valuable by many remote and rural indigenous Australians.

Buffalo can be seen as a natural resource worthy of economic exploitation for the benefit of Aboriginals in Arnhem Land. There are undoubted issues regarding the externalised costs of buffalo production (e.g., environmental damage), but in terms of strategic decision-making regarding the management of introduced buffalo, these costs should be measured against the multiple benefits described in this case. Indeed, regardless of the results of the cost-benefit analysis, it is unlikely they will be eradicated in the short-term (McMahon *et al.* 2010b). However, increasing harvest rates and expanding the buffalo harvesting to more communities could reduce densities in the medium to long-term and thus produce highly desirable economic and biodiversity conservation outcomes.

We conclude that (1) It is unlikely that the current harvest rate will negatively impact the buffalo population in the long term, (2) the buffalo mustering done by the Gulin Gulin Buffalo Company makes substantial contributions to the capital assets of individuals and the community, thus improving their livelihoods, (3) the lack of long-term density reduction of buffalo at Bulman will not provide environmental benefits unless harvest rates are increased, and (4) expanding this type of enterprise to more communities willing to engage in wildlife-based industries could bring further social benefits to indigenous people, and potentially realise a better environmental outcome. Having shown the long-term viability of mustering feral animals for export purposes, we also conclude that this harvesting could be profitable as a local source of high-grade protein (Lapitan *et al.* 2004). Not only are buffalo an accessible food source, but commercial harvesting for local consumption could bring substantial employment (e.g., harvesting, butchering, marketing, etc.). Indeed, a partnership between the members of the Gunbalanya community in Arnhem and the Indigenous Land Corporation is re-opening the abattoir at Gunbalanya and will be processing buffalo meat for local consumption as part of their business (McPherson 2010). It therefore follows that buffalo should therefore be considered as a potential basis for viable indigenous economic development in northern Australia.

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