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Artists as Harvesters: Natural Resource Use by Indigenous Woodcarvers in Central Arnhem Land, Australia

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Abstract Plant resources are used, managed and conserved by local communities in many parts of the world. However, very few studies have examined the site-specific factors and mechanisms that affect resource extraction. We apply methodology from the social and biological sciences to examine the cultural and socio-economic factors that influence the harvest practice and resource use of indigenous wood carvers in the Maningrida region of central Arnhem Land. Woodcarvers from this region use a small number of carving timbers with two species dominant, *Bombax ceiba* and *Brachychiton diversifolius*. There were many cultural differences in harvest practice, with artists from the Kuninjku/Kunibeidji language community harvesting a greater number of tree species, larger quantities per harvest trip and smaller sized stems. Socio-economic factors also played an important role in facilitating the collection of stems as artists owning a vehicle acquired more stems than those who did not. Harvest sites closest to the township of Maningrida had higher visitation frequencies than those further away. These influences on harvest practice have significant implications for the ecological sustainability of timber harvesting in this region and we highlight the need to examine such localised factors when assessing the sustainability of indigenous wildlife harvests.

Keywords Non-timber forest products · Resource use · Woodcarving · Ethnobotany · Timber harvest · Central Arnhem Land, Australia

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Introduction

Indigenous people throughout the world have harvested wild plants for hundreds of centuries for domestic use. However, in recent years customary harvest and conservation practices have been weakened by cultural change, increasing human populations and their needs, and importantly, a rapid shift from subsistence to market exchange, the commodification of production (Comaraff and Comaroff 2009). The harvest of non-timber forest products (NTFPs) by indigenous peoples has been promoted as one way of providing economic development which has lower impacts on forest communities and ecosystem processes than other land uses (Cunningham 2001; Endress *et al*. 2004; Siebert 2004; Kusters *et al*. 2006). NTFPs can roughly be defined as any useful and valuable product that can be extracted when timber production is not the primary focus of forest management, including wild foods (Aagesen 1998; Muniz-Miret *et al*. 1996; Orlande *et al*. 1996), medicinal products (Botha *et al*. 2004; Tran *et al*. 2001) and materials for art and craft production (Coomes 2004; Peters *et al*. 2003; Runk 2001). In many instances the demand for such products is low and does not exceed sustainable supply, however, the harvest of NTFPs can also result in overexploitation and this has been well documented in recent years (Ticktin 2004).

Given the economic importance of NTFPs to indigenous people, the last few decades have seen an increase in the number of studies examining the harvest of wild plants for both subsistence and commercial use, particularly in areas of Africa, Asia, South America and Latin America. These include descriptions of ethnobotanical uses, production, harvest and species inventories (Aguilar and Condit 2001; Dahdouh-Guebas *et al*. 2000; Joyal 1996; Ladio and Lozada 2004; Luoga *et al*. 2000), quantitative assessments of availability (Griffiths *et al*. 2003; Obiri *et al*. 2002; Omeja *et al*. 2004; Paoli *et al*. 2001), the use of population models to assess sustainability (Freckleton *et al*. 2003; Olmstead and Alvarez-Buylla 1995) and the impact of harvesting on plant communities (Botha *et al*. 2004; Endress *et al*. 2004; Shackleton 2001; Siebert 2004; Ticktin 2004). However, very few studies have examined the site-specific factors and mechanisms that influence resource extraction. Plant resources are primarily used, managed and conserved by local communities, and an understanding of the harvest and management strategies employed by them is essential to evaluate the sustainability of extraction (Endress *et al*. 2004; Rist *et al*. 2010).

In Australia, indigenous people were hunter-gatherers for up to 60,000 years until colonisation (Russell-Smith *et al*. 1997). In the short period since European colonisation, indigenous Australians have experienced massive social and economic transformations associated with the loss of land and access to resources. In the early 1970s a combination of statutory land rights and a policy change to self-determination resulted in a repopulation in many places of ancestral lands (Altman 2003; Commonwealth of Australia 1987). However, there is usually little opportunity for commercial activity on these lands, particularly as they are often located in environmentally inhospitable and isolated areas remote from the markets (Taylor 2003). One resource that remote indigenous communities have access to in abundance is native plants, the harvest of which plays an important role in the customary sector of now mixed or hybrid economies, providing a source of food, medicine, firewood and material for ceremonial artefacts (Altman 2010; Yunupingu *et al*. 1995). Whilst there are few commercial opportunities in Australia for the sale of wild plants, one major industry is reliant on the harvest of native plant material – the indigenous visual arts sector (Altman 2005; Altman and Whitehead 2003; Wright 1999).

In this paper we undertake an extensive field-based study to quantitatively describe a commercial plant harvest undertaken by indigenous woodcarvers in the Maningrida region of Arnhem Land. Harvest regimes can vary greatly between and within cultures, and even between individual harvesters (Ticktin and Johns 2002). In the Maningrida region, there are over a hundred sculpture artists with differing personal characteristics including gender, language community affiliation and location of residence, as well as artistic ability (Koenig *et al*. 2007). The aim of this research was to describe the factors that influence the harvest practice and resource use of woodcarvers in the Maningrida region. In doing so we identify the trees that indigenous artists are harvesting to carve wooden sculptures and the sites from which trees are harvested. We document the harvest practices, of local artists and examine how these aspects of resource use are influenced by cultural and socio-economic factors using generalised linear modelling. We also establish whether a community arts database could be used as a cost-effective means to monitor local resource use in the future.

Materials and Methods

Study Location and Artist Participants

This study was carried out in the Maningrida region, an administrative area of approximately 10,000 km^2 located in central Arnhem Land, Australia (Fig. 1). This region lies in the wet-dry tropics of Australia where 92.6% of the rain falls between December and April (mean annual rainfall is 1,284 mm; Bureau of Meteorology 2011). The township of Maningrida is a small, remote Aboriginal community that was established as a service locality by the Welfare Branch of the Northern Territory administration in 1957 to administer then Aboriginal ‘wards of the state’. The last five-yearly national census (2006) estimated that just under 3,000 indigenous Australians resided in the region (Altman 2008): the majority reside in the main township of Maningrida and a smaller number live at over 30 outstations (small family based communities usually with between 10 and 50 residents) scattered throughout the Maningrida region. There is an increased tendency in recent years for people to live between town and country, especially on a seasonal basis (Altman 2006). The landscape is structurally intact and characterised by the Arnhem Land sandstone escarpment to the south and extensive wetland and lowland plains to the north where the dominant vegetation is *Eucalyptus* savanna (Griffiths *et al*. 2000).

Linguistically it is a very diverse region. Over ten different language communities in this region of Arnhem Land produce wooden sculpture for sale at the art centre, of which six comprise the majority of carvers (Koenig *et al*. 2007). For this study, these six language communities were broadly classified into two groups of producers. The first consists of wood-carvers from the Kuninjku and Kunibeidji language groups (hereafter referred to as language cluster A), and the second consists of carvers from all the other language groups: Burarra, Djinang, Gunartpa and Rembarrnga artists (referred to in this paper as language cluster B). Members of these two

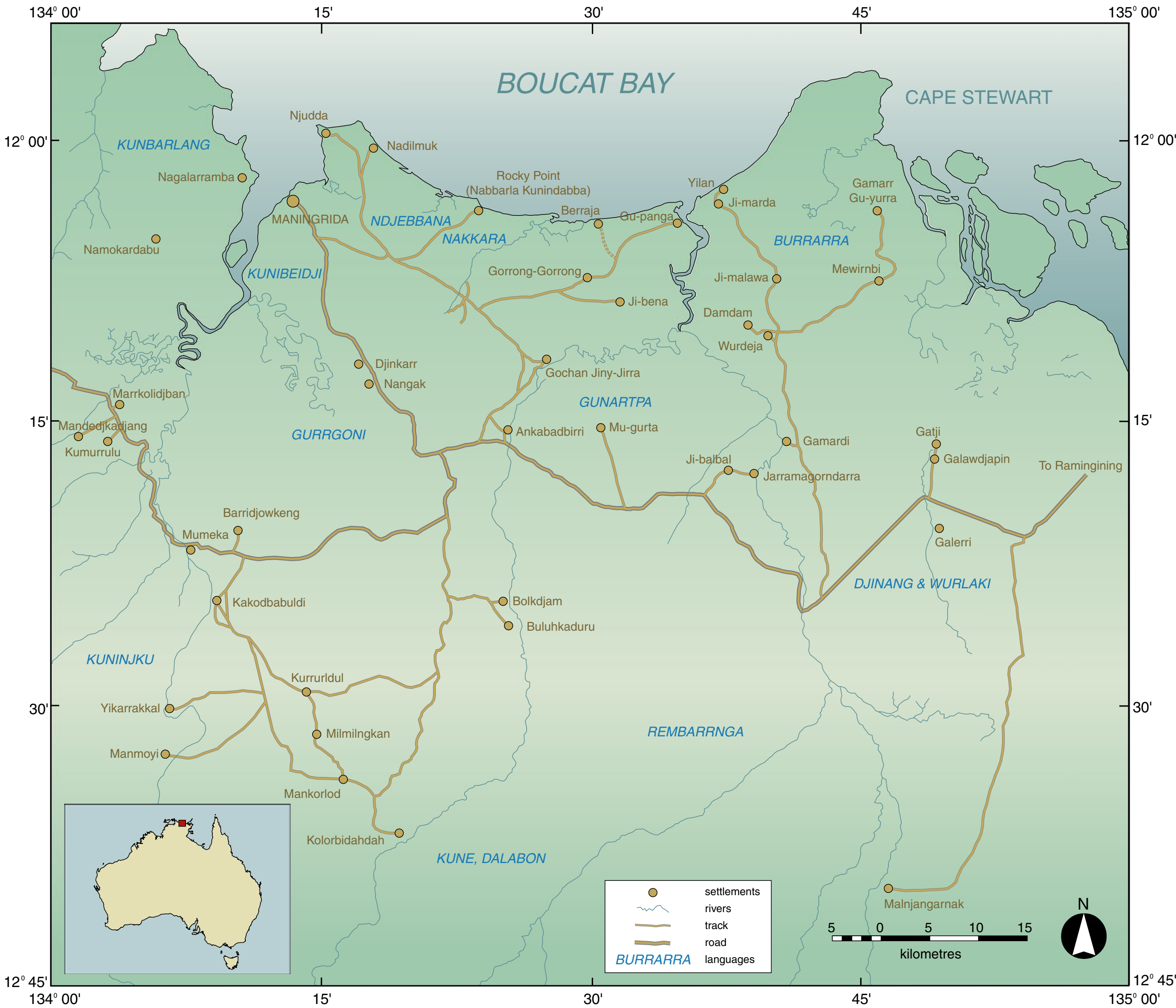

Fig. 1 Map of the Maningrida region in central Arnhem Land, Australia, showing the location of outstation residences and language groups (in italics)

language group clusters have been producing sculpture since at least the early 1980s and account for over 80% of the carving produced in the region (Koenig *et al*. 2007). We stratified the languages this way as earlier work indicated that the harvest practice of artists from the Kuninjku/Kunibeidji community were quite distinct, although not perfectly discrete, from other producers in the region. The Kuninjku and Kunibeidji language groups are particularly closely allied, with existing cultural ties and are interrelated through kin-based social networks and marriage.

All artists from these two language groupings (cluster A and B) who were actively carving during 2002 and who were willing to participate in the study were involved. These artists covered a range of demographic variables, including gender, age, artistic experience and residence location (either primarily in Maningrida or primarily at one of the regional outstations). Of the 31 artists involved in the study, 18 were from language cluster A, and 13 from the language cluster B. This included 24 male and 7 female woodcarvers. Nine of the artists involved in the participant observation study, who were actively carving during 2002, were inactive during 2003. Participants were paid local consultants rates for giving their time to help with this research.

Participant Observation

Participant observation was used as a preliminary method for gathering information on the timber species used by artists in the Maningrida region to carve sculpture, the sites from which they harvest these trees and aspects of their harvest practise. Between May and September 2002, the senior author accompanied 21 individual artists on 25 wood collecting trips. The vehicle and fuel was provided for the trips. However, artists used their own harvesting equipment. During the harvest trips, we recorded the following information for each harvested stem: the tree species, its height (m), diameter at breast height (cm), and reproductive condition (the presence of flowers or seeds were noted), the number of pieces taken from the tree stem and the dimensions of these pieces. A GPS waypoint was taken for every individual tree that was harvested. During the process, artists were also questioned informally on cultural aspects relating to the harvest.

Resource Accounting

The participant observation described above was a somewhat artificial method of data collection where the researcher (JK) was actively involved in the collection of tree stems and provided key resources for the harvest trip (e.g., vehicle and fuel), perhaps making it easier for artists to acquire stems than it would otherwise be. To further investigate patterns of resource use, we undertook a resource accounting study (Zent 1996), where the resource types (i.e. tree species) and the amounts acquired or utilised by artists during specific periods were observed. The senior author undertook the resource accounting study over six consecutive months between June and November 2003 with 31 artists from the region. Each month all the artists were visited on two occasions spaced 7 days apart. Artists were visited at their place of residence and visits were generally random and unannounced (permission was granted by each artist at the start of the study). If an artist was unavailable at this time, family members were involved and/or follow-up questions were directed to the artist on a subsequent trip. On each of these visits any harvested stems or unfinished carvings were measured and documented. In conjunction, artists were questioned on aspects of the harvest such as: the location of the harvest, the time since stems were cut and the tree species harvested.

Semi-Structured Interviews

Semi-structured interviews were conducted with artists involved in the resource accounting study. Interviews were undertaken opportunistically throughout 2003, at the artist's place of residence and local language interpreters were used. All interviews were recorded using a digital Minidisk and later transcribed. Interview questions related to many aspects of woodcarving from the history of sculpture production, to harvest practices and the cultural determinants of tree species and site selection. The interview data were collated and responses to structured questions were grouped into themes. We have included a small number of direct quotes to highlight the main themes raised by artists.

Arts Database

Since the Maningrida township-based art centre, Maningrida Arts and Culture (MAC), is the only outlet in the region for artists to sell their work, the centre's database has the potential to be a useful tool for monitoring tree species use. Each piece of art that is brought to the centre is individually labelled and recorded in a database that includes: artist's name, primary language community, the date of production, size, sale price, and the plant species used to produce the work. At the commencement of this project, we developed a tree identification booklet of the range of species used for carving in the region. This book contained colour photographs of each tree, its leaves, bark, flowers and/or seeds and a description of its habitat. Accompanying each photo was a list of local language names for each species. As each sculptural work was brought into the art centre the artist would flip through the book and identify the species used for the carving and for the duration of the project this information was entered into MAC's database. Based on the length and diameter measurements of stems observed in the field, the arrival of individual stems at the art centre could be traced and the field data linked to the arts data. This enabled comparisons to be made between the tree identifications observed in the field and those recorded at the art centre.

Data Analysis

Descriptive statistics were used on both the participant observation and resource accounting data to describe trends in harvest practice and resource use. Wilcoxon or Students t-tests were used to compare the difference between two means and contingency table analyses were used to compare the frequency of variables in the art centre database. All data were tested for significance at the $p=0.05$ level and checked for relevant assumptions prior to analysis.

An information-theoretic approach was used to examine the factors that affect the frequency of harvest site use and the number of stems acquired by artists (Burnham and Anderson 1998). Models were fitted using generalized linear modelling (GLM) and a poisson (log link) distribution was used in both cases, as the response variables were count data (Crawley 2002). Model selection was based on Akaike's Information Criterion from an *a priori* candidate set of models (Burnham and Anderson 2001). We estimated overdispersion ($\hat{c}$) using the ratio of mean deviance to degrees of freedom for the global model and where there was evidence of overdispersion ($\hat{c}>1$) we used the quasi-likelihood modification (QAIC). We also used the second order criterion (QAICc) if the sample size was small compared to the number of parameters. ΔAICc or ΔQAICc values, the log likelihood (log (L)), and Akaike Weights (w_i) were calculated based on Burnham and Anderson (1998) allowing the easy interpretation and ranking of candidate models. Values of ΔAICc less than 2 have substantial support given the data, values between 4 and 7 have considerably less support and values over 10 essentially no support (Burnham and Anderson 1998). A given w_i is considered as the weight of evidence in favour of model i being the actual K-L best model given the models at hand (Burnham and Anderson 1998). All analyses were undertaken using R 1.9.1 (© The R Foundation for Statistical Computing).

Results

Tree Species Harvested

Sculpture artists were observed to collect timber from seven different tree species during the participant observation trips and the resource accounting study (Table 1). The two methods revealed similarities in the number of tree species; however, two of the six species were observed only during the participant observation (*Excoecaria ovalis* and *Sterculia quadrifida*) and the use of *Hibiscus tiliaceus* was observed only during the resource accounting. All of the species that were used for sculpture are native to the region and distributed widely throughout northern Australia (Brock 2001). Of the tree species, two are large (≥20 m in maximum height), two are medium sized (10–20 m height) and three are small to medium sized trees (Table 1). Five out of the seven trees species are deciduous or semi-deciduous, and all seven tree species do not suffer from internal insect damage (e.g., compared to the termite hollowing of trunks which is common in other tree species in northern Australia; Fox and Clark 1972). The two methods of data collection showed similar relative use of the tree species. During the participant observation, *Bombax ceiba* and *Brachychiton diversifolius* accounted for the majority of harvested tree stems (29% and 63% respectively); however, whilst these species continued to dominate in the resource accounting, the use of another species, *Nauclea orientalis*, accounted for 30% of harvested stems.

Harvest Sites

A total of 20 harvest sites were identified from the participant observation (n=13) and resource accounting (n=12) studies and of these, five sites were observed during both. During the participant observation, artists travelled an average distance of 33.4±4.3 km to harvest sites. A Wilcoxon rank-sum test revealed that there was no significant difference between the two language communities (cluster A and B) with respect to the mean distance travelled to harvest sites (W=94.5, df=24, p=0.61).

Results from generalised linear modelling showed that the variation in frequency of use of a harvest site (including results from both the participant observation and resource accounting) was best explained by the distance of that site from the main township of Maningrida (Table 2). As evidenced by the differences in ΔAICc and Akaike weights (w_i), the models containing this parameter were better supported compared to others in the candidate set (making up over 90% of the Akaike weights; Table 2).

Harvest Quantity

A total of 177 trees were harvested during 2002 on the participant observation trips (n=25). All trees were destructively harvested. The entire tree was felled at the trunk between 5 and 50 cm from the ground using a metal axe and the artists cut different lengths of timber from the fallen tree for their carvings. Two tree species were targeted more often than others – *B. ceiba* and *B. diversifolius* (Fig. 2). Of the 25 harvest trips that we participated in, *B. ceiba* was felled on 14 trips and *B. diversifolius* on 11 trips (Table 3). The number of individual trees harvested, and thus the average number of trees cut per trip, was much higher for *B. diversifolius* compared to *B. ceiba* (Table 3). However, the average number of pieces of timber taken from each tree (i.e., the number of sculptures that will be made per tree) was higher for *B. ceiba*, at around two pieces per tree, compared to an average of one piece per tree for *B. diversifolius* (Table 3). There were marked differences

Table 1 Summary of tree species harvested by woodcarvers in the Maningrida region of Arnhem Land

Tree species	Family	Habitat	Height	Habit
Bombax ceiba	Bombaceae	Monsoon Forest	medium	Deciduous
Brachychiton diversifolius	Malvaceae	Open Forest	small-med	Semi-deciduous
Canarium australianum	Burseraceae	Monsoon Forest	med-large	Deciduous
Exoecaria ovalis	Euphorbiaceae	Mangrove Forest	small	Deciduous
Hibiscus tilaceus	Malvaceae	Coastal	small	Evergreen
Nauclea orientalis	Rubiaceae	Monsoon Forest - Riparian	med - large	Semi-deciduous
Sterculia quadrifica	Sterculiaceae	Monsoon Forest	small	Deciduous

Table 2 Results from generalised linear modelling of the factors affecting the frequency of harvest site use. The global model included the following parameters; distance to Maningrida, distance to artist, region and species. The ΔAIC_c=the difference between that model's Akaike's Information Criteria (AIC_c) value, and the minimum AIC_c value in the candidate set. Log (*L*)=the likelihood of the model and w_i= Akaike weights. Null deviance=64.1. Candidate models with significant levels of empirical support ($\Delta QAIC_c$<2) are shown in italics

Model	Parameter	Change in deviance%	K	AIC	ΔAIC_c	Log *(L)*	w_i
1	Distance to Mng	*17*	*2*	*110.43*	*0*	*−52.86*	*0.64*
2	*Distance to Mng+Distance to artist*	*19*	*3*	*111.78*	*1.35*	*−52.49*	*0.32*
3	Distance to artist	6	2	117.02	6.59	−56.16	0.02
4	Language cluster	4	2	118.76	8.34	−57.03	0.01
5	Global	61	10	121.43	11.01	−38.49	0.00
6	Species	25	7	123.99	13.57	−50.33	0.00

between the two language communities with respect to their choice of timber. Combining all results of tree use (participant observation and resource accounting), artists from language cluster B mostly harvested *B. ceiba* stems for their carvings (Fig. 3). In contrast, artists from language cluster A were more varied in their choice of timber (Fig. 3). Amongst the cluster A artists, the majority (23 out of 30) only used one tree species for their carvings. However a small percentage of artists sourced their timber from a number of tree species (Fig. 4).

Fig. 2 Artists harvesting *B.ceiba* (**a**) in monsoon rainforest and *B. diversifolius* (**b**) in open woodland for the production of wooden sculptures in the Maningrida region

Individual trees were selected for harvest based on the attributes the artist desires for their sculpture (i.e., length, thick *vs* thin, straight *vs* curvy). The length and diameter of a harvested stem was significantly different between different regions. Cluster A artists harvested significantly longer (mean length=2,088 mm *vs* 1,800 mm, t=4.11, df= 136, p<0.0001) and skinnier tree stems (mean dbh=9.3 cm *vs* 16.8 cm, t=13.8, df=126, p<0.0001) than artists from language cluster B. As artists from language cluster B harvest *B. ceiba* stems, they had the largest diameter at around 16 cm, whilst *B. diversifolius*, *N. orientalis* and *Canarium australianum* stems (the species used by cluster A artists) had smaller diameters (Table 4). These patterns do not reflect the maximum diameter of mature trees of these species but selection of particular size classes by artists. *B. diversifolius* was the only tree in which curvy and straight stems were harvested; however the number of straight trees chosen was greater than that of curvy ones (Table 4).

Over the 42-day sampling period of the resource accounting study, artists acquired a total of 211 pieces of timber. The average number of stems acquired by each artist during each 7-day period (spread over 6 months) is given in Table 5 and divided into the two language clusters. From these figures we have extrapolated the figures up to the average number of stems acquired by an artist each month (28-days) and per carving season (taken as encompassing 6 months; Koenig *et al*. 2007). From these figures we estimate that each active carver in the Maningrida region would produce 11 carvings per carving season, with cluster B artists producing an average of four carvings and cluster A artists an average of 17 carvings per season (Table 5).

Results from the model selection indicated that the model containing both parameters language and vehicle best explained the variation in the total number of stems acquired by artists during the resource accounting study

Table 3 Summary of harvesting trips undertaken during the participant observation study and the number of trees harvested. Average values displayed are ± one standard error

Tree species	# Trips	Total # Trees	Total # pieces	# Pieces/Trip	# Pieces/Tree
B. ceiba	14	34	64	4.57±0.50	1.88±0.16
B. diversifolius	11	124	138	13.9±2.96	1.12±0.02
C. australianum	1	8	8	8.00	1.00
N. orientalis	2	11	11	5.5±4.50	1.00

(having a 42% probability of being the best model from the candidate set; Table 6). The other candidate models with good support given the data were univariate models of language (w_i=0.21) and vehicle (w_i=0.18). Indeed, the models that made up the top 81% of Akaike weights contained only the two parameters language and vehicle. This indicates that the total number of stems acquired by artists was primarily influenced by their language cluster (A or B) and whether the artist owned their own vehicle. Cluster A artists acquired more stems per unit time than those in cluster B, and artists who owned their own vehicle acquired greater numbers of stems.

Cultural Determinants of Species and Site Selection

There were some distinct patterns in the transfer of skills and knowledge about woodcarving. An artist's use of tree species was highly influenced by who taught them about carving. All of the women interviewed identified that they had learnt carving techniques from their husbands who were also artists. In contrast, the male woodcarvers identified that they learnt about carving from their fathers (40%) or older male relatives (55%). One cluster A artist describes this as follows: *I started carving when I was 18 years old, I looked at my father when he was making them and I saw. So I do it the right way, doing carving like my father taught me, he told me "when I die just work this carving because every carving belongs to me".* (Cluster A artist CK 2003). The older Cluster B woodcarvers (n=4) identified that they learnt about carving from elder men who used to carve dugout canoes from the *B. ceiba* tree.

Over 80% of artists mentioned that carving was started in the region by a Kuninjku man, Crusoe Kuningbal, during the 1960s and 1970s for use in a trade or exchange ceremony context and also for sale at the art centre. One of Kuningbal's sons describes his father's use of carvings in the following way: "*He made it (carvings) for sale and for shows as well. He used to put it (the carving) in the middle and would dance around it*" (Cluster A artist CK, 2003). Kuningbal only used *B. diversifolius* for his carving and around two thirds of the Cluster A artists in this study (including three of his sons) indicated that they used *B. diversifolius* as they are following the influence and tradition of this now deceased man.

When asked about restrictions for harvesting timber, none of the artists identified any restrictions for harvest based on language group, gender or moiety (in much of Arnhem Land, individuals are classed as belonging to one of two patrilineal moieties; Duwa and Yirritja; (Morphy 1998)). However, a small percentage of artists indicated that there are harvesting restrictions related to certain sites, such as ceremony or Dreaming sites. Over 90% of artists mentioned that you must ask for permission if you are harvesting timber from other peoples land (over 80% of artists harvested stems at one time or other from country that was outside of their clan estates). Artists described this, saying: *There are some secret places. You ask the traditional owner first before you go through and cut them, you have to ask the right way so they can show you the right place, they*

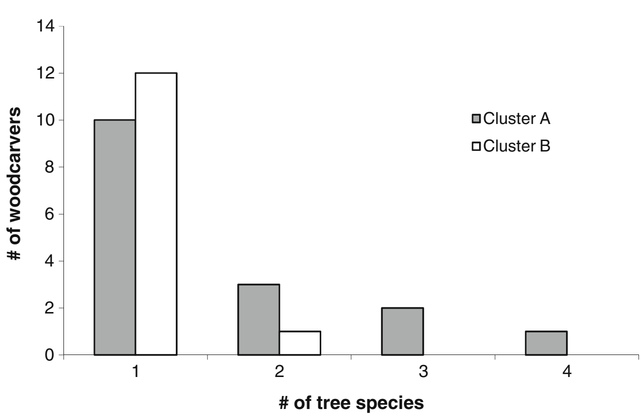

Fig. 3 The differences in the number of tree species used for woodcarving by the two language communities in the Maningrida region as observed during the participant observation and resource accounting

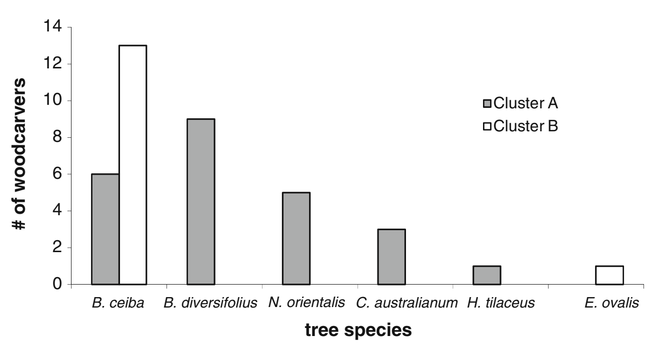

Fig. 4 The relative use of the different tree species for woodcarving by artists from the two language communities in the Maningrida region during the participant observation and resource accounting

Table 4 The characteristics of harvested stems observed during the participant observation. Average values are displayed ± one standard error. Straight: Curvy is the ratio of the number of straight to curved stems

Tree	Length of stem (cm)	Diameter of stem (cm)	Straight:Curvy
B. ceiba (*n*=34)	191.8±7.2	16.2±0.5	34:0
B. diversifolius (*n*=124)	193.5±4.8	11.2±0.3	22:1
C. australianum (*n*=8)	247.4±13.1	6.8±0.2	8:0
N. orientalis (*n*=11)	282.6±12.4	5.9±1.0	11:0

might say don't go through there, don't cut that tree. (Cluster A artist OY 2003).

Seasonal access was not identified as a problem for collecting *B. diversifolius* stems; however, artists mentioned that most *B. ceiba* sites are flooded and inaccessible during the wet season months. The most accessible *B. ceiba* sites year round identified by artists are also the patches located closest to the main settlement of Maningrida. When describing the good characteristics of the woods that they use for carving, artists using *B. ceiba* mentioned "soft" and "easy to carve" whilst artists using *B. diversifolius* mentioned "hard" and "doesn't crack." A few alternative uses of these tree species were described by artists, including the production of string and rope, edible seeds and tap root for *B. diversifolius*, and use of timber for dugout canoes and honey or water collecting dilly bags, an edible tap root and cottonwool like material used in ceremonies for *B. ceiba*. Only two artists (a husband and wife) spoke of a dreaming story related to the *B. ceiba* tree at a particular site in their country. *When you go to that jungle, to that tree (B. ceiba), don't touch that tree because it's really dangerous. When they (artists) have an axe or especially if kids touch that tree we'll have lots of wind and really cold weather and make rain out of that tree, really strong just like a cyclone.* (Eastern artist BB 2003). Other artists mentioned that the trees were created in the Dreamtime, but had no particular story.

Species Inventory from the Arts Database

There were 14 tree species recorded as being used for sculpture production during 2002 and 2003 in the arts database. This corresponded exactly with the total number of trees that were in the identification booklet (some of which were included as placebos). Two species were recorded in the art database as the main species used by artists in the region, *B. diversifolius* and *B. ceiba* (Table 7), accounting for 40% and 39% respectively of known tree use (excluding unknown records). However, many species recorded in the arts database were not observed to be harvested in the field (Table 7). Using the linked field data and art centre data, the tree identifications recorded in the arts database ranged in accuracy with the most commonly used species *B. ceiba* and *B. diversifolius* having the highest percentage of correct identifications (57% and 47% respectively; Table 8). The less commonly used timbers showed a high degree of error in identifications (Table 8).

Discussion

A paper reviewing the ecological implications of indigenous timber harvesting around the world, highlighted the importance and yet lack of research on the variation in local harvest regimes and how these variations affect assessments of harvest sustainability (Ticktin 2004). Previous studies have relied on interview data or informant recall, which have many inherent biases (Aguilar and Condit 2001; Jensen and Meilby 2010), or focused on experimental assessments of harvests. In the latter case researchers mimic the harvest rates gleaned from local informants and the effects of the harvest are documented (Endress *et al*. 2004). The multidisciplinary approach and integrative methodology in this study provided an accurate way of quantifying local resource use and harvest strategies. Such data are crucial for modelling and assessing the sustainability of indigenous harvest regimes accurately, which is not only essential for the conservation of the plant species but also for the livelihoods of people in the region (Ticktin 2004).

Woodcarvers from the Maningrida region of central Arnhem Land use a relatively small range of timbers to

Table 5 The average number of stems acquired by individual artists per carving season ± one standard error. Results are extrapolated from the average number of carvings acquired during the 7-day resource accounting period. Carving season is taken as 6 months of the year (May to December)

Group	Av. #/7 days	Av. #/month	Av. #/carving season
Cluster B (*n*=13)	0.15±0.11	0.6±0.44	3.6±2.64
Cluster A (*n*=18)	0.70±0.25	2.8±1.0	16.8±6.0
Total (*n*=31)	0.47±0.16	1.89±0.64	11.34±3.84

Table 6 Results from generalised linear modelling of the factors affecting the number of stems acquired by artists during the resource accounting. The global model included the following parameters; language community (cluster A or B), vehicle, residence (outstation or town), gender and average $ return. The $\Delta QAIC_c$=the difference between that model's Akaike's Information Criteria ($QAIC_c$) value, and the minimum $QAIC_c$ value in the candidate set, Log (L)=the log likelihood of the model and w_i=Akaike weights. Null deviance= 165.734. Candidate models with significant levels of empirical support ($\Delta QAIC_c$<2) are shown in italics

Model	Parameter	Change in deviance%	K	QAIC	$\Delta QAIC_c$	Log *(L)*	w_i
1	*Language+ Vehicle*	*33.5*	*3*	*34.7*	*0*	*−77.5*	*0.42*
2	*Language*	*19.8*	*2*	*36.1*	*1.41*	*−88.9*	*0.21*
3	*Vehicle*	*19*	*2*	*36.4*	*1.66*	*−89.6*	*0.18*
4	Language+Residence	32.1	4	38	3.30	−78.6	0.08
5	Residence+Language+Vehicle	40.6	5	38.8	4.03	−71.6	0.06
6	Residence	15	3	40.2	5.45	−92.8	0.03
7	Return	2.4	2	41.3	6.55	−103.3	0.02
8	Gender	1.8	2	41.4	6.70	−103.8	0.01
9	Global	45.6	8	49.6	14.82	−67.4	0.00

produce wooden sculptures. Whilst there are hundreds of available tree species in the region, two species dominate in the production of carvings, *B. ceiba* and *B. diversifolius*. Many species that are available in the Maningrida region and not utilised by local woodcarvers are used in other indigenous communities of the 'Top End'. For example, on the nearby Tiwi Islands carved mortuary poles are made solely from the Ironwood tree, *Erythrophleum chlorostachys* (Hoff 2000), and in eastern Arnhem Land the timbers from over 10 plant species have been identified as being used commonly for woodcarving (Yunupingu *et al*. 1995). The regional diversity and differences in resource use for carvings reflects the development of sculpture production in particular areas. As in other parts of the world, a small range of different timbers are often favoured as a result of social, cultural and historical factors (Chibnik 2003; Cunningham and Choge 2004).

The artists in this study from language cluster B used just one species, *B. ceiba,* for their sculpture whilst artists from cluster A utilised a range of species but predominantly *B. diversifolius* for their carvings. This difference in species use with respect to these language groupings is not related to the tree species distribution in the region as most of the trees (aside from *H. tilaceus and E. ovalis* which are distributed along the coast) are found throughout the area (Griffiths *et al*. 2000). Instead, these patterns of timber use can be related to the development of sculpture production within particular language communities and pre-colonial artistic practises. In this region of central Arnhem Land, woodcarvings were not produced in pre-contact times outside restricted ceremonial contexts. A Kuninjku artist, Crusoe Kuningbal, was the first artist to produce sculpture in this region for inclusion in a local trade ceremony and later for sale at the newly established art centre during the 1960s. Kuningbal carved spirit figures from *B. diversifolius* and today, artists from the Kuninjku/Kunibeidji language cluster continue to produce the majority of carvings from this tree. As the market developed (see Taylor 2005 for details) many more artists, from many language groups in the region started using this medium to depict their own cultural themes (Taylor 2005).

The early woodcarvers from the other language groups (particularly Burrara, Gunartpa and Rembarrnga) drew from their knowledge of *B. ceiba,* which was used to

Table 7 Summary of the tree species recorded in the art centre database as being used for woodcarving as identified using the identification booklet between 2002 and 2003

Common name	Scientific name	% carvings (n=1851)
Cottonwood	*Bombax ceiba*	31.7
Kurrajong	*Brachychiton diversifolius*	30.8
Leichhardt tree	*Nauclea orientalis*	8.2
Peanut tree	*Sterculia quadrifica*	2.9
Beach Hibiscus	*Hibiscus tilaceus*	2.2
Coral tree	*Erythrina variegata*	1.8
Ironwood	*Erythropleum chlorostacys*	1.7
Canarium	*Canarium australianum*	0.2
Other		1.0
Unknown		19.4

Table 8 The percentage of correct tree identifications between tree stems observed in the field and identifications for that stem later recorded in the arts database during 2002 and 2003. *no*=not observed during that year. Sample sizes (n) are displayed as 2002 and 2003 consecutively

Species	2002 (%)	2003 (%)	Average (%)
B. ceiba (*n*=73; 57)	67	47	57
B. diversifolius (*n*=141; 104)	40	54	47
C. australianum (*n*=8; 2)	12.5	0	6.2
E. ovalis (*n*=8)	0	*no*	0
N. orientalis (*n*=16; 87)	0	22	11
H. tilaceus (*n*=7)	*no*	43	43

produce dugout canoes, to derive their timber for woodcarvings. It is interesting to note that dug-out canoes were strongly influenced by the Macassan traders from Indonesia who visited the coastline of Arnhem Land on a regular and seasonal basis in search of trepang (sea cucumber) between the 1500s and 1900s (Morphy 1998), and *B. ceiba* is a species widely distributed throughout the Asia-Pacific region (Brock 2001).

Tree sizes are selected based on the attributes the artists require for their carving and this is influenced by cultural subject matter. Artists from the cluster B language community carve a number of spirit and animal (mostly bird) figures, whereas Kuninjku/Kunibeidji artists predominantly just carve mimih spirit figures (Koenig *et al*. 2007). Culturally, mimih spirits are recognised as tall slender spirits who live in the rock crevices of the Arnhem Land escarpment (Taylor 2005) and so sculptural representations are also tall and slender. Thus, the average diameter of stems harvested by cluster A artists was almost half the average diameter of those harvested by the other artists (Fig. 5). These differences in size class selection can have significant influences on the sustainability of the timber harvest. Studies have shown that the harvesting of reproductively active, adult stems can increase the risk of over-harvesting in many tree species (Peters 1994). Often it is the survival of the largest size classes that contribute the most to population growth while seed and juvenile survival contributes relatively little (Ticktin 2004).

Harvest models have shown that the timing, form and intensity of harvesting are all important in determining plant population behaviour (e.g., Freckleton *et al*. 2003). The cluster A artists, particularly the Kuninjku, demonstrated a higher intensity of harvest than the other artists in the study and this has been documented elsewhere as a result of a number of social, cultural and economic factors (Koenig *et al*. 2007). The average harvest sizes for *B. ceiba* and *B. diversifolius* are well over the minimum reproductive sizes recorded for these species in the Maningrida region (Koenig 2007). The harvesting of timber for woodcarvings is conducted during the dry season months (June-November), the timing of which coincides with the production of flowers and seeds (Brock 2001). Whilst harvesting may affect the reproductive potential of trees in the short term, the actual method of harvesting has been observed to be conductive to coppicing in *B. ceiba*. Griffiths *et al*. (2003) estimate that 80% of the *B. ceiba* trees harvested in the Maningrida region will coppice, of which many will grow to become reproductively active. The contribution of coppicing to sustainable yields of non-timber forest products has been recognised for other tree species around the world (e.g., Obiri *et al*. 2002; Shackleton 2001).

Harvested plant species that have a low rate of occurrence or restricted distribution in the landscape may be more susceptible to over-harvest (Tran *et al*. 2001). The two main species utilised for carving in the Maningrida region differ in their distributions and habitat. *B. diversifolius* is found throughout the eucalypt savanna landscape in

Fig. 5 The size differences between carvings from the two language communities. The three sculptures on the left are Mimih spirits carved by language community A artists, the two carvings on the left are Wangarra and Wurum spirits carved by language community B artists

varying densities (Griffiths *et al*. 2000), with patches of particularly high density located around coastal fringes and watercourses. In contrast, *B. ceiba* is constrained in distribution to small and isolated dry monsoon forest patches that are scattered throughout the eucalypt-dominated forest and woodland. Whilst *B. ceiba* is well distributed in monsoon forest throughout the region (Griffiths *et al*. 2003), its confinement to rainforest vegetation may leave it more susceptible to over-harvest at the individual patch level.

The indigenous population in the Maningrida region is highly mobile, with people moving between the service centre of Maningrida township (where most reside for part of the year) and outstations (Altman 2006). The harvesting sites closest to the main township of Maningrida are used by artists living permanently in Maningrida and also those who may reside there at some time during the year. Griffiths *et al*. (2003) found that harvesting intensity for *B. ceiba* at individual rainforest patches was highly variable across the region and showed a trend towards an increase of intensity at the sites closest to Maningrida (Griffiths *et al*. 2003). This is supported further by our analyses in which the sites closest to Maningrida showed an increased frequency of use. Such patterns of use and potential over-use at the individual patch level may affect the economic and social viability of the carving industry, as some artists who depend on local patches may be unable to access more distant sources and may be disadvantaged.

Socio-economic factors play an important role in determining the quantity and frequency of harvesting timber for woodcarvings. The average distance of 33 km that an artist travels to harvest timber is not a trivial distance when taking into account the high fuel prices, the bad condition of roads and the low rate of vehicle ownership. Artists are generally not harvesting from local patches near their place of residence but are actively travelling significant distances to reach particular sites. Artists may be travelling these distances in order to harvest from particular sites with high densities of the target species. Artists who possessed a vehicle were able to acquire more tree stems and thus were able to be more active in arts production and income generation. Whilst the local art centre has a vehicle that is used periodically to take artists to collect plant materials for artwork, this vehicle supports over 300 artists and is not monopolised by any individual artist. Artists of lower economic standing without the means to purchase a vehicle may be disadvantaged in their attempts to participate in the arts industry and earn an income from arts production. In other parts of the world, these access issues have been mediated by having the wood resource cut and delivered by intermediary suppliers (Standa-Gunda *et al*. 2007). In many cases this has evolved due to local depletions of the wood resource, requiring supplies to be delivered from other communities (Chibnik 2003; Cunningham and Choge 2004).

In the Maningrida region, traditional landowners manage their lands and are responsible for the health of their country (Gambold 2009). Artists mentioned that there are cultural restrictions on the use of particular sites for harvesting carving trees, and hence they were required to ask permission when collecting wood from other peoples land. In practice, this may translate to asking permission once a year and it is difficult for landowners to regulate the exact intensity of harvest on their land due to the large tracts of country involved. In general, landowners receive no monetary reward for the timber that is sourced by other indigenous artists in the region from their land (except when they are the carvers). Once the timber is cut it becomes the resource of the harvester and they gain most of the monetary benefits from the production and sale of the artwork (in some cases there may be redistribution to kin). The supply of some timber from local landowners could help in regulating the amount of harvesting that occurs on their land, may help to spread the harvest throughout the region rather than focussing on timber patches close to the main township and could provide employment and an income source. However, this could also lead to over supply and wastage as currently artists just take what they want to carve and there is little wastage (J Koenig pers. obs.)

The integrative use of several different methodologies in this study provided a robust means of examining the resource use and harvest practise of indigenous woodcarvers in central Arnhem Land. However, this methodology proved to be very time consuming and expensive (the senior author drove 4000 km each month on remote dirt roads). As an alternative, the local art centre database has the potential to be a useful and inexpensive tool for monitoring resource use. We found that for the most commonly used species, *B. ceiba* and *B. diversifolius*, tree identifications were 50% accurate in the database. The arts data overestimated the total number of species used – the number of species recorded equalled the number of species in the identification book, some of which were included as a control mechanism. However, the actual number of carvings and artist information recorded in the arts database are likely to be accurate, as records must be entered into the computer before the artist can be paid (Koenig *et al*. 2007). The data showed a trend towards more accurate tree identifications in the second year of the study and the results of this study should facilitate the collection of more accurate data.

The resource use and harvest practice data highlight potential factors that could indicate whether the woodcarving practice in the Maningrida region is likely to be sustainable. However, the sustainability of any plant harvest can only be determined by directly measuring the rate of extraction and comparing it to the rate of natural replacement and this requires an understanding of the dynamics of plant populations and the effects of harvesting (Choquenot 1996; Ticktin

2004). In a parallel study we have examined the population ecology of the two main carving wood species, *B. ceiba* and *B. diversifolius*, including their growth, recruitment and pre- and post-harvest survival (Koenig 2007). Whilst it was not within the scope of this paper, the localised harvest data reported here will be used along with the ecological data to assess the sustainability of timber harvesting in this region of Arnhem Land using population and harvest modelling. Such harvest models can also be used to assess a variety of future harvesting scenarios that are of concern to traditional landowners. Fortunately, in northern Australia indigenous landowners and resource users have the opportunity to monitor and manage timber harvests before over exploitation and depletion occurs. This will help to ensure that culturally and economically important plant species, such as carving wood trees, are conserved and available for future generations for purposes of sustainable production possibilities and appropriate development.

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