Sullivan

Proposed research in Owambo, Namibia:
Pilot study April - May 1994
Main period of fieldwork August 1994 - August 1995

The effects of changing land tenure on the sustainability of arid land wild resource use in Owambo, northern Namibia.

Conventional research concerning agricultural and pastoral subsistence strategies by people in rural Africa has only recently started to pay attention to the contribution that uncultivated and unhusbanded natural resources make to people's livelihoods. This is despite the fact that these resources may be of central, as opposed to peripheral, significance to food and income security, and often constitute a final buffer against absolute poverty for the rural poor. Such resources may be particularly important during certain seasons of the year or in times of environmental stress such as drought periods, and are often especially significant for vulnerable groups such as women and children.

Recent research in central Owambo, northern Namibia, has illustrated the dietary significance of indigenous plant resources. Wild fruits, for example, make an important contribution to local diets through both their regular household consumption and the incidental gathering of such fruits by children during their daily activities away from the homestead[1]. The sale of unprocessed natural resources and of the products of rural industries such as basketry, using indigenous weaving and dye materials, or the distillation of liquor from wild fruits, also provides important sources of cash income[2]. Such rural industries are often practised by women and are particularly important in northern Namibia where male out-migration and the impact of the Independence war have resulted in a high incidence of female-headed households[3].

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1 Hamata, S. and Cunningham, A.B. (in prep.) Edible wild plant use in Owambo, Namibia.

2 For estimates of utilization impacts on *Hyphaene petersiana* palms (the leaves of which provide the main raw material on which local basketry relies) in central Owambo see:
Sullivan, S., Konstant, T.L. and Cunningham, A.B. The impact of the utilization of palm products on the population structure of the Vegetable Ivory Palm (*Hyphaene petersiana*) in Owambo, northern Namibia. Submitted to Economic Botany.
Konstant, T.L., Sullivan, S. and Cunningham, A.B. The effects of human population pressure on *Hyphaene petersiana* basketry resources in the palm savanna of Owambo, northern Namibia. Submitted to Economic Botany.

3 Tapscott, C. (1990) The social economy of livestock production in the Owambo region. NISER (Namibian Institute for Social and Economic Research) Discussion Paper 4. University of Namibia.
This publication records that >40% of households in the Owambo region are female-headed.

It is hypothesised that:

A. Household decision-making over wild resource use is influenced by:

i. supply factors, primarily biological productivity and constraints on access to resources due to land tenure rights;

ii. socio-economic factors such as household food security, income and gender;

iii. demand factors, including the effects of human population increase, the commercialization of handicraft production using wild resources, and the availability of substitutes;

B. Current changes in land tenure towards range privatisation will:

i. exacerbate pressure on remaining wild resources on communal land;

ii. exclude the most vulnerable groups, who have the greatest need for wild products, from these resources.

This study will use a combination of social and natural science techniques to:

i. quantify the harvest of resources from areas of different tenure by people from different socio-economic categories. Participatory survey techniques will be used as a pilot study method to establish species used, their perceived importance, dominant trends and problems associated with resource use and collection. From this initial survey four or five key species to be studied in depth will be selected on the basis of their quantified contribution to food and income security. More detailed information regarding major issues related to these economically important species will be collected using semi-structured interviews and through preference and time allocation studies. Changes in resource use with seasonal variation and differences related to socio-economic characteristics and differential resource access rights will be emphasised;

ii. establish the availability of important wild resources in terms of both biological productivity and accessibility with regard to land tenure. Biological productivity and impact measurements based on standard botanical, phenological and forestry techniques will be used to determine resource availability and current utilization pressures on each of the economically important species identified;

iii. model changes in scale and type of household wild resource use with different
  a. land tenure patterns
  b. demands
  c. household socio-economic profile,
  and model the effects of these different levels of offtake on resource productivity and accessibility;

iv. predict the likely changes in resource use patterns that will occur under different economic and ecological conditions;

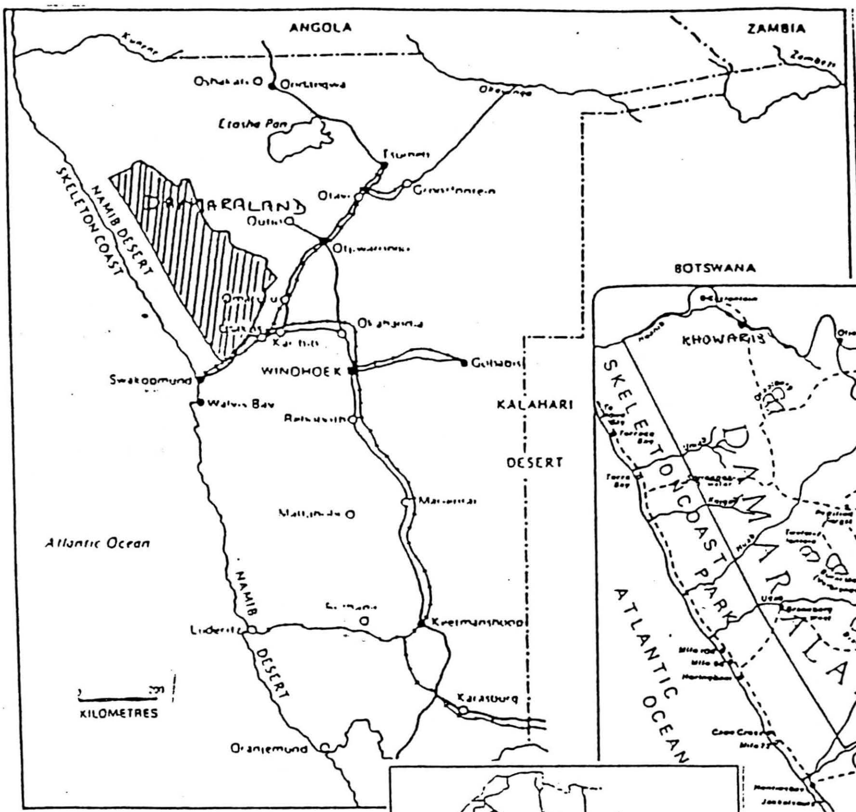
v. assess the implications of these changes in resource use patterns for,
  a. human health, welfare, food and income security
  b. the sustainability of resource use.

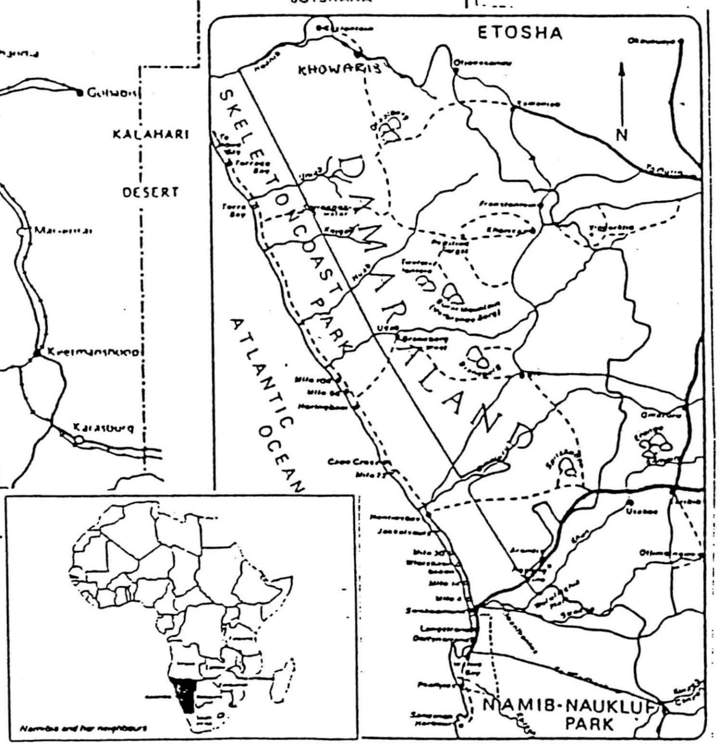
SRT

INTRODUCTION

The primary objective of 'Crafts for Conservation' was to generate information regarding the use of wild resources by Damara people with particular reference to those resources used for potentially income-generating handcraft industries. The project was closely linked to the Namibian NGO 'Save the Rhino Trust' (SRT) whose community-based work in Damaraland is focused on harmonising the development of local economies with conservation of the ecosystem. The data collected by 'Crafts for Conservation' is directly relevant to SRT's efforts to promote the sustainable production of handcraft items as a means of providing cash income for the local people through the sale of these items to the growing influx of visitors to the area.

The expedition took place from the beginning of July to mid-September, 1992, and involved two team members from University College London with Namibian counterparts who acted as interpreters and helped considerably with the field identification of useful plant species. Team leader: Sian Sullivan, c/o Anthropology Department, University College London, Gower Street, London, WC1E 6BT.





EXPEDITION AREA

The fieldwork took place in Damaraland, an arid and remote region of west Namibia characterised by semi-desert and savanna transition vegetation (see map).

SUMMARY

The project was divided into two field studies:

Field study 1 (headed by Isobel Stoddart)

Information concerning present, past and potential art and craft production, including the raw materials utilized, production techniques and present marketing strategies, was collected using structured interviews conducted in communities throughout Damaraland. A separate questionnaire was also conducted with guest-farm/lodge/rest-camp owners to ascertain whether these potential outlets could be established for local crafts in the future. Informal interviews were carried out with local headmen and elderly members of the community concerning items that were handcrafted in the past, the production techniques of which could possibly be revived in the manufacture of items with appeal to tourists currently visiting the region.

Field study 2 (headed by Sian Sullivan)

The Khowarib settlement in northern Damaraland was chosen as the focus for a detailed investigation of indigenous woody species utilization. The very recent establishment of a small community-run tourist camp

at this settlement, with an outlet for the sale of local handcraft items, is likely to initiate an influx of tourists and create an unprecedented pressure on some natural resources. Fieldwork was split broadly into an interview survey within the settlement, in which particular attention was paid to species used in craft production, and a vegetation survey conducted within, on the outskirts of, and 5km away from, the settlement. The former consisted of in-depth interviews of approximately half the settlement's households concentrating on which species of tree, and which part of those species, are used for what purpose. The vegetation work consisted of transects in three identified vegetation types around the settlement (plain, riverine and mountain) to assess the extent of obvious damage caused by human utilization to different species and provide some measure of species density and composition. Time was also spent in the field with members of the Khowarib community establishing the identity of tree species known only by their Damara names from the interview survey.

The remoteness of the area and the consistent perception of the Damara people by early missionaries, government representatives and development professionals as being without significant material culture has resulted in a dearth of knowledge concerning both traditional handcraft production and local nomenclature for plant species. The table presented below indicates the range of household utensils produced in Khowarib from indigenous woody species (many of which could be produced for a tourist market), the diversity of species used and Damara names for the species which were identified botanically in the field following the interview survey. Information on both the supply of, and demand for, natural resources is essential for the sustainable development of both human communities and the resource base.

Botanical name	Damara name	Part of tree used	Utensil made	No. of times use was recorded n=13
Acacia montis-usti	ǀhū.b	timber	ǂgoub (winnowing bowl)	4
		timber	buckets	2
		timber	spoons	1
Colophospermum mopane	tsàű́rá̋hȁì.s	timber/roots	spoons	2
		timber	cooking sticks	1
		roots	pipes	1
		timber	knobkieries	1
		stems	bows	1
Commiphora multijuga	ǀgâua.b	timber	spoons	2
		timber	pipes	1
		timber	buckets	1
		timber	ǂgoub	1
Commiphora anacardifolia	!khoebe.b	timber	ǂgoub	2
Terminalia prunoides	ǂkhèé̋rá̋.s	timber	hoe handles	1
		timber	knobkieries	1
Berchemia discolor	ǂhȕ̋i.s	timber	knobkieries	1
Cordia sinensis	ǁkhō.s	timber	ǂgoub	1
Grewia tenax	ǁhaí.b	timber	rake handles	1
Tamarix usnoides	tamara	timber	spoons	1
Ziziphus mucronata	ǂárő.s/i	timber	knobkieries	1

Table showing woody species used for household utensils in Khowarib settlement, northern Damaraland.

FINANCES

Total budget: £2500 Sponsorship: £1700. nb. We were loaned a vehicle by SRT for the duration of the project which dramatically reduced our expenses.

PUBLICATIONS

Expedition Report due to be completed in May 1992; Paper (in prep.) concerning the utilization of, and impact on, perennial woody species by the Khowarib settlement; Technical note (in prep.) listing Damara names for identified woody species.

SUGGESTED FOLLOW-UP WORK

More detailed information regarding the importance of wild resources to people's livelihood strategies and traditional craft skills throughout Damaraland. Continued monitoring of the impact of local tourism development at settlements such as Khowarib, Twyfelfontein and Ongongo.

The utilization of, and impact on, indigenous woody species at Khowarib settlement, northern Damaraland, with particular reference to those used for potentially income-generating craft activities.

Sian Sullivan
Anthropology Department
University College London

1993

Report for the Royal Geographical Society.
'Crafts for Conservation' Expedition, 1992.

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ABBREVIATIONS

CCA	Canonical Correspondence Analysis
CIIR	Catholic Institute for International Relations
DCA	Detrended Correspondence Analysis
IDAF	International Defence and Aid Fund
MPLA	Popular Movement for the Liberation of Angola
OPO	Owamboland People's Organisation
SADF	South African Defence Force
SRT	Save the Rhino Trust
SWAPO	South West African People's Organisation
UN	United Nations
UNIN	United Nations Institute for Namibia
UNITA	National Union for the Total Independence of Namibia

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SUMMARY

The national context of Damaraland is discussed with reference to the dominant environmental factors controlling subsistence production in Namibia and the country's recent historical background. This is followed by an account of the historical background of the Damara, the physical environment of Khowarib settlement and the past and present utilization of indigenous plant resources. The current importance of indigenous woody species to the livelihood strategies of Khowarib's inhabitants is presented from the results of a household interview survey concerning the use of tree products. The impact of this utilization is assessed using data derived from vegetation transects in different topographic categories analysed using a variety of techniques including partitioned chi-square tests and multivariate analysis. Anticipated future impacts are discussed focussing on the effect on resource use, for the production of handcraft items in particular, of the newly estabished tourist camp at Khowarib.

INTRODUCTION

Rural subsistence in Namibia is dominated by three main factors: first, natural primary productivity is restricted by low and unpredictable rainfall; second, rural subsistence has been consistently undermined throughout this century by the aims of the colonial German and the recent South African administrations; and third, disruption resulting from twenty years of guerilla war with South Africa. In this context, increased understanding of traditional subsistence strategies, including the use of indigenous plant resources, is essential if the livelihoods of the rural majority are to be maintained and improved in Independent Namibia without eroding the resource base on which they rely.

1.1 Physical environment

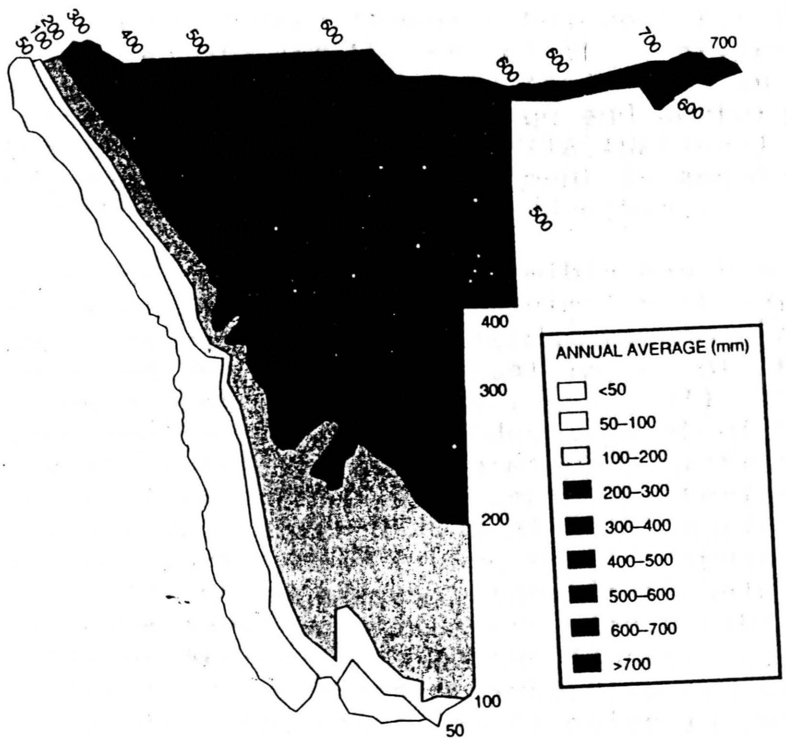
Namibia is located in the south-west of Africa (Fig. 1) and is dominated by three main topographical regions; the narrow Namib desert in the west, the natural watershed of the Central Plateau, and the Kalahari Desert Belt in the east (Aulatch and Asombarg, 1985: 5). The dominant environmental factor controlling agricultural productivity in Namibia is precipitation which increases progressively with movement inland from the Namib Desert in the west to the Kalahari Desert in the east. For much of the country the rainfall too low and unpredictable for arable farming to be depended on alone for subsistence purposes and farming in Namibia relies to varying degrees, therefore, on livestock production.

Fig. 1. Location of Namibia.

Broadly speaking, Namibia can be divided into three distinct agricultural zones corresponding to rainfall isohyets (Fig. 2) (Moorsom, 1982: 13-14; UNIN, 1986: 22):

1. large stock in the north of the country where rainfall exceeds 300mm;
2. small stock where rainfall is less than 300mm in the south and following the Namib Desert margin in the west;
3. mixed farming where rainfall is between 500mm and 600mm, such as in eastern Caprivi and the Otavi Highlands, or where seasonal flooding raises potential productivity as in the Owambo floodplain in the north.

Fig. 2. Annual rainfall isohyets for Namibia.



1.2 Historical background

The rough Atlantic seas and seemingly impenetrable desert along Namibia's coastline meant that Namibia remained relatively unexplored by Europeans until the late 19th century. Namibia was declared a protectorate of Imperial Germany in 1884 under the name of South West Africa. Germany's administration lasted until 1919 when it was forced to give up its colonies by the Treaty of Versailles in 1919. In 1920 South Africa was granted mandate over South West Africa on behalf of the British Crown by the United Nation's General Assembly. In 1966 the UN officially revoked South Africa's mandate over South West Africa on the grounds that South Africa had violated the UN provisions for mandate through the imposition of an apartheid-style administration. In particular, the introduction of the Odendaal Plan in 1964, which initiated the 'fragmentation of Namibia into a series of economically unviable "homelands" for Africans', undermined the economic independence of Namibian communities, forcing them to enter the commercial sector as cheap hired labour and increasing their dependence on 'white' areas and on South Africa (UNIN, 1986: 12).

In 1969, the UN Council for Namibia was established but, despite calls on South Africa by the UN Security Council to withdraw from Namibia, and the recognition of SWAPO (South West African People's Organisation formed in 1960 from the Owamboland People's Organisation) by the UN General Assembly as the sole authentic representative of the Namibian people , South Africa remained in administrative and military control. Twenty years of bloody conflict, mainly in the north of the country, followed during which the SWAPO troops were supported by the Cuban backed MPLA (Popular Movement for the Liberation of Angola) in Angola and by several other African countries (IDAF, 1989: 17, 69). SADF (South African Defence Force) miltary bases established in Kavango and western Caprivi to supply the South African backed UNITA (National Union for the Total Independence of Angola) movement in Angola further heightened the tension in northern Namibia.

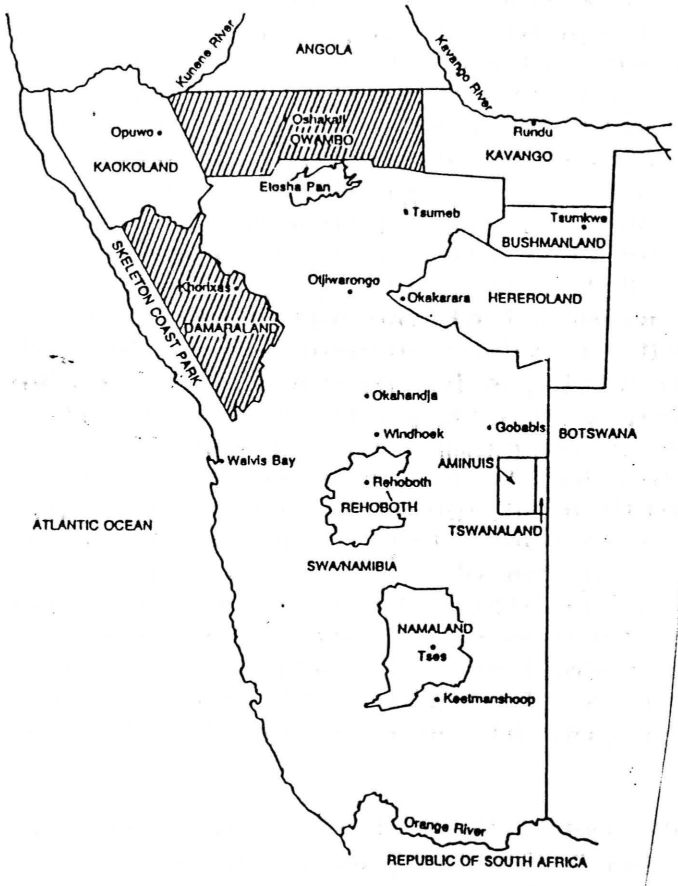
Twenty years of guerilla war in Namibia has had an enormously disruptive impact on traditional animal husbandry and agricultural practices through stimulating migration from rural areas and due to the physical impact of the movement of troops through some regions (IDAF, 1989: 31). Furthermore, paralleling much of Africa, the development of Namibia's economy by its colonial-style German administration and its occupation by South Africa has been characterised by a bias towards commercial livestock ranching and agriculture, and the industrial manufacture and mining sectors (UNIN, 1986: 21; IDAF, 1989: 31). Consequently, traditional animal husbandry and subsistence farming in most areas of Namibia have been consistently undermined through the expropriation of land, the disproportionate channelling of subsidies and expertise to the commercial sector, the migration of males in search of wage labour as their rural subsistence base declines, and the externalisation of wealth generated within Namibia (Geingob, 1985: v; UNIN, 1986: 7).

1.3 The importance of indigenous plant resources to rural societies

In this context of declining rural subsistence productivity an understanding of traditional livelihood strategies is extremely important if the welfare of rural people is to be improved in Independent Namibia. In particular, knowledge concerning the regular contribution of indigenous plant resources to household food and income security, as well as the periodic utilization of wild 'famine' foods in times of drought, is important in order to prevent the undermining of a resource base that may have the crucial ability to prevent absolute poverty when crop and livestock productivity fail. In arid environments such as Namibia, where woody species are inherently relatively resilient to the desiccating effects of drought, trees and their useful products are likely to be especially significant to people's livelihoods.

This project presents evidence for the importance of indigenous woody species to people's livelihoods in Damaraland, northern Namibia (Fig. 3). This arid, small stock rearing area has received little recent attention by outside researchers due to the remoteness of local communities coupled with the difficult Khoekhoe language. Quantitative data concerning the use of indigenous plant resources by rural communities throughout Namibia is, however, essential to illustrate the important contribution that such resources make to people's livelihoods and to aid the sustainable utilization of such resources so that they continue to provide a buffer against rural poverty into the future.

Fig. 3. Location of Damaraland.



Indigenous tree use by inhabitants of Khowarib settlement, northern Namibia

1.0 Introduction

1.1 Historical background

The Damara or Dama only became known to the outside world in 1792 when an expedition under Willem van Reenen penetrated Namibia as far as the Auas Mountains near Windhoek (Steyn and du Pisani, 1985: 37). As a people they are negroid but speak a Khoisan or 'click' language and traditionally practised a Khoikhoi or San hunting and gathering subsistence strategy as opposed to the agropastoral lifestyle associated with other southern African Bantu groups (Knappert, 1981: 71). Conversely, the Nama-speaking people, or Groot Namaqua, of the same region culturally follow a herding subsistence strategy but are physically similar to the normally hunting and gathering Khoikhoi peoples (Hildesheim, 1986: 1).

It is still unclear as to how this unusual set of racial and cultural combinations came about. The Damara have traditionally been seen as the aboriginal inhabitants of Namibia and, indeed, archaeological evidence for the existence of hunting and gathering nomads in the Brandberg Mountain of Damaraland dates back to more than 6,000 years (Kinahan, 1983: 95). Early pastoral peoples in this area utilized both the low grassy plains and pastures of the Upper Brandberg for livestock grazing and, in times of serious drought, moved west towards the Atlantic Ocean using pasture along water-courses and probably consuming meat from seals and occasionally beached whales on the coast (Smith, 1992: 188-9). Hoernle (1923: 22) considered that the earliest Damara inhabitants of this region were gradually suppressed by the Nama with whom some Damara appear to have developed a patron-client relationship. Alternatively, the missionary Vedder (1928: 41, 109) was of the opinion that the Damara moved southwards from the African interior as the servants of Hottentots during the latter's movement away from their northern Nilotic origins. This hypothesis is based on the existence of expressions within the Damara vocabulary which do not have their roots in the Nama language but are instead considered derived from several Sudanese languages. This long contact with the Nama arising well before the arrival of the Damara in their present territory would, if accepted, explain why no remnants of the original Damara language exist, even in very remote groups (Malan, 1980: 14).

More recent analyses, however, indicate that the Damara are derived from Negroid hunting peoples who first came into contact with Khoi speakers only 2-3 millennia ago in present-day Angola (Smith, 1992: 86). Such a migration from the north or north-east is suggested, for example, by oral tradition collected by Andersson in the 19th century (1856: 218). Throughout their long history of contact with other ethnic groups the Damara appear to have remained racially distinct even though they adopted the lifestyles of different people (Büttner, 1879: 285-6; Hall-Martin *et al*, 1988: 55). This might be explained by a one-way gene flow which could have occurred if Damara women were allowed to intermarry with neighbouring people of higher status while the reverse was not true. If this was indeed the case the Damara were, in effect, forced to remain physically distinct through low social status (Smith, 1992: 88). Biological evidence based on comparisons of levels of a protein polymorphism in southern African groups supports this hypothesis (Morris, 1990).

1.2 Population

Before the arrival of the Herero and the Owambo in Namibia the Damara had a much larger population, occupying the northern third of the country. A long period of livestock raids by the more powerful Herero and Nama, often in retaliation to Damara raids, gradually reduced the territory of the Damara to the security of the mountainous area of north-west Namibia (Knappert, 1981: 73-4). Tension between these tribal groups is still apparent; the inhabitants of Khowarib regularly complained about the use of pastures traditionally regarded as their own, by the Herero of Warmquelle, a larger settlement 15kms north of Khowarib.

The breaking up of tribal cohesion following the establishment of new district boundaries, first by the German authorities after the Herero War of 1905 and subsequently by the South African administration following the Second World War, together with rises in infectious diseases such as tuberculosis and an increase in male migrant labour away from the area, resulted in a dramatic decline in the Damara population after the late 19th century (Knappert, 1981: 72). In 1978, the Damara were estimated as forming 8.5% of the total population, then roughly 931,000 (du Pisani, 1978: 1). Today, only a quarter of the 80,000 Damara survive as pastoralists in Damaraland, the rest working as mine-workers or as labourers in farms and in local towns.

Khowarib settlement has a total population of 189. This includes children of school-going age who spend their terms at the district school in Sesfontein, 70kms north of Khowarib. Several adult male and female inhabitants also spend much of their time away from the settlement in remittance work in Khorixas, the administrative centre of Damaraland.

1.3 Physical environment

Damaraland is located in north-west Namibia with a western border comprised of the Namib desert which runs in a north-south band stretching roughly 32kms inland from the Atlantic Ocean. Damaraland's northern boundary with Kaokoland follows the Hoanib River while its southern border is shared with the Karibib district and its eastern border with the districts of Outjo, Otjiwarongo and Omaruru (Fig. 1). The settlement of Khowarib is situated on the southern bank of the Hoanib in the north-east of the region (S 19°15 E 3°15) (Fig. 2).

Fig. 1. Geographical location of Damaraland. Khowarib settlement is in the north-east (source: SRT, 1992: 7).

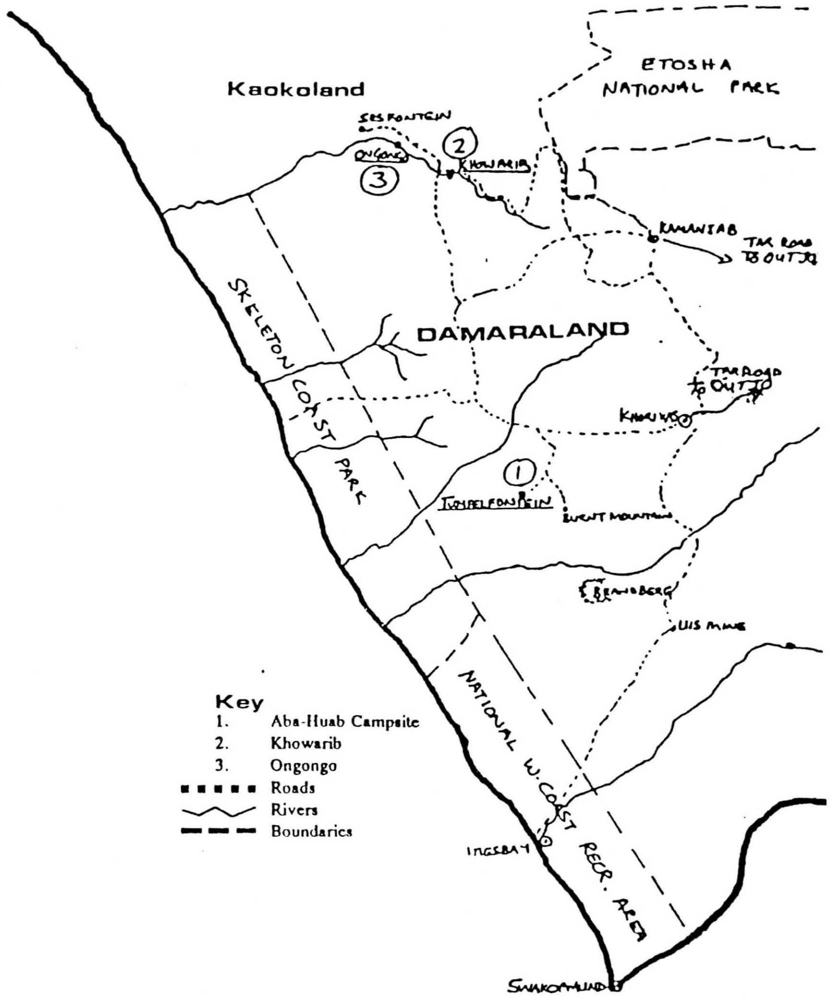


Fig. 2. Location of Khowarib (source: Ordnance Survey).

Damaraland can basically be divided into two morphological zones; the Central Hereroland Plateau or Interior Highlands in the east and the Transitional or Pro-Namib Plains, which merge into the Namib Coastal Plain, in the west (Mabbutt, 1952: 335-7; du Pisani, 1978: 3; Malan and Owen-Smith, 1974: 134). Broadly speaking, Khowarib is situated on the western edge of the Transitional Plains.

Several large rivers, such as the Hoanib, traverse these morphological regions. The Hoanib forms a deeply incised valley system with many large tributaries (Malan and Owen-Smith, 1974: 134, 136). Along its length are rocky outcrops, many of which are formed of porous dolomite. Moving upstream, east from Khowarib the Hoanib very quickly becomes constrained by these uplands forming the steep slopes of the Khowarib 'Schlucht' or gorge (Plate 1) (Hall-Martin *et al*, 1988: 9). West of the Khowarib settlement, however, stretch flat semi-desert plains of alluvial sands (Plates 2 and 3).

Khowarib falls between the 100mm and 150mm isohyets and annual rainfall is, therefore, an extremely important constraint on overall productivity (Hall-Martin *et al*, 1988: 2). The temperature regime is characterised by high diurnal and annual variation, reaching a summer day-time maximum of approximately 30-35°C and a winter and night-time minimum of around 10°C.

The vegetation of the area around Khowarib changes markedly in response to topographic factors. Following Giess (1971: 9-10), the area contains many species characteristic of the northern extension of the 'semi-desert and savanna transition' zone including two *Acacia* species only found in this vegetation type, *A. montis-usti* and *A. robynsiana* (Plate 4), and common *Acacias* being *A. senegal* var. *rostrata* and *A. tortilis* subsp. *heteracantha* (Plate 5). Other common species include various *Commiphora* species (Plate 6) and *Colophospermum mopane* (Plate 5).

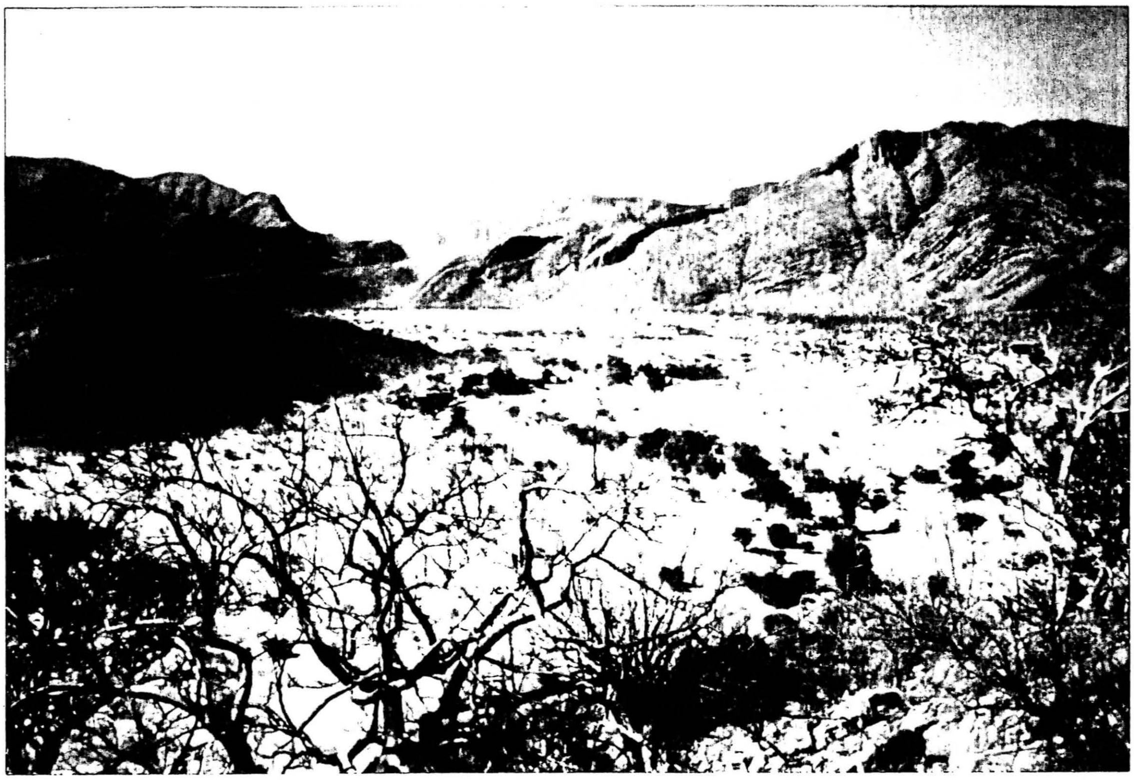


Plate 1. The constraining of the dry Hoanib River into the Khowarib 'schlucht' or gorge to the east of Khowarib settlement.

Plate 2. Alluvial plains to the west of the settlement.
Plate 3. View of plains traversed by the line of riverine vegetation which marks the Hoanib River.

1.4 Settlement and subsistence

1.4.1 Settlement location

The major environmental factor influencing Damara settlement and subsistence is the low level, and consequent high variability, of rainfall (Hoernle, 1923: 21). In such an environment river beds, where the water table is closer to the surface than elsewhere, form 'lifelines' for animal and human existence. One of the ways in which they do this is by extending the range of plant species normally typical of higher rainfall areas (Hall-Martin *et al*, 1988: 17). Damara settlements, both past and present are, therefore, typically located on dry riverbeds which are likely to provide important sources of subterranean water. Khowarib, with its location on the south bank of the Hoanib River is consistent with this pattern and it is likely that this is the most important factor in its location. Within the Hoanib, springs forming linear oases also provide intermittent surface water during the dry season. One of these is located approximately 3kms west of the Khowarib settlement and is a particularly important source of perennial water for livestock.

1.4.2 Settlement constructions

The settlement is comprised of approximately 40 traditional wattle and daub huts, sometimes fenced, and 35 tin-roofed houses with walls consisting of larger building poles (Fig. 3 and Plate 7). The huts built in the traditional style are circular in shape, typically 2-2.5m in diameter, and constructed from thin branches slightly bent so that they meet at the upper end (Plate 8). A gap is left for the door and the whole is usually covered with a mixture of dung and sand and sometimes decorated with clays of different shades (Vedder, 1928: 48). The construction of square buildings which are larger than these traditional structures is also common throughout Damaraland and requires a greater quantity of building poles (Plate 9). The demolition of old buildings and the building of new ones is usually a continuous process (du Pisani, 1978: 6) and at Khowarib it appeared to be common practice to salvage the wood from old buildings either for use in new constructions or for firewood.

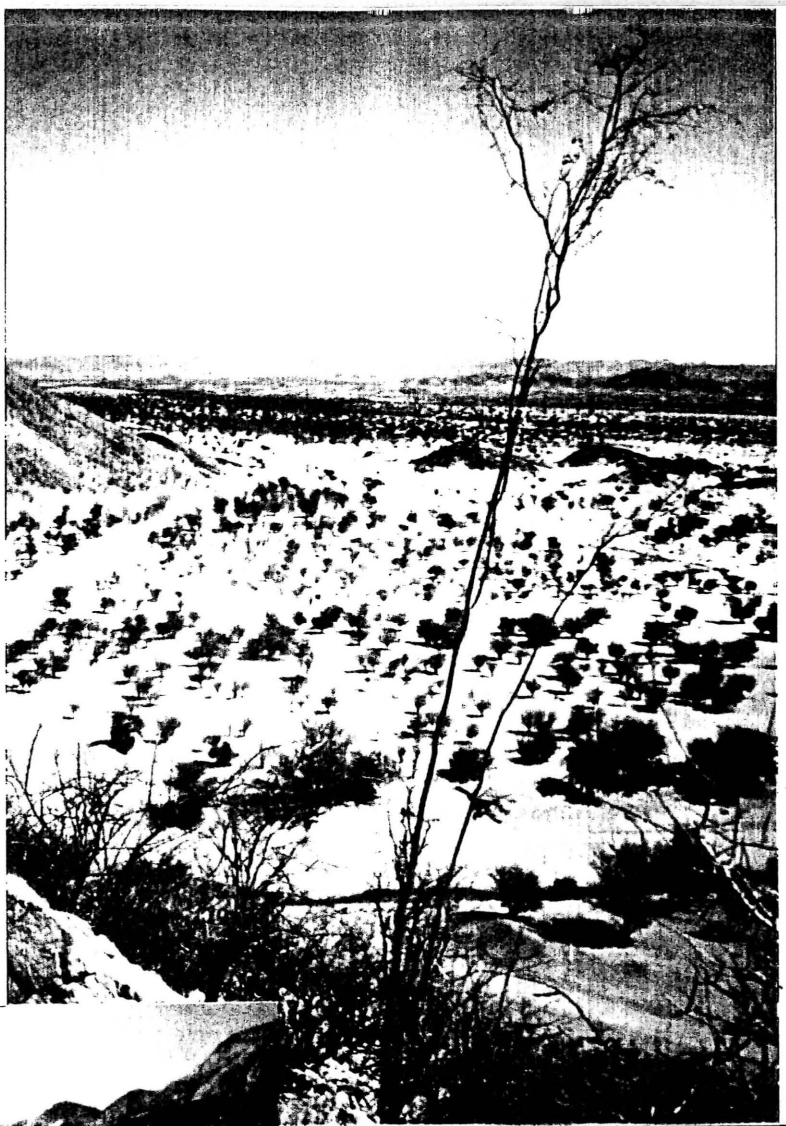


Plate 4. *Acacia robynsiana.*
Plate 5. Mixed *Acacia tortilis* and *Colophospermum mopane* woodland.
Plate 6. *Commiphora multijuga.*

Fig. 3. Sketch map of Khowarib settlement.

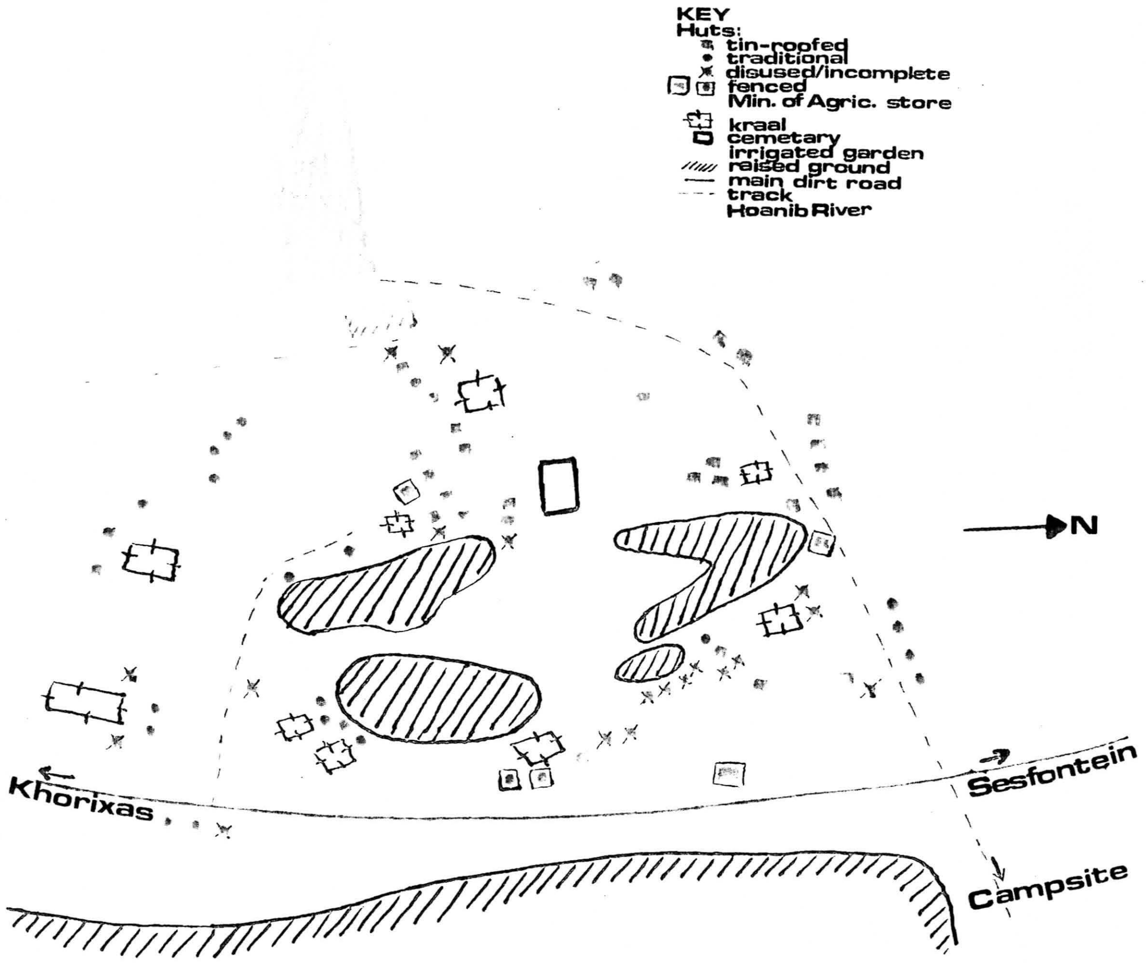


Plate 7. View of khowarib from the highest point.

Plate 8. Traditional round huts made of small branches and covered with dung and clay plaster.

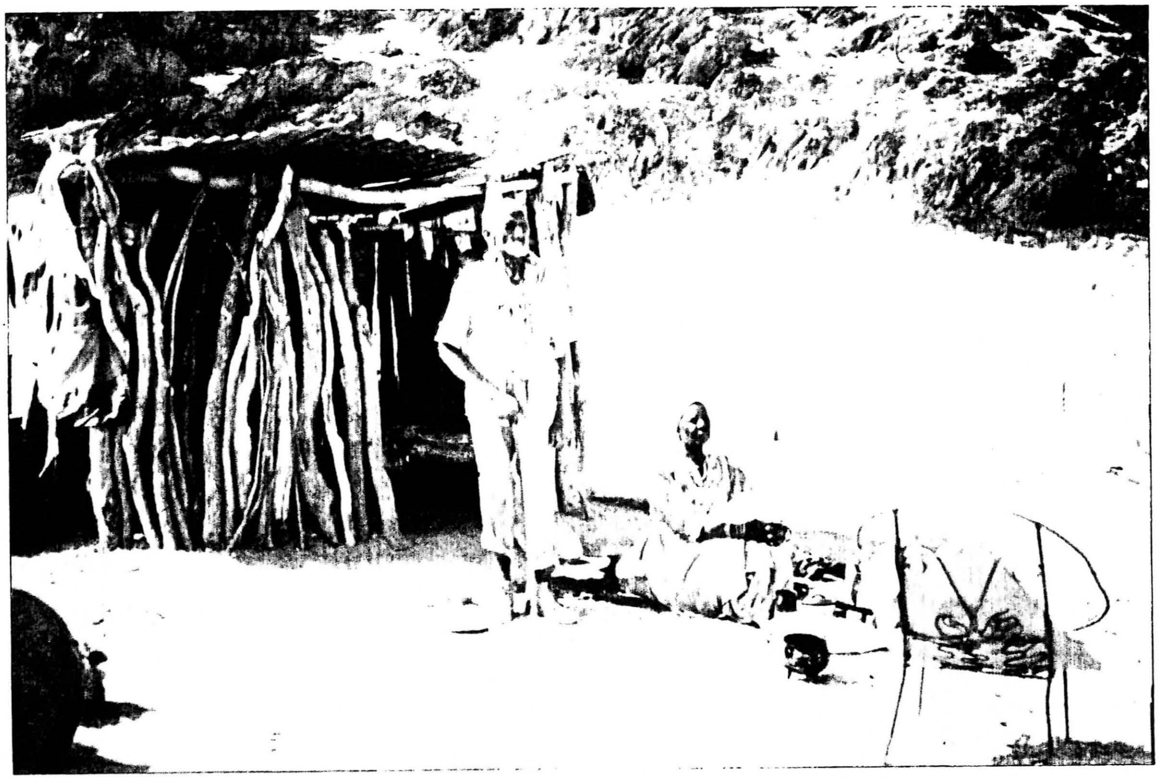


Plate 9. Square hut with tin-roof showing use of larger building poles (mainly *Colophospermum mopane*).

1.4.3 Cultivation

The impact of variable rainfall is alleviated to some extent at Khowarib by the establishment by the Ministry of Agriculture in the 1970s of an irrigated 'garden'. Here staple foods can be cultivated throughout the year, a dry season crop of wheat and a rainy season crop of maize (*Zea mays*) being harvested annually (Plates 10 and 11). Other foods grown include oranges, lemons and water melons, while tobacco is also important and is often exchanged for other commodities, sometimes cash.

The produce of this garden now forms the major source of subsistence for this community resulting in the transformation of its inhabitants' lifestyles from semi-nomadic pastoralism to one in which plough agriculture, and accompanying sedentarism, have become the norm. Even the small gardens of the Damara on the Ugab River in southern Damaraland are reported to require more attention than livestock even though they are not as central to people's livelihoods as at Khowarib (du Pisani, 1978: 15-16). Elsewhere in Damaraland, cultivation encouraged by missionaries did not reach a level whereby crops made a significant or consistent contribution to Damara diets (Steyn and du Pisani, 1985: 39).

1.4.4 Livestock

Livestock, predominantly goats and some cattle, while no longer dictating people's lifestyles and movements are still important for subsistence purposes and as wealth holdings (Plate 12). Generally speaking the acquisition of livestock and the replacement of a hunting and gathering lifestyle by pastoralism has been relatively recent, resulting from barter, through existing patron-client relationships with the Nama and Herero, and by raids of the latter's stock (Steyn and du Pisani, 1985: 48).

At Khowarib, the subsistence value of livestock is through the provision of milk and meat by goats and cattle and the use of donkeys as draught animals, the donkey-cart being the major mode of transport in this area. The Damara of 13 households interviewed at Khowarib had an average of 32 goats per household (range = 0-150) and 6,6 cattle (range = 0-25). Few donkeys were kept, the maximum for a household being 12 animals. These figures are substantially lower than the Damara of Okombahe in the Ugab valley who were recorded as having an average of 42,75 goats or sheep per male stock owner and 37,29 per female stock owner and an average of 13,73 and 11,3 cattle for male and female stock owners respectively (Steyn and du Pisani, 1985: 49). The Damara of this latter area, who rely predominantly on herding for subsistence purposes, consider a herd of roughly 50 animals to be the minimum amount from which to make a reasonable living (du Pisani, 1978: 12). The lower herd numbers recorded for the Damara at Khowarib are a result of the recent development of a reliance on the irrigated garden for subsistence, the working of the garden having reduced the flexibility necessary to allow transhumant movement and the consequent maximisation of available pastures and dispersed water sources.

1.4.5 Wild foods or 'veldkost'

Despite the adoption of a pastoral subsistence strategy by the Damara, wild plant species have remained important in the provision of food products throughout Damaraland (du Pisani, 1978; Steyn and du Pisani, 1985). The highly variable nature of the climate in this area means that many of these foods are only available in particular seasons. These times of availability, however, often occur during periods of low productivity of cultivated crops and, therefore, constitute an essential as opposed to a supplementary source of nourishment during these times. Others are treated more as delicacies than necessary food items but may in themselves provide important nutrients not available in staple foods.

Early descriptions of Damara subsistence stress the importance of gathering plant foods and hunting wild animals (Büttner, 1879: 288; Hahn, 1928: 223; Steyn and du Pisani, 1985: 37), with Vedder (1923: 67-71) recording the use of over 80 plant species. Some sources of 'veldkost' are reported as being particularly important. Grass seeds (**saui** and **bosui**) of the genus *Stipagrostis* (eg. *S. obtusa*), for example, were traditionally collected using digging sticks from termite hills where they are stored each year by termites (**ānin**) (Vedder, 1928: 60; du Pisani, 1978: 14). This practice has the advantage of procuring several kilogrammes of a normally dispersed food resource from a single location. The continuing importance of this food product is indicated at Khowarib where four households were recorded as utilising **saui** and five utilised **bosui**, and where the use of these seeds for beer making was reported. Du Pisani (1978: 14) also records the sale of grass seeds as an important means of income generation in the Ugab valley.

Other significant sources of 'veldkost' are 'ointjies' or underground bulbs, normally available on mountain slopes and often an important factor determining settlement location. Locusts, which are roasted and ground into a porridge, several species of caterpillar, ostrich eggs, honey (**danib**), fruits and tree exudates are also important (Büttner, 1879: 289; Von François, 1896: 249; Vedder, 1923: 75, 1928: 59-60; du Pisani, 1978: 15; Steyn and du Pisani, 1988: 37-48). These foods are typically communally owned and utilized by all and are mainly gathered by women (du Pisani, 1978: 15; Steyn and du Pisani, 1985: 43). The exception to this is honey which is gathered by men, each bees-nest considered as 'belonging to' the first man who found it (Plate 13) (Steyn and du Pisani, 1985: 39).

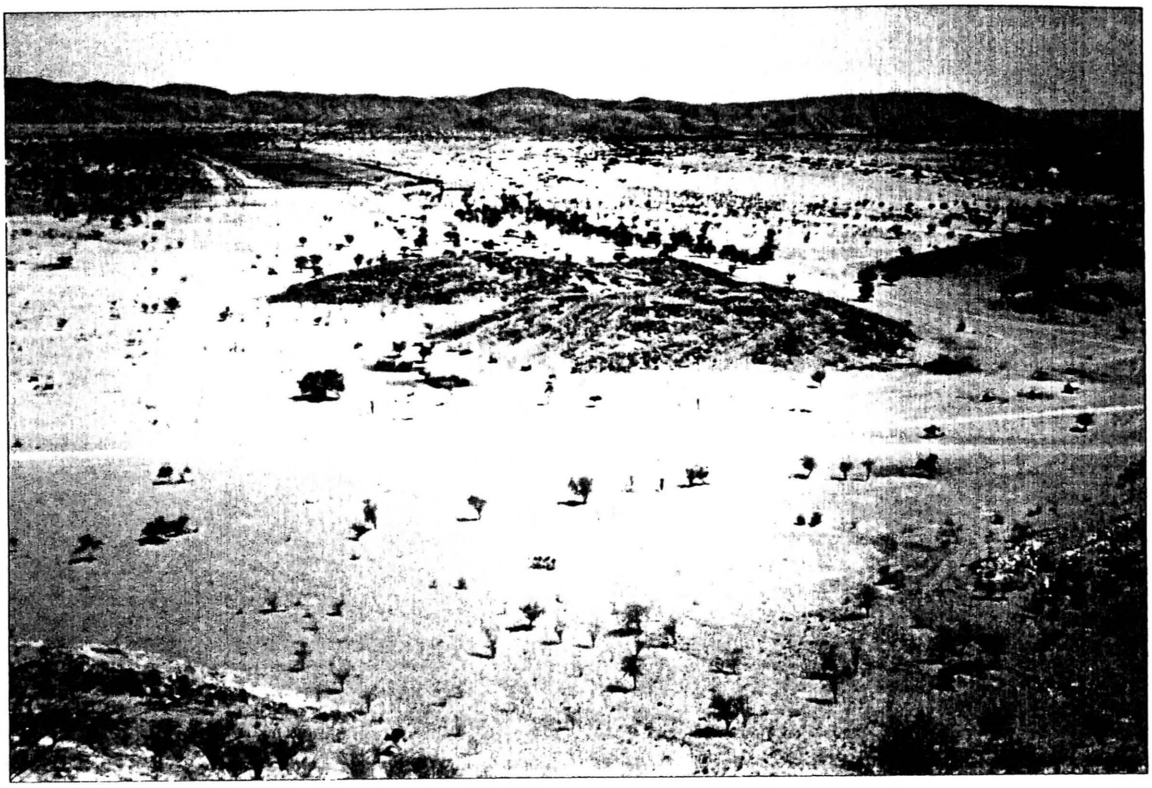


Plate 10. View of settlement with irrigated garden in the background.

Plate 11. Irrigated garden at Khowarib.

Plate 12. Goat-herding just outside Khowarib settlement.

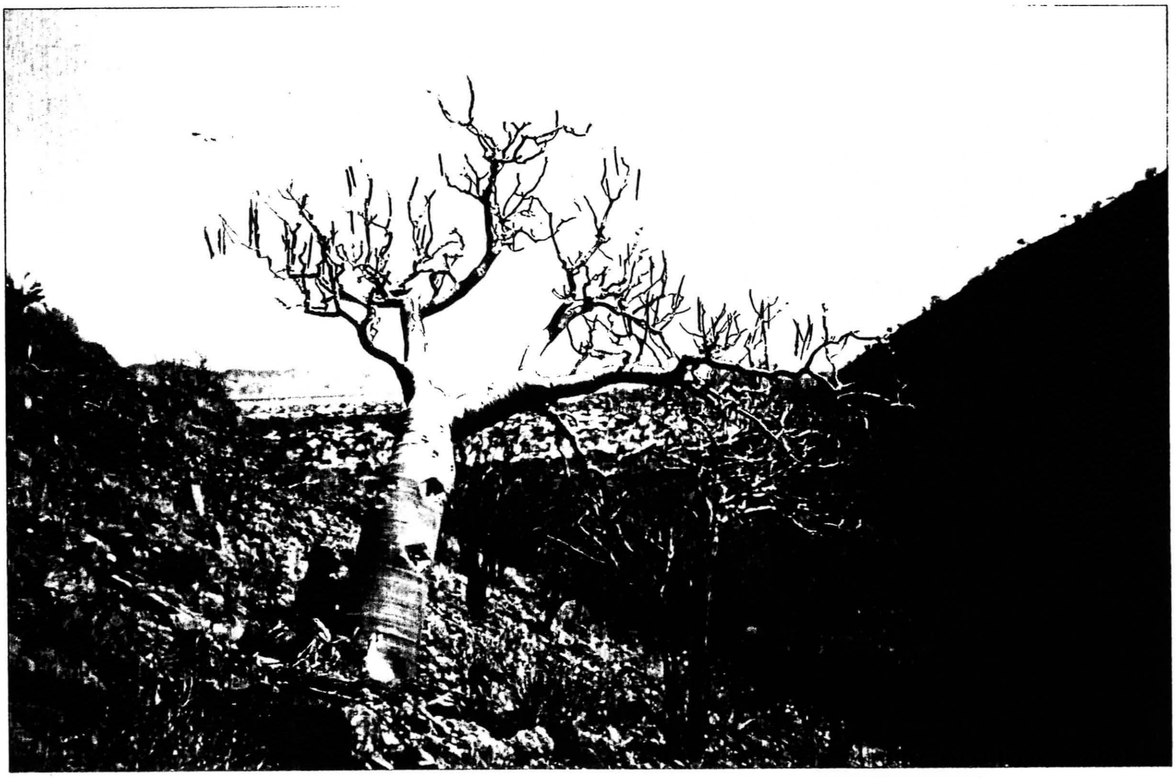


Plate 13. *Moringa ovalifolia* with stones wedged in old bees-nests in trunk which, in the past, aided the collection of honey.

1.4.6 The contribution of the newly established tourist camp at Khowarib to people's livelihoods

Within the last year, a small bush-camp for tourists has been established at the mouth of the Khowarib Schlucht, 3km east of the settlement (Plates 14 and 15). The main initiative for this camp came from Eliu Ganuseb, who runs the camp with other members of the Khowarib community. Establishment of the camp was assisted to some extent by Save the Rhino Trust, a non-government organisation which, through small community-based development projects, works for conservation of the threatened black rhino (*Diceros bicornis*) and elephant (*Loxodonta africana*) populations in this area.

As yet the camp brings little in the way of a regular cash income to members of the Khowarib settlement. It does, however, have the potential to affect the livelihoods of Khowarib's inhabitants in two main ways. First, the influx of tourists into the area is likely to create a demand for handcraft items which could, in turn, improve people's livelihoods by providing an important source of cash income. The construction of a handcraft shop at the camp (Plate 16), together with current Save the Rhino Trust encouragement of handcraft production as a means of both generating cash income and compensating the people of Khowarib for the increase of visitors to their land, provide an organising framework for meeting this demand. Many of the informants interviewed had, in fact, already tried to sell handcraft products at the camp, thus indicating the effects that this outlet may have on people's livelihood strategies into the future. Second, the camp is likely to have a negative impact on the vegetation surrounding the settlement through the production of handcraft items using locally available natural resources and the increased need for construction materials and firewood for visitors. The identification of intense pressure on particular resources, through, for example, the sale of carved items from preferred woody species, is necessary to prevent the long-term degradation of local resources and to maintain and develop the means of improving the livelihoods of Khowarib's inhabitants through local industries.

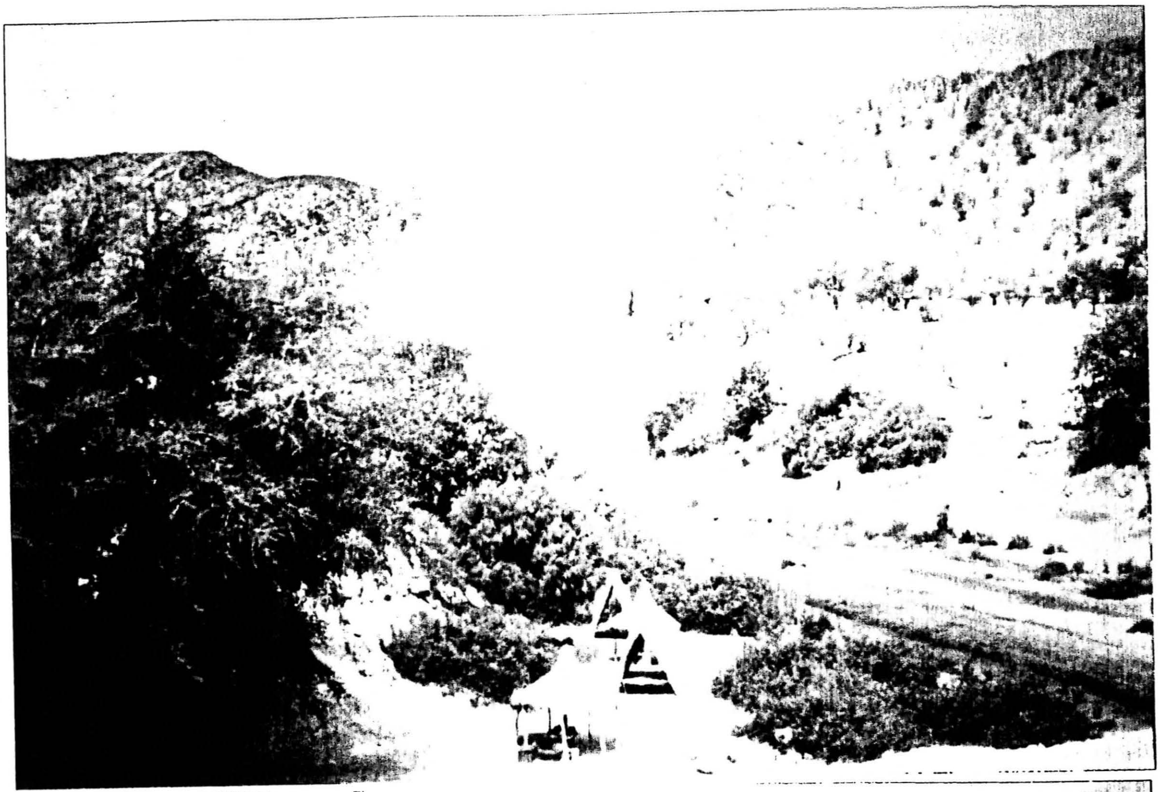


Plate 14. Khowarib campsite on the banks of the Hoanib.
Plate 15. Main campsite at Khowarib.
Plate 16. Handcraft shop at Khowarib camp.

2.0 Objectives

This case study had two objectives; to ascertain the importance of perennial woody species to the livelihoods of inhabitants of the Khowarib settlement, and to draw some conclusions regarding the impact of such utilization on the vegetation surrounding the settlement. In terms of surrounding vegetation, general subsistence strategies and culture, parallels can be drawn between Khowarib and other settlements of similar size within Damaraland. As described above, the recent establishment by the Khowarib community of the tourist camp in the Khowarib Schlucht can be expected to create an increase in demand for timber and other tree products and it is hoped that this study will highlight the more destructive forms of such demand so that alternatives can perhaps be found. The use of wood for carvings for sale to tourists at the camp may, for example, not be sustainable in the long-term, especially if relatively uncommon species are sought after. The recently established camps at Twyfelfontein (Aba-huab) in central Damaraland and Ongongo to the north of Khowarib (Fig. 1) which, like Khowarib, are run by the local community, can be expected to experience similar resource requirements thus making this work particularly applicable to these settlements.

3.0 Methodology

In order to obtain data on both the demand for tree products and the supply or resource base it was necessary to adopt a two-pronged methodological approach involving both anthropological and botanical fieldwork techniques.

3.1 The demand for tree products

A household interview survey of a representative sample of Khowarib's inhabitants was carried out in 13 of the households covering 82 of the total population of 189 (mean household size=6.3). Each interview was conducted with the help of Damara and Afrikaans interpreters (Plate 17). A semi-structured interview format was followed including questions concerning the use of firewood, building poles, fruits and exudates for food, important forage species, the use of wood for carving and the use of leaves, bark and roots for products such as leather dye and tanning agents and household medicines. Questions regarding the sale of handcraft products requiring tree materials at the bushcamp were also included in order to ascertain the degree of future impact this may have on the surrounding vegetation. A complete list of the questions asked in each interview can be found in Appendix 1 at the end of this case study.

3.3.2 Identification of species utilized

In the above interviews the trees used were reported using their Damara names. The botanical names of these species were then identified in the field with the help of inhabitants of the settlement (Plate 18). The Damara-to-botanical names recorded in le Roux (1971) and Eiseb *et al* (1991) were also consulted.

Plate 17. Conducting an interview at khowarib.

Plate 18. Tree identification in the field.

3.2 Impact on vegetation

3.2.1 Sampling strategy

The vegetation surrounding Khowarib was surveyed using a 'zig-zag' transect method as described in Amuyunza (1988) after Leithead (1979) (Fig. 4). In this method each consecutive individual is sampled according to its proximity to the preceding individual, providing it is within 45° on either side of a stated compass bearing from the preceding individual. For each individual the species was identified and the degree of lopping or branch removal and browsing, as measures of human and animal impact, recorded. These were then related to species composition and diversity within each sample. Measuring the height of the browse line when one could be easily discerned (Plate 19) provided an indication of browsing impact. Lopping (Plate 20) was classified according to the following scale:

- 0 no lopping
- 1 slight lopping - 1-2 large branches or only small ones removed
- 2 moderate lopping - 25-50%
- 3 severe lopping - >50%
- 4 cut through the main trunk/s so that the height of the tree was substantially reduced

The area can clearly be divided into three main habitat types according to the topography around Khowarib. These three topographic categories were sampled separately and at different distances from the settlement. The topographic categories and placement of transects were as follows (Fig.5):

Plains

Khowarib itself was situated within this topographic region and the vegetation sampled within the settlement therefore falls within this category. A total of 12 transects were carried out in the plains vegetation consisting of 4 within the settlement itself, 4 on the outskirts of the settlement and 4 5kms away from the settlement. Broadly speaking, these transects radiated out from the centre of the settlement.

Riverine

These transects were located in the riverine vegetation of the alluvial banks of the Hoanib River. Seven transects were carried out in this category; 3 on the outskirts of the settlement and 4 5kms away.

Mountain

The eastern side of Khowarib is flanked by the mountains of the Interior Highlands which at this point constrain the Hoanib into the Khowarib Schlucht. Six shorter transects were located on these mountains, 3 on the lower slopes and 3 on the upper slopes. As these mountains rise dramatically to substantial heights it was thought that the effect of altitude could, to some extent, legitimately replace the effect of distance in this category.

In each transect in the plains and riverine categories approximately 30 individuals were sampled while the mountain transects each contained a smaller sample of roughly 15 individuals. A total of 650 individuals were sampled.

Plate 19. Marked browse line on *Colophospermum mopane*.

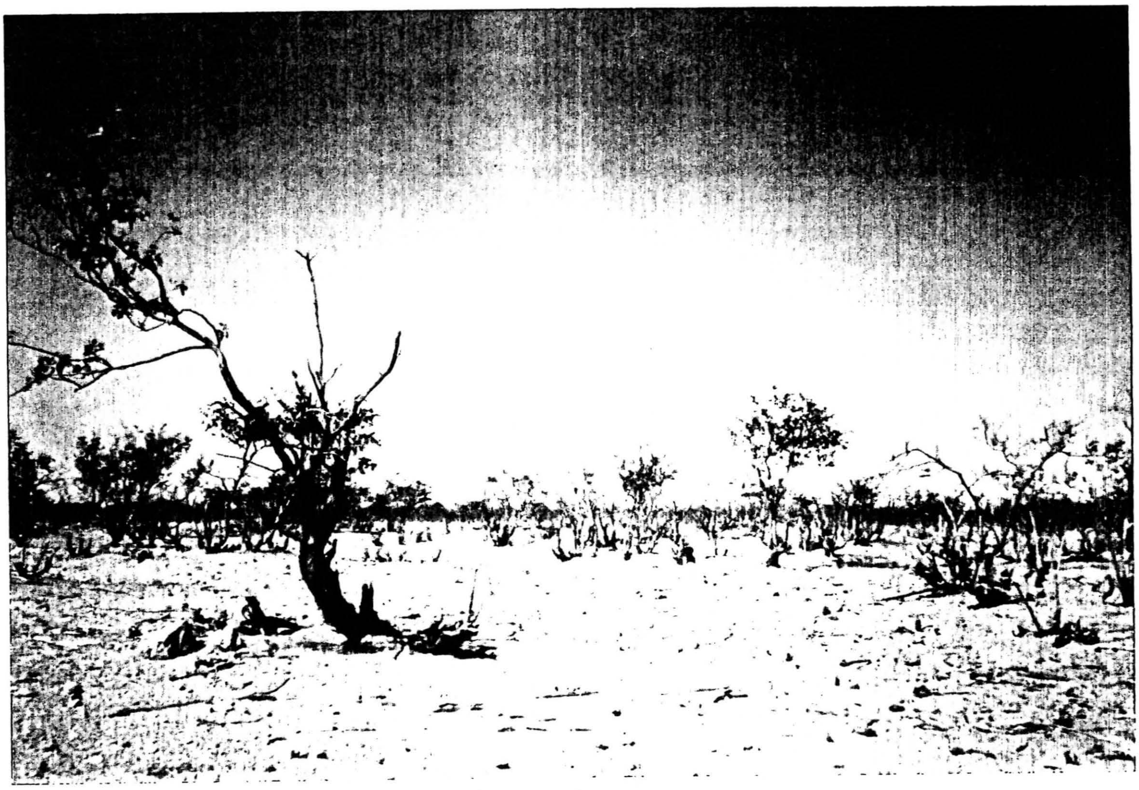
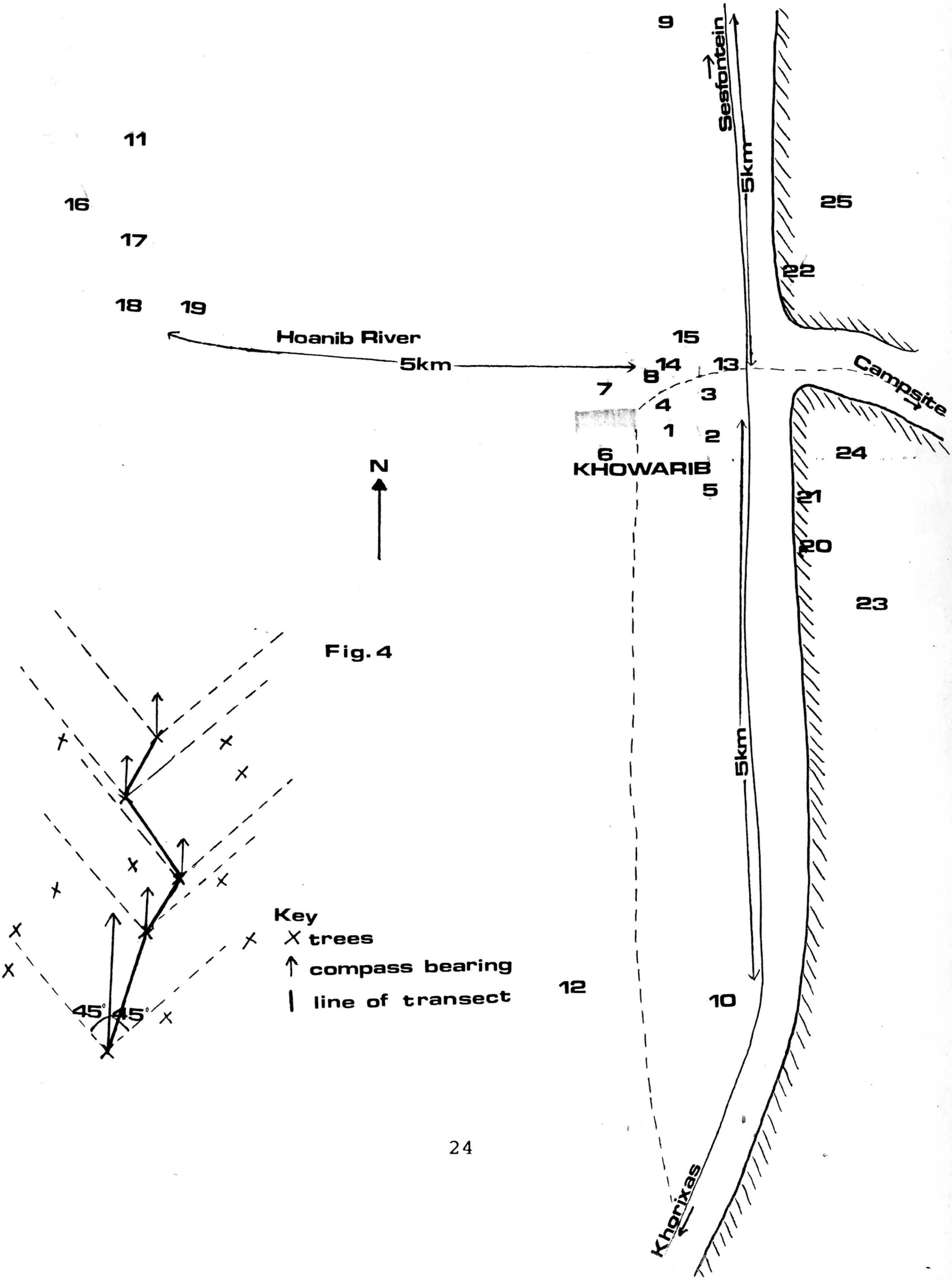


Plate 20. Heavily lopped and coppicing *Colophospermum mopane*.

Fig. 4. Diagram of transect method.

Fig. 5. Distribution of transects (1–12=plain vegetation; 13–19=riverine; 20–25=mountain).



3.2.2 Statistical analysis of the vegetation data

A suite of exploratory and analytical techniques were used to assess the relationship between the species recorded in each sample and the underlying environmental variables. These have been selected for this project to display the application of a variety of statistical techniques. It is recognised that multivariate analysis in the form of ordination, classification and correspondence techniques are rather time-consuming and rigorous for the size of the Damara data set. They are presented here, however, to indicate their potential applicability to the analysis of the larger data set that could theoretically be produced by longer term data collection along the lines presented here.

Chi-square

Chi-square tests were applied to explore species associations with each of the sample sites in the three topographic categories. The sensitivity of the test was increased by partitioning the original matrix to reveal the most significant components within the overall chi-square value (Maxwell, 1961: 52).

Ordination: Detrended Correspondence Analysis (DCA)

Ordination techniques are multivariate methods which organise community data on the basis of species abundance by arranging species and samples in a low-dimensional space such that similar species and samples are close together and vice versa (Gauch, 1982: 109, 115; Goldsmith *et al*, 1986: 501-2; ter Braak, 1986: 1167; Gaillard *et al*, 1992: 7). The reduction of multi-dimensional data to a low-dimensional space (i.e. 2-3 dimensions) is possible because other dimensions or axes are normally correlated with the most influential axes and, therefore, the location of species and samples along these axes is likely to reflect the underlying structure of the data (Gauch, 1982: 116). The strength of these axes or gradients, i.e. the total variability they account for, is represented by their eigenvalues (Dudziński and Arnold, 1973: 905; ter Braak, 1988: 159).

Relationships between community patterns and known environmental variables can be inferred from ordination to produce an ecological interpretation of the community data which can be tested using other methods. As such, ordination is an indirect gradient analysis method from which species-environment relationships can be explored and described in a qualitative manner (ter Braak, 1986: 1167). Detrended Correspondence Analysis (DCA) was applied to a samples-by-species matrix derived from the Damara vegetation data set (Appendix 2) using the computer program CANOCO 3.12 which performs partial, detrended and canonical correspondence analysis (CCA).

Diversity

CANOCO was also used to produce Hill's N2 diversity index for each sample and these figures were then related to distance from the settlement (Hill, 1973). This is based on Simpson's index (λ) which calculates the proportion that each species represents in a population and gives the probability that an individual drawn at random from this population will be of a particular species (Appendix 3) (Simpson, 1949). Hill's N2 index summarises this information in a single figure which represents the number of effective or dominant species in a sample. A sample with a single very abundant species is, therefore, described by a low N2 (Ludwig and Reynolds, 1988: 85, 90-1).

Classification
The description of the vegetation data by DCA was complemented using the TWINSPAN (Two-Way Indicator SPecies ANalysis) program (Hill, 1979b). This is a polythetic divisive classification technique which uses information on all the species data to divide the samples into a hierarchy of successively smaller and smaller groups based on indicator species and floristics (Goldsmith *et al*, 1986: 494). In TWINSPAN the data are first ordinated by reciprocal averaging and the samples are divided or polarised through emphasizing the species that characterise extremes on the reciprocal averaging axes (Gauch, 1982: 201-2). The values presented in the resulting table are new values or 'pseudospecies' based on levels of abundance for each species in each sample.

Canonical Correspondence Analysis (CCA)
CCA, applied using CANOCO 3.12, is a multivariate analysis technique developed by ter Braak to relate community composition directly to environmental variables, by finding the ordination axes which reveal to the greatest possible extent the common structure of the samples-by-species and samples-by-environmental variables matrices (Appendices 2 and 4) (Gauch, 1982: 163; ter Braak, 1986: 1167, 1988: 159). Canonical ordination techniques such as CCA can combine both ordination and regression to produce a multivariate direct gradient analysis of the relationships between a number of species and environmental variables (ter Braak, 1986: 1167, 1988: 159).

CCA of a data set can be presented as an ordination diagram in which the species and sites are represented as points and the environmental variables as vectors portrayed in two ways: as arrows if the variable is ordinal or continuous, or points if the variable is nominal or dichotomous (ter Braak, 1986: 1167). In the case of ordinal variables, environmental information is expressed by the directions and relative lengths of the representative arrows. The length of the arrow is a measure of how much of species change is accounted for by that variable. More important variables (i.e. those with higher eigenvalues) are, therefore, represented by longer arrows. The position of a species point in relation to the arrows of the ordinal environmental variables reflects the distribution of that species along that environmental gradient. Nominal environmental variables, on the other hand, are represented by points located at the centroid (i.e. weighted average) of the sites belonging to that environmental class. The completed ordination diagram, therefore, shows visually the dominant patterns in the community produced by the relationship of species and sites to the environmental variables.

Testing of specific hypotheses: Monte Carlo permutation testing and partial CCA

Using the program CANOCO, specific hypotheses were tested concerning the influence of particular environmental variables on the vegetation community using the forward selection of these variables by Monte Carlo permutation tests (Ter Braak, 1988: 159; Gaillard *et al*, 1992: 7). Environmental variables are viewed as 'treatments' imposed on the vegetation and the resulting community pattern as the 'response' to this treatment (Gaillard *et al* 1992: 9). In doing this the percentage of variation in species abundance that can be attributed to a particular variable is revealed as the probability of that variable contributing significantly to the assemblage after a number of permutations (Gaillard *et al*, 1992: 7). To overcome the problem of close association between variables a partial CCA can be applied so that the effect of 'background' variables are statistically partialled out as covariables and the significance of a particular variable in its effect on the vegetation assemblage can be tested (ter Braak, 1987b: 557, 1988: 159; Gaillard *et al*, 1992: 9).

This analytical method was used to test the null hypotheses that there was no significant difference in species assemblages in samples with differing:

i. intensities of lopping
ii. intensities of browsing
iii. distances from the Khowarib settlement

4.0 Results

4.1 The demand for products provided by perennial woody species

The total number of tree species recorded in the interview survey as utilized by inhabitants of Khowarib was 39. Table 1 indicates the number of species important for different forms of utilization.

Table 1. Numbers of species recorded for different forms of utilization at Khowarib settlement, Damaraland.

type of utilization	numbers of species recorded (total used = 39)
food:	21:
fruit	14
resin	7
household medicines	17
household utensils	10
leather dyes/tanning agents	8
browse for livestock	15

4.1.1 The importance of food resources from trees

At Khowarib perennial woody species are the source of two important food products; fruits, of central significance to people's diets, and resins or exudates, regarded as a seasonally available delicacy (Table 2). Earlier ethnobotanical studies in similar regions of Damaraland and Kaokoland have also recorded the use of many of these species. Du Pisani (1978: 15), for example, records the use of *Ficus sycamorus* (**|nòmá.s**), *Hoodia* sp. (**!khòbà.s**) and *Grewia flava* or **≠âú.n** fruits and Malan and Owen-Smith (1974: 154-63) list the importance of *Salvadora persica* (**khòòrí.s**), *Berchemia discolor* (**≠hûi.s**), *Grewia* spp., *Ziziphus mucronata* (**≠áró.s**), *F. sycamorus*, *Ximenia americana* (**≠ero.n**) and *Boscia albitrunca* (**|hùní.b**). Many of the species from which edible exudates are obtained, such as *Acacia erubescens*, *A. mellifera* subsp. *mellifera* (**!noe.s**) and *A. reficiens* (**!gòú.b**) reported in Steyn and du Pisani (1985: 44) are also similar and records from the late 19th century and the early 20th century indicate that resins have long been a food resource that was sought after (Von François, 1896: 249-50; Vedder, 1923: 71). While there is some overlap in the range of species recorded in these studies when compared with those recorded at Khowarib, there are also a substantial number of species listed in this study whose use has not been recorded elsewhere. Similarly, there are species whose utilization is described in other studies of the same region but which were not recorded as utilized for the same purposes at Khowarib.

Table 2. The utilization of food products from perennial woody species at Khowarib settlement, Damaraland.

botanical name	Damara name	no. of times use was recorded n = 13
FRUIT		
Salvadora persica	khòòrí.s	13
Berchemia discolor	≠ hûí.s	10
Grewia flava	≠ âú.n/s	10
-	sabibes	9
Hoodia sp.	!khòbà.s/b	7
Grewia tenax	ǀ nàí.b, ǀ àí.b	6
Cordia sinensis	/ai.s	6
Cordia sinensis	ǀ khō.s	5
Ziziphus mucronata	≠ áró.s/i	5
Ficus sycomorus	ǀnòmá.s	3
Ximenia americana	≠ èérò.s	3
Grewia sp.	ǀ arabe.s	2
-	ûia.n	2
Boscia albitrunca	ǀhùní.b	1
RESIN		
Acacia tortilis subs. *heteracantha*	ǀnàrá.b	13
Terminalia prunoides	≠ khèérá.s	9
Acacia senegal	nu.b, tû.n (nûù.s?)	6
Acacia mellifera subsp. *detinens*	!noe.s	4
Acacia reficiens	!gûú.b/s	3
Acacia fleckii	!úrí!gòhnè.s	1
Acacia montis-usti	ǀhū.b	1

4.1.2 Tree products used for household medicines
Serious diseases or medical ailments throughout traditional societies are normally explained with reference to supernatural, as opposed to purely physiological, causes and are treated by specialist healers considered to have control over these forces. The Himba nomadic pastoralists of Kaokoland, north of Damaraland, for example, ascribe such disorders to the power of ancestral spirits or the actions of witch doctors (Malan and Owen-Smith, 1974: 142). In many cases the plant resources used in the treatment of such diseases bears little relationship to the physiological causes of the disorder, their effectiveness being assigned to magico-religious power and their administration requiring the specialist knowledge of traditional healers.

Such societies do, however, usually have a 'secular conception' of certain common ailments which are treated within the household using remedies for which the necessary knowledge and resources necessary are available to everyone. The cosmopolitan medicinal use of many of these resources reinforces the evidence for the effectiveness of these household medicines. Like the Damara pastoralists at Khowarib (Table 3) the Himba of Kaokoland, for example, also use *C.*

mopane for a variety of disorders, and the leaves of this tree are widely believed to have disinfectant properties (Malan and Owen-Smith, 1972: 153-55).

Table 3. Tree products used for household medicinal purposes at Khowarib settlement, Damaraland.

botanical name	Damara name	part of tree used	medicinal purpose	no. of times use was recorded n = 13
Colophospermum mopane	tsàúráhàì.s	leaves	stomach ache	7
			poultice for headache	2
			colds	1
Combretum imberbe	!hàà.s/b	leaves	colds	6
Salvadora persica	khòòrí.s	roots	stomach disorders	2
Acacia tortilis	ǀnàrá.b	roots	back pain	1
Commiphora pyracanthoides	ǀiínî.b	bark	chest pain	1
Commiphora sp.	ǀâna.s	twigs	heart	1
			coughs	1
Ficus ilicina	ǀùì.b	bark	kidneys	1
Hoodia sp.	!khòbà.s/b	leaves	eyes	1
Maerua schinzii	gòárdà.b	roots	earache	1
Terminalia prunoides	≠khèérá.s	bark	dressing for injury	1
		roots	stomach disorder	1
Ziziphus mucronata	≠ âró.s/i	bark	back pain	1
		roots	chest pain	1
Grewia sp.	sabibe.s	roots	stomach ache	1

4.1.3 Timber and other tree products used for household utensils

Table 4 below indicates the wide range of species whose timber is commonly used by the inhabitants of Khowarib to make a variety of products such as wooden buckets, oval winnowing bowls or ≠goub, mortars and pestles and weapons such as knobkieries. Many of these handcraft products are items which are produced almost exclusively for domestic use but their appeal to tourists visiting the area make it likely that their production will increase to take advantage of the outlet provided by the newly established bushcamp.

Table 4. Tree species used for the production of household utensils at Khowarib settlement, Damaraland.

botanical name	Damara name	part of tree used	utensil made	no. of times use was recorded n = 13
Acacia montis-usti	ǀhū.b	timber	≠ goub (winnowing bowl)	4
		timber	buckets	2
		timber	spoons	1
Colophospermum mopane	tsàúráhàì.s	timber/roots	spoons	2
		timber	cooking sticks	1
		roots	pipes	1
		timber	knobkieries	1
		stems	bows	1
Commiphora multijuga	ǀgâua.b	timber	spoons	2
		timber	pipes	1
		timber	buckets	1
		timber	≠ goub	1
Commiphora anacardifolia	!khoebe.b	timber	≠ goub	2
Terminalia prunoides	≠ khèérá.s	timber	hoe handles	1
		timber	knobkieries	1
Berchemia discolor	≠ hûí.s	timber	knobkieries	1
Cordia sinensis	ǀkhō.s	timber	≠ goub	1
Grewia tenax	ǀhaí.b	timber	rake handles	1
Tamarix usnoides	tamara	timber	spoons	1
Ziziphus mucronata	≠ áró.s/i	timber	knobkieries	1

4.1.4 Tree products used as dyes and tanning agents for leather

The use of animal skins for clothing and bedspreads is still important at Khowarib, the leather being tanned and dyed using traditional processes requiring a variety of locally available plant resources (Table 5). Many of these are used elsewhere in Damaraland; du Pisani (1978: 15), for example, records the use of *Combretum imberbe* (!hàà.b) bark in skin-working among the Damara of the Ugab valley.

Table 5. Tree products used as dyes and tanning agents for leather at Khowarib settlement, Damaraland.

botanical name	Damara name	part of tree used	colour of dye produced	no. of times use recorded n = 13
Acacia montis-usti	|hũ.b	bark	orange/red	7
Combretum imberbe	!hàà.b	leaves	green	4
		bark	red	3
Colophospermum mopane	tsàúráhàì.s	roots	orange/red	5
		bark	red	1
Ficus sycomorus	|nômá.s	bark	red	3
Commiphora crenato-serrata	anto.b	bark	red/brown	2
Commiphora multijuga	|gâua.b	bark	red	2

4.1.5 Important forage species for livestock

The importance of trees in the provision of browse for the livestock of pastoralists is rarely given as much attention as the availability of pasture. In many areas of sub-Saharan Africa, however, the productivity of nutritious pasture in response to the low and variable rainfall characteristic of these regions is extremely seasonal in nature. Under these circumstances, there are typically long periods of the year when livestock have to rely on browse as their main form of sustenance. Rees (1974) in Homewood and Rodgers (1991: 159) found, for example, that ±34% of metabolisable energy from forage in the Zambian **chitemene** resource use system during the dry season came from browse and Homewood and Hurst (1986) in Homewood and Rodgers (1991: 159) similarly found that browse comprised up to 40% of wet season feeding time, even though this was the time of peak annual availability of graze. This importance of browse is certainly the case in Namibia, where in years of particularly low rainfall the leaves of perennial woody species may be the primary source of food throughout the year for livestock.

At Khowarib the significance of woody species in the provision of livestock forage was recognised throughout the community (Table 6), many people specifying the parts of a species that are particularly nutritious. The nourishing pods of the *Acacias* and the browse and fruits of *Boscia* spp., *Terminalia prunoides* and *Maerua schinzii* are, for example, known to be sought after by domestic livestock and many species of wild herbivores throughout Damaraland and Kaokoland (Malan and Owen-Smith, 1974: 141-59; Steyn and du Pisani, 1985: 49).

Table 6. Species important in the provision of browse for livestock at Khowarib, Damaraland

<table>
<tr><th>botanical name</th><th>Damara name</th><th>times use was recorded n=13</th></tr>
<tr><td>Terminalia prunoides</td><td>≠khèérá.s</td><td>9</td></tr>
<tr><td>Catophractes alexandri</td><td>!gàwà.s</td><td>5</td></tr>
<tr><td>Acacia albida</td><td>àná,ànáhài.s</td><td>4</td></tr>
<tr><td>Acacia erioloba</td><td>|âna.s</td><td>4</td></tr>
<tr><td>Acacia tortilis</td><td>|nàrá.b</td><td>4</td></tr>
<tr><td>Boscia albitrunca</td><td>|hùní.b/s</td><td>4</td></tr>
<tr><td>Colophospermum mopane</td><td>tsàúráhài.s</td><td>3</td></tr>
<tr><td>Commiphora pyracanthoides</td><td>|iinî.b</td><td>2</td></tr>
<tr><td>Salvadora persica</td><td>khòòrí.s</td><td>2</td></tr>
<tr><td>Acacia montis-usti</td><td>|hū.b</td><td>1</td></tr>
<tr><td>Boscia foetida</td><td>xáúbè.s</td><td>1</td></tr>
<tr><td>Combretum apiculatum</td><td>≠óó.b/s</td><td>1</td></tr>
<tr><td>Maerua schinzii</td><td>gòárdà.b</td><td>1</td></tr>
<tr><td></td><td>ao-ana.b</td><td>1</td></tr>
</table>

4.2 Impact of utilization on surrounding vegetation communities

4.2.1 Chi-square results

Plains (original matrix presented in Table 7; partitioned matrices presented in Appendix 5)
The relationship between species composition and distance from the settlement was highly significant (x^2=176.78, p <0.0001, df=10; matrix with rows reversed, cell [1,3]: x^2=101.89, p <0.00001; columns reversed, cell [3,1]: x^2=49.46, p <0.00001; rows and columns reversed, cell [1,1]: x^2=78.31, p <0.00001).

The overall species composition differs significantly between the samples within and on the outskirts of Khowarib (rows reversed, cell [1,2], x^2=20.09, p <0.00001). There was, however, no significant difference between these samples for *A. tortilis* and *C. mopane*, these species showing comparable distributions, with both significantly associated with the Khowarib samples (rows reversed, cell [3,2], x^2=14.14, p <0.0002). The distribution of these two species did differ significantly between the samples 5km from the settlement compared to the Khowarib and outskirts samples, *C. mopane* being significantly associated with the 5km samples and *A. tortilis* significantly associated with the Khowarib samples (original matrix, cell [2,3], x^2=77.1, p <0.00001; columns reversed, cell [2,2], x^2=53.305, p <0.00001, cell [2,1], x^2= 24.35, p <0.00001). *A. tortilis* displayed a particularly strong association with the samples within Khowarib in contrast to all other species (rows reversed, cell [2,2]

x^2=10.13, p <0.001, cell [2,3], x^2=6,72, p <0.009; rows and columns reversed, cell [1,2], x^2=43.69, p <0.00001).

S. persica and *Catophractes alexandri* had significantly different patterns of distribution when compared with each other and with *A. tortilis* and *C. mopane* (columns reversed, cell [4,2], x^2=28.53, p <0.00001). *S. persica* was significantly associated with the outskirts samples whereas, as explained above, *A. tortilis* and *C. mopane* were associated within and 5km away from Khowarib respectively (original matrix, cell [3,2], x^2=43.7, p <0.00001, cell [3,3] x^2=6.7, p <0.009; columns reversed, cell [3,1], x^2= 49.46, p <0.00001). *C. alexandri* was, on the other hand, significantly associated with the 5km samples (original matrix, cell [4,3], x^2=37.8, p <0.00001).

When *C. alexandri*, *M. schinzii*, *C. mopane* and the category 'other' species were aggregated they also showed significantly different distributions compared to *A. tortilis* and *S. persica* (rows reversed, cell [4,3], x^2=13.27, p <0.0003; rows and columns reversed, cell [4,2], x^2= 10.74, p <0.001, cell [3,2], x^2=19.42, p <0.00001, cell [2,2], x^2= 14.58, p <0.001); the former group (*C. alexandri* in particular) are positively associated with the 5km samples whereas *A. tortilis* is positively associated with the Khowarib samples and *S. persica* with the outskirts samples.

Table 7. Original chi-square species-by-site matrix for the plains samples (O=Observed frequency; E=Expected frequency; x^2=chi-square value).

species	sample areas									total	
	in Khowarib			outskirts			5km away				
	O	E	x^2	O	E	x^2	O	E	x^2	O	x^2
Acacia tortilis	92	53.2	28.24	61	55.5	0.54	9	53.2	36.75	162	65.53
Colophospermum mopane	11	17.7	2.56	5	18.5	9.86	38	17.7	23.13	54	35.55
Salvadora persica	1	22	20.06	40	23	12.62	26	22	0.72	67	33.4
Catophractes alexandri	0	5.3	5.26	0	5.5	5.49	16	5.3	21.95	16	32.7
Maerua schinzii	1	5	8	5	4.8	0.01	8	4.6	2.51	14	5.34
Other	10	9	18	9	12.7	1.07	18	12.2	2.81	37	4.26
Total	115		59.32	120		29.59	115		87.87	350	176.78

Riverine (original matrix presented in Table 8; Partitioned matrices presented in Appendix 6)

There was a significant difference in overall species composition between samples near to and 5km away from Khowarib

(x^2=114.37, p <0.00001, df=6). Partitioning of the matrix indicates that *S. persica*, *Acacia erioloba*, *Acacia albida* and *Combretum wattii* are, for example, strongly associated with the samples 5km from the settlement whereas *A. tortilis* and *C. mopane* are significantly associated with the near Khowarib samples (original matrix, cell [3,2], x^2=69.67, p <0.00001, cell [4,2], x^2=11.25, p <0.0008, cell [5,2, x^2=14.89, p <0.00001, cell [6,2], x^2= 17.04, p <0.00001; rows reversed, cell [6,2], x^2=9.51, p <0.002, cell [2.2], x^2=68.51, p <0.00001).

Table 8. Original chi-square species-by-sites matrix for riverine samples (O=Observed frequency; E=Expected frequency; x^2 = chi-square value).

species	samples						total	
	outskirts			5km away				
	O	E	x^2	O	E	x^2	O	x^2
Acacia tortilis	36	18.9	15.58	8	25.1	11.69	44	27.27
Colophospermum mopane	34	15.9	20.76	3	21.1	15.57	37	36.33
Salvadora persica	10	26.1	9.97	51	34.9	7.48	61	17.44
Acacia erioloba	3	8.1	3.25	16	10.9	2.44	19	5.68
Acacia albida	0	6.4	6.43	15	8.6	4.82	15	11.25
Combretum wattii	0	9	9	21	12	6.75	21	15.75
Other	7	5.6	0.37	6	7.4	0.27	13	0.64
Total	90		65.35	120		49.02	210	114.37

Mountain (original matrix presented in Table 9; Partitioned matrices presented in Appendix 7)
Again, there was a significant difference in overall species composition between the lower and upper slopes (x^2=25.94, p <0.00001, df=3). Partitioning of the matrix reveals that there is a significant difference in the distribution of *T. prunoides* and *C. mopane* compared with 'other' species, the former being associated with the lower slopes and the latter group with the upper slopes (original matrix, cell [4,2], x^2=19.99, p <0.00001). The association with the lower slopes is particularly strong for *C. mopane* compared to all other species (rows reversed, cell [3,2], x^2=22.13, p <0.00001). *Boscia foetida* is relatively evenly distributed throughout.

Table 9. Original chi-square species-by-sites matrix for mountain samples (O=Observed frequency; E=Expected frequency; x^2=chi-square value).

species	samples						total	
	lower slopes			upper slopes				
	O	E	x^2	O	E	x^2	O	x^2
Boscia foetida	5	4.5	0.06	4	4.5	0.06	9	0.11
Terminalia prunoides	27	23	0.7	19	23	0.7	46	1.39
Colophospermum mopane	10	5	5	0	5	5	10	10
other	3	12.5	7.22	22	12.5	7.22	25	14.44
Total	45		12.97	45		12.97	90	25.94

4.2.2 Detrended Correspondence Analysis (DCA) results

When DCA was applied to the Damara vegetation data set it was apparent that, while the overall variation was high (gradient length or sum of eigenvalues = 4.17), a considerable amount of the variation in the data could be explained by the first two axes constructed to fit the data. Axis 1, for example, had an eigenvalue of .872 and accounted for 20.9% variance of the vegetation data whilst axis 2 had an eigenvalue of .313, the cumulative percentage variance accounted for by these two axes being 28.4%.

When the ordination scores for species and samples were listed in order of their position on axis 1 it was possible to detect some pattern in their ranks (Table 10). Broadly speaking, the first four ranked samples (16-19) are those which occurred in the riverine vegetation 5km away from the Khowarib, thus indicating similarity in the composition of these samples. These are followed by a combination of plains samples at all distances from the settlement (1-9, 11, 12) and riverine samples close to the settlement(13-15). The fact that the riverine samples 5km away from Khowarib occur closely together and are separated in rank from the riverine samples near Khowarib suggests that there were factors associated with distance from the settlement that were affecting species composition independently of other environmental constraints. Like the riverine samples 5km from the settlement, the six mountain samples (20-25) also occur very closely together in rank, separated only by one plains sample (10) from 5km outside Khowarib which appears to be an atypical sample in terms of these ranked scores. The species ranks follow this pattern with species associated with the riverine samples from 5km outside the settlement (e.g. *A. albida* and *Combretum wattii*) ranked closely together at one end of the spectrum, followed by a broad group of species found in both plains samples at all distances from the settlement and riverine samples from near the settlement (e.g. *A. tortilis*, *C. mopane* and *S. persica*), and completed by species such as *Terminalia prunoides* and *Commiphora* spp. associated with mountain samples.

Table 10. Ranked scores for samples and species in relation to the axis 1 ordination scores produced by Detrended Correspondence Analysis (DCA). (The relationship between sample scores and the groups produced by TWINSPAN classification as described below is indicated).

SAMPLE TWINSPAN GROUPS	sample	ranked Axis 1 scores	species	ranked Axis 1 scores
3	18	.0000	*Pechuel-loeschea leubnitziae*	-.9237
3	19	.0138	*Acacia albida*	-.9087
3	17	.2996	*Combretum wattii*	-.6696
3	16	.9004	*Acacia erioloba*	.0510
1	07	1.1395	*Lycium oxycarpum*	.7786
1	06	1.2297	*Salvadora persica*	.8583
1	11	1.5093	*Acacia tortilis*	1.6287
1	14	1.5489	*Tamarix usnoides*	1.8495
1	02	1.6030	*Colophospermum mopane*	2.6473
1	01	1.6856	*Boscia albitrunca*	2.6991
1	04	1.7225	*Gossypium triphyllum*	2.6991
1	08	1.7726	*Maerua schinzii*	3.1646
1	05	1.7938	*Boscia foetida*	3.7947
1	03	1.9343	*Terminalia prunoides*	4.5622
1	15	2.0322	*Acacia senegal*	4.6332
1	12	2.1315	*Commiphora multijuga*	4.7185
1	13	2.2717	sorab	4.9276
1	09	2.3240	*Commiphora pyracanthoides*	5.2316
2	22	3.4386	*Catophractes alexandri*	5.3118
2	21	4.2150	*Commiphora* sp. (/anas)	5.7234
2	20	4.3202	*Combretum apiculatum*	6.3973
2	23	4.3458	/aba/hub	6.3973
2	24	4.5929		
2	10	4.9262		
2	25	5.8618		

Likewise, the combined presentation of the DCA ranked sample and species weighted averages in an arranged matrix as in Table 11 reveals, in the concentration of larger values along the matrix diagonal, the underlying pattern in the community data described above.

Table 11. Arranged matrix of samples-by-species abundances based on DCA scores for axis 1.

species	samples: values = numbers of individuals in each sample																								
	18	19	17	16	07	06	11	14	02	01	04	08	05	03	15	12	13	09	22	21	20	23	24	10	25
Pechuel-loeschea leubnitziae	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acacia albida	8	5	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Combretum wattii	7	4	7	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acacia erioloba	4	5	6	1	1	-	4	2	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Lycium oxycarpum	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Salvadora persica	8	9	12	22	17	16	11	3	1	-	-	3	4	-	5	9	2	6	-	-	-	-	-	-	-
Acacia tortilis	3	1	3	1	12	6	4	23	21	26	24	21	22	21	8	5	5	-	-	-	1	1	-	-	-
Tamarix usnoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-
Colophospermum mopane	-	1	-	2	-	-	4	-	-	-	2	5	-	9	12	5	22	22	8	2	-	-	-	-	-
Boscia albitrunca	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-
Gossypium triphyllum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-
Maerua schinzii	-	-	-	1	-	3	-	2	-	1	-	1	1	-	2	4	-	2	-	-	-	-	-	2	-
Boscia foetida	-	-	-	-	-	-	-	-	-	-	1	-	3	-	-	3	-	-	2	2	1	1	2	1	1
Terminalia prunoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	10	12	9	8	5	2
Acacia senegal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-
Commiphora multijuga	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	3	-	-
Sorab	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Commiphora pyracanthoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Catophractes alexandri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16	1
Commiphora sp. /anas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Combretum apiculatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9
Commiphora sp. /aba/hub	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1

4.2.3 Classification

The results of the TWINSPAN classification are represented by an ordered two-way table of the original data (Table 12). The levels of species abundance for each sample are as follows:

level 1 = 0–2 individuals
2 = 3–5
3 = 6–10
4 = 11–20
5 = >20

Table 12. Ordered two-way table of the original sample-by-species matrix produced by TWINSPAN classification.

species	samples: values = TWINSPAN abundance levels																									spp. divs:
	16	17	18	19	12	06	09	11	13	15	07	01	02	05	14	03	04	08	20	23	24	21	22	10	25	
Acacia albida	-	2	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0000
Acacia erioloba	1	2	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0000
Combretum wattii	2	3	3	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0000
Pechuel-loeschea	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0000
leubnitziae	5	4	3	3	3	4	3	4	2	3	4	-	1	2	2	-	-	2	-	-	-	-	-	-	-	0001
Salvadora persica	1	2	2	1	3	3	-	2	3	3	4	5	5	5	5	5	5	5	1	1	-	-	-	-	-	0010
Acacia tortilis	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0011
Boscia albitrunca	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0011
Gossypium triphyllum	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0011
Lycium oxycarpum	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0011
Tamarix usnoides	2	-	-	1	3	-	5	4	5	4	-	-	-	-	-	3	2	3	-	-	-	2	3	-	-	01
Colophospermum mopane	1	-	-	-	2	2	2	-	-	2	-	1	-	1	2	-	-	1	-	-	-	-	-	2	-	01
Maerua schinzii	-	-	-	-	2	-	-	-	-	-	-	-	-	2	-	-	1	-	1	1	2	2	2	1	1	100
Boscia foetida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	1010
Acacia senegal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	1	-	-	-	1010
Commiphora multijuga	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1010
sorab	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	3	3	4	3	3	2	1010
Terminalia prunoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	1011
Commiphora sp. /anas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	1	11
Catophractes alexandri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	11
Combretum apiculatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	11
Commiphora pyracanthoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	11
Commiphora sp. /aba/hub																										
sample divisions:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	
																			group 2							
	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1	
	group 3				group 1																					
						0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	1	1		
						sub-group 1b						sub-group 1a														
									0	1	1	1	1	1	0	0	0	0	0	1	1	1				
											0	1	1	1	1	0	1	1	1	1						

As can be seen from Table 12, TWINSPAN classified the Damara samples into three major sample groups which did not correspond exactly to the three known habitat types, thus indicating that species composition and abundance were reflecting other underlying external variables. The three groups were as follows:

Group 1

A. tortilis is the indicator species for this group which is representative of plains samples at all distances from Khowarib and of the riverine samples near to Khowarib. The plains samples within Khowarib have the highest weighted averages for *A.*

tortilis. Also characteristic of this group are *S. persica, C. mopane* and, at lower levels, *Acacia erioloba, Maerua schinzii* and *Boscia foetida*.

The third TWINSPAN division splits group 1 into two sub-groups. Sub-group 1a contains all the plains samples from within Khowarib, most of the plains samples from the outskirts of Khowarib and one near Khowarib riverine sample whilst sub-group 1b contains most of the remaining plains outskirts and 5km away samples and two riverine samples from the outskirts of the settlement. This indicates that distance from the settlement was having an effect on the species composition of these plains and riverine samples, independent of the topographic habitat divisions. Table 9 indicates that sub-group 1a is dominated particularly strongly by *A. tortilis* and, with only 6 species found in the 8 samples of this group, has a generally lower species diversity than sub-group 1b in which 10 species were recorded in only 6 samples.

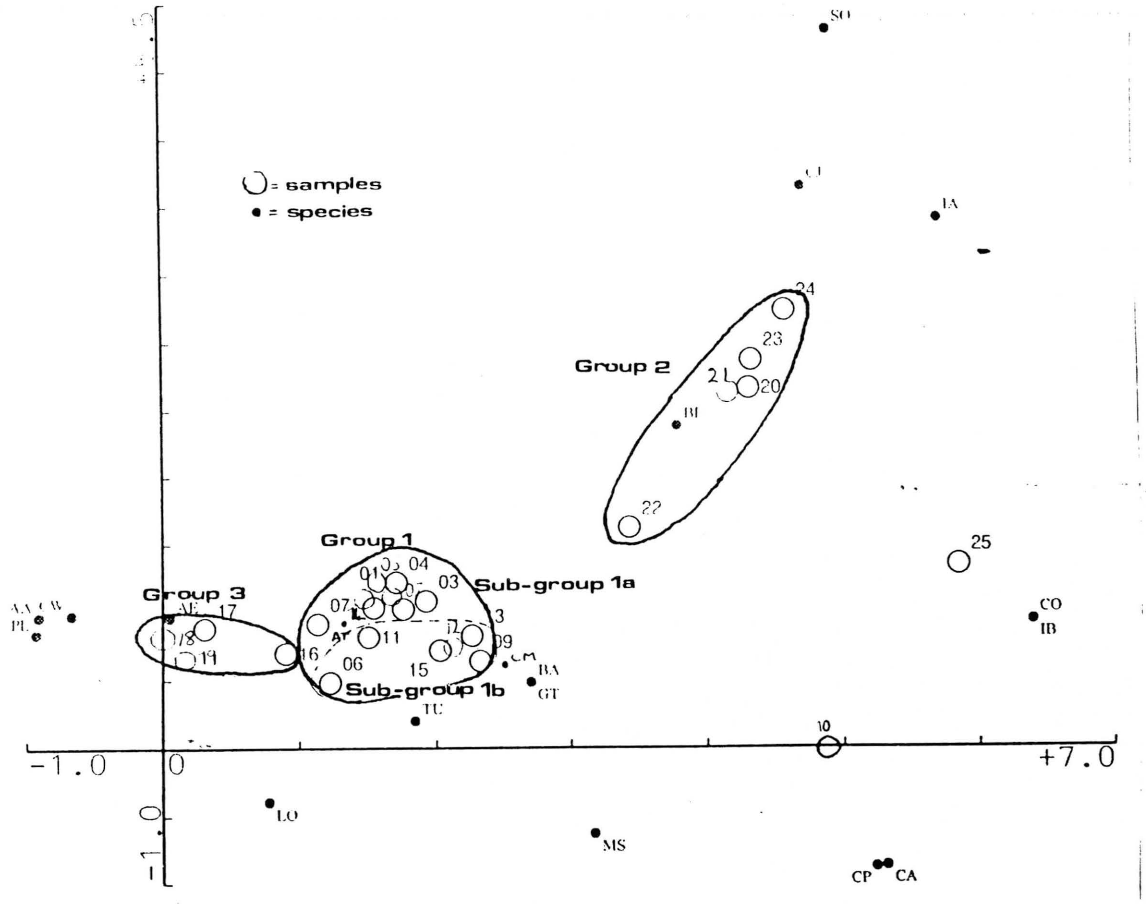
Group 2
This is a very well-defined group characterised by *T. prunoides* and, to a lesser extent, *B. foetida* and *A. senegal*. These samples represent those located in the mountain topographic category and this appears to be the major underlying factor determining species composition in this groups. The exception to this is sample 10 which is a plains sample located 5kms from Khowarib.

Group three
This group is characterised by high levels of *S. persica* with *C. wattii* and *A. albida* represented only in this group and *A. erioloba* also being an important species. This group contains only the four riverine samples located 5kms from Khowarib and, therefore, indicates that distance from the settlement was having a strong effect on species composition in the riverine samples. Not only, for example, was species richness slightly higher in the samples 5km away from the settlement but the composition itself was very different with two species which are relatively dominant in this group, *C. wattii* and *A. albida*, being recorded only at this site.

The graphical presentation of the DCA ordination and the TWINSPAN classification groups described above is shown in Figure 6 in which the three outlined communities correspond with the TWINSPAN groups described above. From this it is apparent that group 2 is very distinct in terms of its characteristic species composition whereas groups 1 and 3 are more similar and can be considered to follow a gradient or continuum of variation in species composition. There are two samples which can be considered outliers of the groups described above. First, sample 10, which is located in the plains habitat 5kms from Khowarib, can be considered as atypical of the other plains samples located 5kms from Khowarib due to its extremely high value for *C. alexandri*, which is only found at one other mountain sample. It also has a relatively high value for *T. prunoides*, a species indicative of mountain samples. Second, sample 25, an upper slope mountain sample, is the only sample containing two species, *C. apiculatum* and *Commiphora* sp. (**/aba/hub**), the former at relatively high levels.

Fig. 6. Ordination diagram of Detrended Correspondence Analysis (DCA) with TWINSPAN classification groups.

Key: AA = *Acacia albida*; CW = *Combretum wattii*; PL = *Pechuel-loeschea leubnitziae*; AE = *Acacia erioloba*; LO = *Lycium oxycarpum*; AT = *Acacia tortilis*; TU = *Tamarix usnoides*; CM = *Colophospermum mopane*; BA = *Boscia albitrunca*; CA = *Catophractes alexandri*; GT = *Gossypium triphyllum*; MS = *Maerua schinzii*; BF = *Boscia foetida*; CJ = *Commiphora multijuga*; SO = **Sorab**; CP = *Commiphora pyracanthoides*; CO = *Combretum apiculatum*; IA = **/anas** (*Commiphora* sp.); IB = **/aba/hub** (*Commiphora* sp.).



4.2.4 Diversity

The N2 index figures presented graphically for the plains, riverine and mountain vegetation in Figures 7a-c appear to be lower with greater proximity to the settlement. This means that samples close to the settlement were typically dominated by only 1 or 2 species which could tolerate the effects of human and animal impact on the vegetation, while those samples further away from the settlement had a more even distribution among several abundant species. Reference to the original samples-by-species data matrix in Appendix 2 illustrates, for example, that all the samples located within the settlement were dominated by *A. tortilis* and it is this that gives them their low N2 values as shown in Figure 7a. Samples 12 and 19 which display the highest N2 values and, therefore, the least dominance by any single species were conversely located 5kms away from the settlement.

Fig. 7. N2 Diversity indices for a. plains, b. riverine samples and c. mountain samples.

Fig. a

1

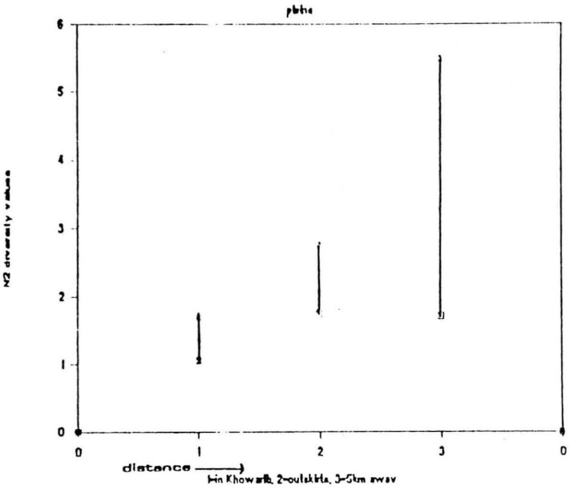


Fig. b

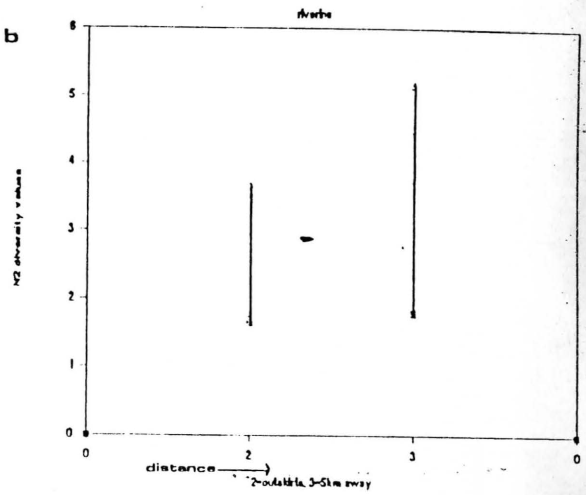
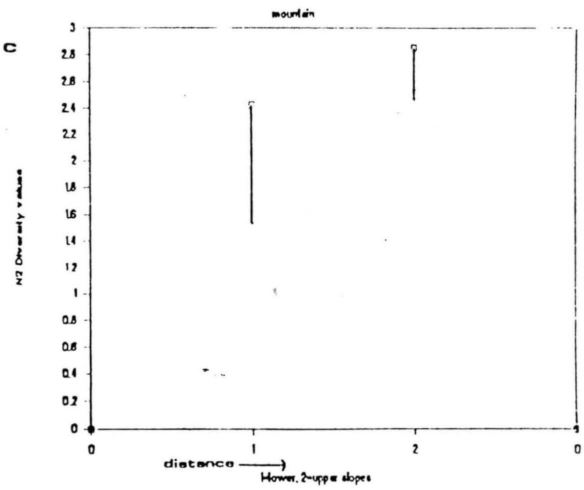


Fig. c



When related indirectly to the known underlying environmental variables using the exploratory techniques above it appears that distance from the settlement, and the associated human and animal impact on the surrounding vegetation, was having an effect on the species composition and diversity of the samples. This effect was stronger in the plains and riverine samples than the mountain samples where the underlying topographic category was more important.

4.2.5 Canonical Correspondence Analysis (CCA)

When CCA was applied to the Damara samples-by-species matrix and environmental variables the axes constructed to explain the variance in the data set indicated a strong division between samples and species explicable with reference to the environmental measurements. Axis 1, explaining 18.3% of variance in the species data and 38.2% of variance in the relationship between species and environmental variables, can be attributed to the strong effect of the mountain topographic category on species composition. It is this axis that explains the graphical separation between mountain samples and plains and riverine samples shown in Fig 4. Axis 2, on the other hand, is represented by significant negative values for the effects of lopping and browsing and and these values are reflected in the figures for the effect of distance from the settlement. This axis explains a cumulative percentage variance of 30% of the species data and 62.4% of the variation in the relationship between species and the environmental variables. Table 13 shows the axis 1 and 2 figures for the weighted correlation matrix from which the ordination diagram is constructed.

Table 13. Axis 1 and 2 figures for the weighted correlation matrix of species, sample and environmental data from which the first CCA ordination diagram is constructed.

environmental variables	species axis 1	species axis 2	environmental axis 1	environmental axis 2
browsing	-.2201	-.6272	-.2274	-.6740
lopping	.1970	-.5143	.2036	-.5527
mountain:	.9426	-.0256	.9739	-.0276
lower slopes	.5047	-.0054	.5215	-.0058
upper slopes	.7777	-.0295	.8035	-.0317
plains	-.3629	-.4794	-.3750	-.5152
riverine:	-.3093	.5300	-.3195	.5696
in settlement	-.2411	-.5802	-.2491	-.6235
outskirts	-.2858	-.2952	-.2953	-.3173
5km away	-.2252	.7851	-.2327	.8437

The ordination diagrams shown in Figures 8a-c were produced from the CCA of the Damara vegetation and environment data. In these diagrams the environmental variables are represented as follows: lopping and browsing are ordinal variables and are, therefore, depicted as arrows. The location of the samples in the plains, riverine and mountain topographic categories and at different distances from the settlement are nominal variables and are represented as points (Fig. 8a). Despite the slightly stronger effect of browsing both the direction and length of the arrows representing browsing and lopping are similar thus indicating that they were having corresponding effects on the vegetation surrounding Khowarib. These arrows extend in the opposite direction to the location of the centroid representing the furthest distance from the settlement category, thereby displaying the greater effects of browsing and lopping with increasing proximity to the settlement.

Figure 8b, which graphically represents the direct relationship between the environmental and sample data, validates the inferences drawn from both the DCA and TWINSPAN classification of the Damara vegetation data set. As described in Table 9 above, samples 20-25, while affected by browsing and lopping, are widely separated from all other samples, their composition being principally determined by their location in the mountains. In accordance with this, Figure 8b indicates a corresponding suite of species, including *A. senegal* and *Commiphora multijuga* which are only found in the mountain samples. While their mountain location was the most important factor underlying species composition in these sites the CCA does place the lower slopes, i.e. the samples nearest the settlement, closer to the vectors representing human and animal impact. This suggests some impact of human and animal utilisation on the composition of the mountain samples. It is important to recognize, however, the complexity of natural micro-habitat changes resulting from different altitudes, slope aspect, geology and drainage patterns in this topographic category, all of which will have their own unique effects on species composition.

The plains and riverine samples, on the other hand, were, as indicated in Figure 6, more similar in species composition and thus represented a continuum in which distance from the settlement, and the corresponding differences in intensity of human and animal utilization, were crucially significant. Figure 8c indicates that both plains and riverine samples located nearer Khowarib shared the greatest similarity in species composition with differences in the species found in these two topographic regions increasing with distance from Khowarib and lower intensities of browsing and lopping. This indicates that the impact of human and animal utilization was overriding the importance of underlying conditions related to topography in the resultant species composition of these samples.

The overlaying of the species information in Figure 8c onto the sample information in Figure 8b, displays which species are most likely to be found at which samples. Samples 20-25 are, for example, characterised by species such as *T. prunoides*, *A. senegal* and *C. multijuga* whilst samples 16-19 have relatively high proportions of *C. wattii* and *A. albida*. These groups of samples were located in the mountains and in the riverine category 5km from the settlement respectively.

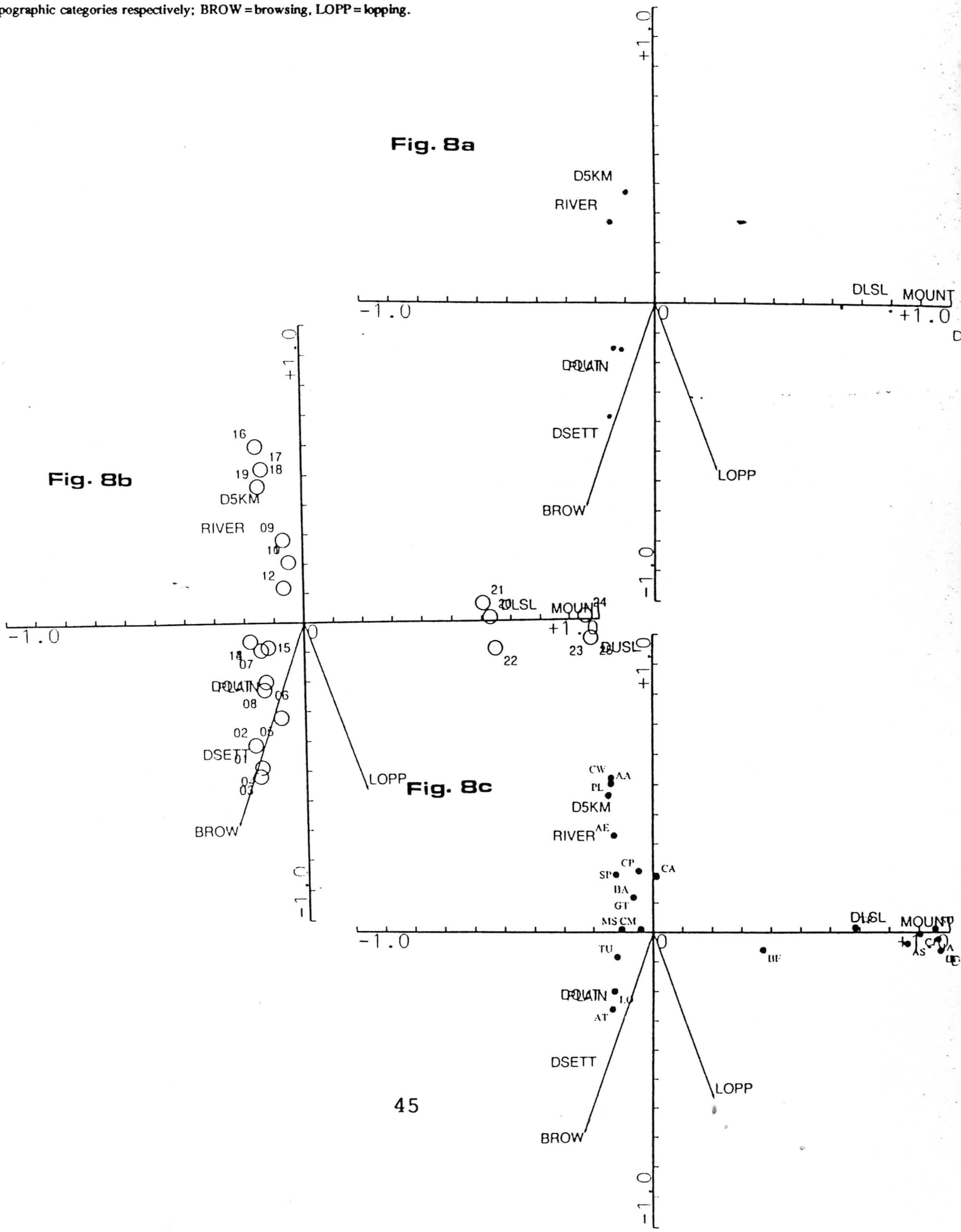
Fig. 8. CCA ordination diagrams: a. environmental variables; b. environmental variables and samples; c. environmental variables and species.

<u>Key</u>

SPECIES: AA = *Acacia albida*; CW = *Combretum wattii*; PL = *Pechuel-loeschea leubnitziae*; AE = *Acacia erioloba*; LO = *Lycium oxycarpum*; AT = *Acacia tortilis*; TU = *Tamarix usnoides*; CM = *Colophospermum mopane*; BA = *Boscia albitrunca*; GT = *Gossypium triphyllum*; MS = *Maerua schinzii*; BF = *Boscia foetida*; CJ = *Commiphora multijuga*; SO = Sorab; CP = *Commiphora pyracanthoides*; CA = *Catophractes alexandri*; IA = *Ianas* (*Commiphora* sp.); IB = *Iaba/hub* (*Commiphora* sp.); CO = *Combretum apiculatum*; SP = *Salvadora persica*; AS = *Acacia senegal*.

SAMPLES: 1-12 = plain; 13-19 = riverine; 20-25 = mountain.

ENVIRONMENTAL VARIABLES: D5KM, DOUT, DSETT = Distance 5km away, outskirts, in settlement; PLAIN, RIVER, MOUNT = plain, riverine and mountain topographic categories respectively; BROW = browsing, LOPP = lopping.



The very distinct nature of the mountain samples indicated by DCA, classification and CCA is exemplified by the fact that location in the mountains accounted for the greatest percentage variance in the first CCA. A second CCA was, therefore, applied to a reduced data set comprised of the more comparable plains and riverine samples. In this case the species environment correlation for axis 1 was extremely significant (0.919) and this axis explained 17.2% and 54.9 % of variance in the species data and the species-environment data respectively. Reference to the weighted correlation matrix (Table 13) indicates that this is due to the significant effects of browsing (0.7113) and distance from the settlement (-0.8817). These are both measures of settlement impact and indicate that proximity to Khowarib was the most important determinant of floristics in these samples. Lopping, the third measure of human impact, also had a positive effect on species composition (0.5804) but was not as significant as browsing and distance. Axis 2 is determined primarily by location in the plains or riverine areas indicating that these topographic categories would, under conditions of no human and animal disturbance, account for most of the variance in species composition in these samples.

Table 14. Axis 1 and 2 figures for the weighted correlation matrix of species, samples and environmental data for the plains and riverine samples from which the second CCA ordination diagram is constructed.

environmental variables	species axis 1	species axis 2	environmental axis 1	environmental axis 2
browsing	.7113	.1003	.7743	.1703
lopping	.5804	.1899	.6317	.3233
distance	-.8817	-.1587	-.9597	-.2703
plains	.5035	-.4071	.5481	-.6933
riverine	-.5035	.4071	-.5481	.6933

The ordination diagrams in Figures 9a and 9b provide a clear graphical representation of these relationships. The wide spread of the samples in Figure 9a, as opposed to clusters around the plains and riverine centroids, indicates the comparable nature of these topographic categories in terms of species composition and the distortion of the data set caused by inclusion of the mountain samples in the first CCA. Figure 9b, of species and the environmental variables, shows very clearly the increasing diversity of species with increasing distance from the settlement, and the tolerance of *A. tortilis* under conditions of high levels of human and animal utilization.

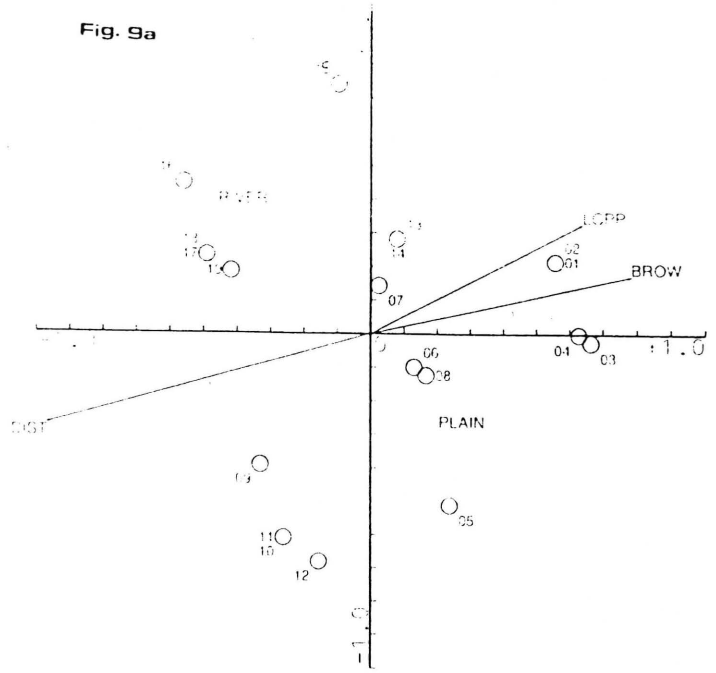
Fig. 9. CCA ordination diagrams of the reduced data set (plains and riverine samples only); a. samples and environmental variables, b. species and environmental variables.

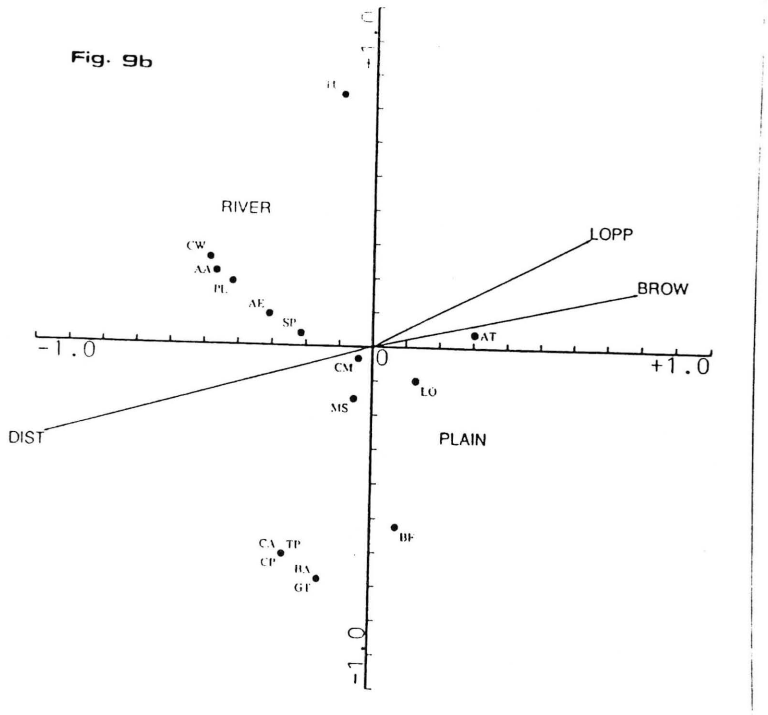
Key

SPECIES: AA = *Acacia albida*; CW = *Combretum wattii*; PL = *Pechuel-loeschea leubnitziae*; AE = *Acacia erioloba*; LO = *Lycium oxycarpum*; AT = *Acacia tortilis*; TU = *Tamarix usnoides*; CM = *Colophospermum mopane*; BA = *Boscia albitrunca*; GT = *Gossypium triphyllum*; MS = *Maerua schinzii*; BF = *Boscia foetida*; CP = *Commiphora pyracanthoides*; CA = *Catophractes alexandri*; SP = *Salvadora persica*.

SAMPLES: 1-12 = plain; 13-19 = riverine.

ENVIRONMENTAL VARIABLES: DIST = Distance; PLAIN, RIVER = plain and riverine topographic categories; BROW = browsing, LOPP = lopping.





4.2.6 Monte Carlo Permutation tests and partial CCA

Unrestricted Monte Carlo Permutation tests and partial CCA were applied only to the reduced data set to test statistically the relationship between floristic variation and the surrogate environmental variables chosen to represent human utilization. The forward testing of the environmental variables using Monte Carlo Permutation test indicated that proximity to the settlement and the associated higher levels of utilization were indeed significant in determining species composition (browsing = $p<0.02$; distance = $p<0.01$; lopping = $p<0.03$). This significance was maintained for distance and browsing following partialling out of the topographic variables ($p<0.01$ and $p<0.04$ respectively).

5.0 Discussion

It is apparent that gathered products from woody species are important to the livelihoods of Khowarib's inhabitants for a variety of purposes. This includes the provision of food items such as fruits and exudates, despite the growing of crops- facilitated by the establishment of the irrigated garden at Khowarib. The levels of human and animal utilization, represented in this study by distance from the settlement and measures of browsing and lopping, were having a significant impact on the woodland surrounding the settlement with utilization affecting species composition up to approximately 4km from the settlement independently of underlying environmental factors.

In an arid area such as Damaraland it is extremely difficult to draw any conclusions concerning the long-term effects of such utilization. This is because the variability of primary productivity due to the unpredictable nature of rainfall means that levels of utilization recorded at any one time may merely reflect the current vagaries of annual precipitation rather than display any long-term trends. The intense browsing around the settlement recorded in this study, for example, may only reflect the reduced availability of graze that is normal in the dry season and may not indicate any long-term trends towards environmental degradation.

The differences in species composition recorded around Khowarib in relation to levels of utilization do, however, represent the longer-term impacts of human settlement in this area. There are two main mechanisms whereby species composition may have been affected by humans and animals in and near the settlement; first, the selective removal of species such that those necessary for building and energy requirements are cut while those important for the annual provision of fruits and other valued products are conserved, and second, due to the impact on recruitment caused by the browsing of seedlings by livestock.

It appears that there are a variety of possible sources of future increases in the destructive use of trees. The cutting of trees for building timber is, for example, likely to increase even without a local increase in human population as construction styles change from traditional huts, using only small branches, to more modern structures requiring the trunks and larger branches of trees. The newly established campsite at Khowarib will also continue to require timber for maintenance and firewood for visitors. Finally, the campsite is likely to encourage production of handcraft items, many using wood, in response to tourist demand for these items. Such production can provide the inhabitants of Khowarib with a welcome, if irregular, source of cash income thus compensating for the influx of visitors to land previously used for grazing and the provision of other resources. Many of the household utensils recorded in Table 4 could, for example, be produced for a tourist market (Plate 21).

Unfortunately, however, slow rates of woody biomass production and the fact that many of the larger items carved from wood require the felling of a whole individual, mean that wood carving is a potentially destructive form of resource use. Many of the sought after species are also those which are relatively uncommon; *Acacia montis-usti*, the most commonly utilized species for the carving of household utensils is, for example, restricted in its distribution to montane habitats in this region and was not recorded once in our vegetation samples.

While the production of handcrafts relying on traditional skills and the promotion of income-generating activities is desirable in such marginal regions it is also important that the resource base on which such rural industry depends is not eroded beyond sustainable levels. To avoid the occurrence of this at Khowarib it is advisable that handcraft activities relying on resources with a higher rate of biomass productivity are encouraged. The current encouragement by SRT of the carving of **Makalani** nuts, the kernel of the vegetable ivory palm *Hyphaene petersiana*, is an example of a craft industry which relies on annually replaced biomass (the fruits) and uses a combination of traditional carving techniques and learned skills to produce an item of high appeal to tourists (Plates 22). The sparse distribution of *H. petersiana* in Damaraland, however, requires the importation of the fruits (which could possibly affect recruitment of the palm elsewhere) and the imposition of some form of quality control may be necessary to prevent the lowering of prices caused by flooding of the market with poorly carved items. Increased production of leather items, utilizing skins from local animals as well as those brought in from elsewhere, could also be promoted. A wealth of traditional dying and tanning skills exist but increased use of bark and root material for these purposes may be detrimental to the rarer species if their use increases substantially. The use of annually replaced biomass, such as the leaves of *Combretum imberbe* (!hàà.b) which are used at Khowarib to produce a green leather dye, is, however, a sustainable and traditional alternative. The use of wood grown specifically for the production of handcraft items could also be explored.

Plate 21. Woman using a wooden ≠goub or winnowing bowl, an item which could possibly be marketed at the Khowarib tourist camp.

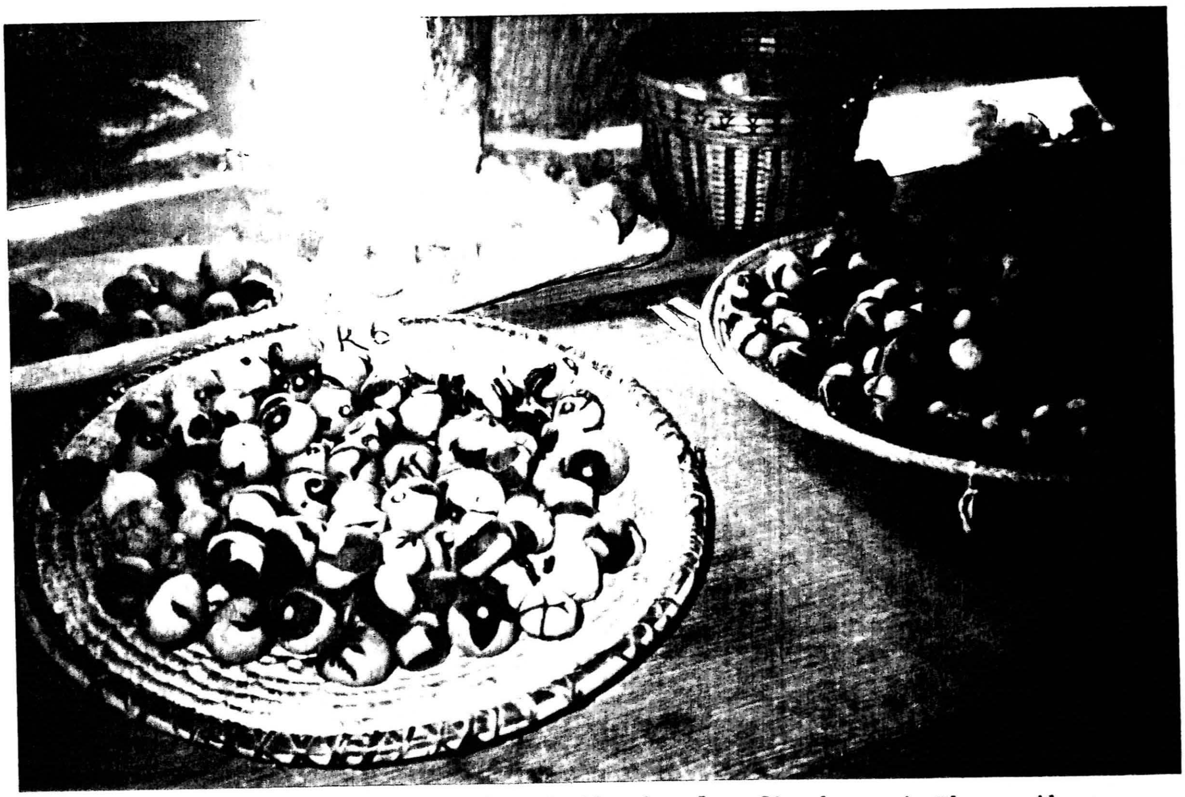


Plate 22. Carved makalani nuts on sale at the handcraft shop at Khowarib camp.

ACKNOWLEDGEMENTS

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APPENDICES

Appendix 1. Questionnaire concerning indigenous woody species utilization conducted at Khowarib settlement.

General

1. Which tribe are you from?
2. How long have you lived at Khowarib?
3. How many people are there in your household? (i.e. how many people eat from the same cooking fire?)
4. What is the composition of your household? (i.e. how many adults, children etc.)

Species use

These questions were repeated for the following tree products:

firewood
building poles
fruit
leaves
bark
roots
exudates

1. Is product x utilized?
2. If yes, which species is preferred and why?
3. For leaves, bark and roots, what are these products utilized for?

4a. Do you experience any problems finding your preferred species and, if yes, what are they?

b. Are these problems worse now than 10 seasons ago and, if yes, why?

4. Do you sell product x and, if yes: a. price
   b. how often
   c. who to
   d. how important is this in generating income?
5. Do you buy product x and, if yes: a. price
   b. how often
   c. who from
6. Who from the household normally collects product x?

7. Where do you collect product x from?
8. Are there any rules or restrictions associated with gathering product x?

Forage

1. Do you have livestock and, if yes, how many of each species do you have?
2. Which tree species are good as forage for your livestock?
3. Which part of these trees do your livestock eat?
4. Are there any particular reasons why these species are good as livestock forage?
5. Are these species easily available for livestock and, if not, why?

Perceptions of campsite

1. Are you involved in anyway with the Khowarib campsite and, if yes, how?
2. Do you think the camp will benefit the Khowarib settlement and, if yes, how?
3. Do you make and sell any handcraft items at the camp and, if yes:
   a. what are these
   b. what materials do you use
   c. what price are they sold for
   d. how often do you sell these items
   e. how important is this for the generation of income?

Appendix 2. Original samples-by-species data matrix for DCA ordination, TWINSPAN classification and CCA applications.

species	samples 01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Acacia albida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	8	5	-	-	-	-	-	-
Acacia erioloba	-	-	-	1	-	-	1	-	-	-	4	-	1	2	-	1	6	4	5	-	-	-	-	-	-
Acacia senegal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2	-	-
Acacia tortilis	26	28	21	24	22	6	12	21	-	-	4	5	5	23	8	1	3	3	1	1	-	-	1	-	-
Boscia albitrunca	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Boscia foetida	-	-	-	1	3	-	-	-	-	1	-	3	-	-	-	-	-	-	-	1	2	2	1	2	1
Catophractes alexandri	-	-	-	-	-	-	-	-	-	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Colophospermum mopane	-	-	9	2	-	-	-	5	22	-	11	5	22	-	12	2	-	-	1	-	2	8	-	-	-
Combretum apiculatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9
Combretum watti	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	7	7	4	-	-	-	-	-	-
Commiphora multijuga	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	3	-
Commiphora pyracanthoides	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Commiphora sp.(/anas)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Commiphora sp.(/aba/hub)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Gossypium triphyllum	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Lycium oxycarpum	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Maerua schinzii	1	-	-	-	1	3	-	1	2	2	-	4	-	2	2	1	-	-	-	-	-	-	-	-	-
Pechuel-loeschea leubnitziae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-
Salvadora persica	-	1	-	-	4	16	17	3	6	-	11	9	2	3	5	22	12	8	9	-	-	-	-	-	-
sorab	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Tamarix usnoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-
Terminalia prunoides	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	12	10	5	9	8	2

Appendix 3. Simpson's diversity index (λ) (From Ludwig and Reynolds, 1988: 90–1)

$$\lambda = \sum_{i=1}^{s} Pi^2$$

where Pi = the proportional abundance of the ith species given by $Pi = \frac{n_i}{N}$ i = 1,2,3,...S

where n_i = the number of individuals of the ith species and N isthe known total number of individuals for all the S (species) in the population.

Simpson's index varies from 0–1 and gives the probability that 2 individuals drawn at random from a population will belong to the same species. If P = high then diversity is low.

λ only applies to finite communities, i.e. those where all members of the population have been counted so that the sample (n) = the population (N). Usually, however, ecologists work with infinite populations because it is impossible to count all the individuals. An unbiased estimator ($\hat{\lambda}$) developed by Simpson is, therefore, used.

$$\hat{\lambda} = \sum_{i=1}^{s} \frac{n_i(n_i-1)}{n(n-1)}$$

The reciprocal of λ yield's Hill's second diversity number N2.

Appendix 4. Original matrix of samples-by-environmental measurements used in Canonical Correspondence Analysis (CCA).

environmental variables	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
NOMINAL VARIABLES																									
Location:																									
plains (1/0)	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
riverine (1/0)	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0
mountain (1/0)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
ORDINAL VARIABLES																									
Distance:																									
plains and riverine (0-2)	0	0	0	0	1	1	1	1	2	2	2	2	1	1	1	2	2	2	2	-	-	-	-	-	-
mountain (0-1)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	1	1	1
Impact measurements:																									
lopping (0-4)	3	3	2	2	0	2	3	2	1	0	0	0	4	0	2	1	0	0	0	3	4	2	1	2	1
browsing (0-4)	3	3	4	3	1	2	1	3	0	0	0	3	3	3	2	0	0	0	2	2	3	3	0	0	0

key for ordinal variables

distance:

plains and riverine
- 0 - in settlement
- 1 - outskirts of settlement
- 2 - 5km from settlement

mountain
- 0 - lower slopes
- 1 - upper slopes

impact measurements: lopping
- 0 - 0
- 1 - class <0.1
- 2 - class 0.2-1
- 3 - class 1.01-1.5
- 4 - class 1.5-2

browsing
- 0 - 0
- 1 - <1m
- 2 - 1-1.1m
- 3 - 1.1-1.5m
- 4 - >1.45m

Lopping classes
0 = none
1 = slight; 1-2 large branches or only small branches removed
2 = moderate; 25-50%
3 = severe; >50%
4 = cut through the main stem/s so that height of the tree is substantially reduced

Appendix 5. Partitioned chi-square species-by sites matrix for plains samples.

cell [rows, columns]	chi-square	probability
partition of chi-square, original matrix:		
[2,2]	0.53	0.4651
[3,2]	43.67	0.0000
[4,2]	0.00	0.9670
[5,2]	1.62	0.2035
[6,2]	0.09	0.7657
[2,3]	77.12	0.0000
[3,3]	6.74	0.0094
[4,3]	37.79	0.0000
[5,3]	4.54	0.0330
[6,3]	4.68	0.0306
partition of chi-square, matrix with rows reversed:		
[5,2]	1.49	0.2211
[4,2]	0.04	0.8367
[3,2]	14.14	0.0002
[2,2]	10.13	0.0015
[1,2]	20.09	0.0000
[5,3]	0.33	0.5644
[4,3]	13.27	0.0003
[3,3]	8.66	0.0033
[2,3]	6.72	0.0095
[1,3]	101.89	0.0000
partition of chi-square, matrix with columns reversed:		
[2,2]	53.31	0.0000
[3,2]	0.94	0.3319
[4,2]	28.53	0.0000
[5,2]	1.53	0.2162
[6,2]	4.13	0.0422
[2,1]	24.35	0.0000
[3,1]	49.46	0.0000
[4,1]	9.27	0.0023
[5,1]	4.63	0.0314
[6,1]	0.64	0.4246
partition of chi-square, matrix with rows and columns reversed:		
[5,2]	0.01	0.9234
[4,2]	10.74	0.0010
[3,2]	19.42	0.0000
[2,2]	14.58	0.0001
[1,2]	43.69	0.0000
[5,1]	1.82	0.1773
[4,1]	2.59	0.1090
[3,1]	3.38	0.0659
[2,1]	2.27	0.1316
[1,1]	78.31	0.0000

Appendix 6. Partition of chi-square species-by-sites matrix for riverine samples.

cell [rows, columns]	chi-square	probability
partition of chi-square, original matrix:		
[2,2]	0.83	0.3615
[3,2]	69.67	0.0000
[4,2]	11.25	0.0008
[5,2]	14.89	0.0001
[6,2]	17.04	0.0000
[7,2]	0.68	0.4084
partition of chi-square, matrix with rows reversed:		
[6,2]	9.51	0.0020
[5,2]	1.80	0.1795
[4,2]	0.01	0.9105
[3,2]	0.04	0.8467
[2,2]	68.51	0.0000
[1,2]	34.50	0.0000

Appendix 7. Partition of chi-square species-by-sites matrix for mountain samples.

cell [rows, columns]	chi-square	probability
Partition of chi-square, original matrix:		
[2,2]	0.03	0.8632
[3,2]	5.92	0.0150
[4,2]	19.99	0.0000
partition of chi-square, matrix with rows reversed:		
[3,2]	22.13	0.0000
[2,2]	3.69	0.0546
[1,2]	0.12	0.7253

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