Study of the Sustainable Utilisation of *Harpagophytum prucumbens* subsp. *procumbens* (Devil's Claw) and *Harpagophytum zeyheri*

An investigation into the optimal harvesting practices including the physiological state of the plant at harvest time, frequency of harvesting and the effect of these parameters on chemical composition.

A project proposal submitted to the RTFP by the National Museum of South Africa in association with the Devil's Claw Range State National Working Group

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1. Introduction

Until now most of the research on the sustainabile utilization of *Hapagophytum procumbens* (Devil's Claw) has revolved around resource inventories or the status of the plant (Strohbach 2001). This has unfortunately resulted in the industry believing that numbers equal sustainability and in the misguided perception that as long as there are enough plants, eradication is impossible. The long-term impact of harvesting on the populations is not currently monitored. A long term study on the biology of Devil's Claw (DC) holds the key to sustainable utilisation.

The problem is to identify the optimal sustainable harvesting regime, not only in terms of mass of dried material per hectare but also in terms of kg of active ingredient per hectare. Alternatively: How can we manage our harvesting practices to ensure maximum sustainable take of active ingredient.

2. Rationale and Motivation

Sustainable management of traditional medicinal plant resources is important, not only because of their value as a potential source of new drugs, but also due to reliance on traditional medicinal plants for health reasons. In South Africa an estimated 75% to 80% of the population still consult the 200 000 to 250 000 traditional healers in the country (SAIRR 2001a; 2001b). Approximately 85% of black South Africans use traditional medicine (Fox 1999) and an increasing number of people of all population groups are turning to such alternatives. The traditional medicine trade in South Africa amounts to between R500 million and R2.3 billion per year (Botha 1998). By the late 1990s in KwaZulu-Natal alone, the total annual volume of plants traded was estimated at 4 400 tons, whilst between 494 and 741 tons of material (valued at R618 to R927 million) are consumed in Mpumalanga annually. At the national level an estimated 20 000 tons of plant material are harvested every year for medicinal purposes (Derwent & Mander 1997). There is also a strong international demand – particularly from Botswana and Namibia – for medicinal plants from South Africa (Pelser 2003).

Where local people are involved, utilisation of these products can contribute to food security, health care and livelihoods of poor rural communities. This potential to improve the quality of life with the sustainable use of an indigenous plant, as well as improving economic development through the involvement of the private sector, is virtually untapped in South Africa. Approximately 350 plant species in the country are regularly, but not necessarily sustainably, harvested for traditional medicinal purposes (Department of Environmental Affairs & Tourism 1999), although the estimate for KwaZulu-Natal province is about 1 000 plant species used. The most popular species are often vulnerable, slow growing and/or slow to reproduce, or species with specific habitat requirements and a limited distribution. The Devil's Claw (DC), *Harpagophytum procumbens* (Burch.) DC. ex Meissn. subspecies *procumbens* (Pedaliaceae) is a perfect example of such a resource that has been over-utilised. One of the biggest threats to DC populations is the use of detrimental harvesting techniques. This is probably driven by an increase in DC demand and the resultant increase in possible income to the harvesters.

Commercial trade of this species clearly focuses on international rather than on domestic markets. The material in trade consists almost entirely of dried and sliced root tubers, which originates almost exclusively from the wild. Processing to retail products does not take place in the range countries themselves, but in Germany and other European countries.

The cultivation of such a species (as an alternative to harvesting in the wild) to meet the current demands is not a simple solution and at present is unlikely to be profitable. Such species should be a priority for *ex situ* conservation and strict protection in core conservation areas.

The IUCN (2000) identified threats to, and the ultimate causes of, the loss of biological diversity. Threats include introduced species, pollution and climate changes, habitat destruction or deterioration and over-harvest of indigenous species and medicinal plant species. Causes include inappropriate land tenure, population change, cost-benefit imbalances, cultural factors, misdirected economic factors and national policy failure. These threats and causes are unfortunately very relevant to the current situation in the DC industry. The loss of biological diversity, in this case DC, in the near future is very possible. An ongoing process of improved management of the resource should achieve sustainability. Management should, furthermore, be adaptive, incorporating monitoring and the ability to modify management to take account of risk and uncertainty (IUCN 2000). The IUCN emphasises the importance of research and analysis. Sustainability needs to be expressed in probabilistic terms *(i.*e. the likelihood of a use being sustainable) in order to carry out scientific analyses. Sustainability should not be seen as a fixed end-point to be reached, but rather as a direction to guide constructive change. The fact that a use may have been sustainable in the past or may be sustainable now is no guarantee that it will remain sustainable in the future. Equally, unsustainable uses may be changed to sustainable uses through a focus on tenure, incentives and adaptive management (IUCN 2000).

Indigenous plant species have many cultural, ethical, ecological and economic values, which can provide incentives for conservation. The likelihood that a use will be sustainable into the future requires consideration of social and economic factors in addition to ecological factors. Where an economic value can be attached to a wild species, perverse incentives removed, and costs and benefits internalised, favourable conditions can be created for investment in the conservation and the sustainable use of the resource, thus reducing the risk of resource degradation, depletion, and habitat conversion. (IUCN 2000; OECD 1994).

DC used to be abundant and considered a problem plant by most farmers. This led to the serious eradication of plant populations by farmers especially in Namibia, from the 1950s to the 1970s. It was not until the medicinal value of DC was widely recognized that large-scale exploitation began. No long-term goals were set to harvest these plants sustainably and due to the rising international demand, levels of exploitation have increased considerably. The very patchy distribution of DC even on favourable soil and in suitable habitats makes it difficult to estimate an overall density of plants per hectare for the total area of distribution. Wild populations of DC normally reach densities of 5–7 plants per hectare, but population sizes of up to 1200 plants/ha may be reached (Hachfeld & Schippmann 2000).

Crosson & Anderson (2002) define sustainable agriculture as a system that indefinitely meets the demands for food and fibre while incurring farm-level economic and environmental costs that societies find acceptable. These costs should meet some broad socially agreed equity criterion. The incomes of poor farm communities must thus rise enough to permit significant improvements in nutrition for all members of the family as well as improved access to health and educational services. Pezzey & Toman (2002) add a normative element (a value judgement) to the standard economic framework. They do this by defining a sustainable, and therefore desirable, path of economic development as one in which expected well-being per capita rises over the long term. They, however, do not foresee that sustainability can be achieved without the interference of governments. Unless greater efforts are made at both national and local government levels to ensure a sustainable supply of indigenous plants to maintain the traditional healing industry, many health, conservation, cultural and economic benefits will be lost (Derwent & Mander 1997).

The International Food Policy Research Institute estimates that between 2002 and 2020, 90% of the increase in local demand for food is expected to be in the less developed countries (Crosson & Anderson 2002). South Africa, as one of these countries, is an area with very limited agricultural potential, especially within the Kalahari, which is approximately the distribution range of DC (Van Wyk, Van Oudshoorn & Gericke 1997).

As a result of the acute scarcity of water in these areas neither dryland crops nor livestock farming can be accepted as solutions to the alleviation of poverty in the Kalahari. The sustainable harvesting of DC can thus become a viable alternative livelihood and can effectively create farm and non-farm employment opportunities to communities in these areas (DEAT 1998; Yeld 1997).

Most if not all of the recent reports on the status of the DC concentrate on the availability of the plant and to a lesser extent on its distribution in Southern Africa (Smith, Goliath, Jefthas, Langenhoven, Letchamo & Simon 2001; Raimondo & Donaldson 2002; Walter, Cole, Kathe, Lovett, & Soldan 2003). Too often data is included that originates from work based on ill-planned experimental layouts that cannot be repeated. Most reports rely heavily on casual observations and on unsound scientific evidence. Research conducted up to this point did not include data from more than one season and therefore lacks reliability. Quite often conclusions are drawn about the possible influence of environmental impacts on plants without ever testing their fitness two or more years after the impact. For the purpose of the proposed study the reproductive activity of individual DC plants and their successful fruit set after a number of post-impact years is regarded as the only measurable means of testing plant fitness (Ruiz, Ward & Saltz 2002).

The current rotation for harvesting is four years. This is based solely on casual observations and experimental work has not been conducted on this aspect. Cycles of harvesting rotation should be tested by monitoring the fitness (reproductive ability and success) of individual plants over a considerable period of time (Ruiz *et al.* 2002).

The people currently involved (those who are benefiting from the DC industry) are conserving DC by replanting the taproot of the harvested plant. The areas around the settlements are divided into four quarters and one such quarter is harvested once in four years (Van der Vyver 2002). Harvesters are not concerned at all about conserving the system as a whole. There is currently no research project under way to determine the optimum harvesting rotation for DC.

From a purely scientific viewpoint it is imperative to study the biology and to determine the optimal harvesting rotation of DC. Although harvesting cannot be stopped before these answers are available, accurate monitoring will at least provide opportunities to achieve certain results. The impacts that harvesting activities have on the environment as a whole (access roads, camps, ablution etc.) have not been determined. By increasing the capacity and awareness of local people to the detrimental effects of their actions on the sustainability of this resource they themselves might later on be in a position to monitor and assess the situation.

The study will be conducted in all three Range States. Specific study sites will be identified after discussions with people who are involved in DC harvesting and/or those responsible in the relevant country’s conservation authorities.

3. Organisation of Work and the Research Team

The project was developed by the Devil's Claw Range State Working Group (DCRSWG) in conjunction with the National Museum of South Africa, which will spearhead and oversee the implementation of the project over a five-year period, starting March 2007. In addition, to providing the essential technical expertise, the National Museum is co-financing the first three years of the project with the RTFP through an annual contribution of R50,000.

The research will be lead by Dr Zietsman, a scientist from the National Museum who will be assisted to undertake laboratory work by experts from the University of the Free State and colleagues at the Museum. Co-investigators from the Range States will assist in undertaking some of the field work in their countries of residence.

The research team will report to the DCRSWG and Head of the National Museum for all technical matters and liaise with the RTFP Programme Management Unit (PMU) on all administrative matters relating to the project.

It is expected that a fair amount of sensitive information will be collected during the course of the project that might be relevant to Intellectual Property and Biodiversity respectively. The research findings shall not be published without prior agreement from the Devil's Claw Range States.

All research protocols (research permits / Material Transfer Agreements etc.) will be adhered to in the Range States where the research is taking place.

4. Research Aims

The overall aim of this project is to determine what the sustainable harvesting rotation for this plant species is by monitoring plant fitness, using phenology as a tool. This will be compared with the concentration of the active substance before and after harvesting. The generally accepted, but not proven, harvesting rotation for this species is four years. This study will therefore have to cover at least the first five years after harvesting impact.

This aim will include the following:

(a) Investigating the possibility of differences in concentration of the active substance between geographically different populations and at different times of the year in order to produce a high quality product with a high concentration of active ingredients.
(b) Determining the concentration of the active substance of a representative sample of at least five populations in all three countries.
(c) A study of the reproductive biology and phenology of these populations and individual plants.
(d) Determining the rate of survival and regrowth of individual plants after harvesting.
(e) Determining the concentration of the active substance in plants recovering from harvesting, annually.
(f) Determine the best harvesting and drying methods.

5. Research Activities and Methods

Activities representing different aspects of this study are:

(a) Fieldwork:

(i) *Identify Study Sites and Collect Voucher Specimens*: Identify with the help of the relevant people in the three Range States at least five potential study sites for experimental work as well as for annual monitoring purposes. One site in each Range State will be used for detailed experimental work. Voucher specimens from each locality (population) will be collected. One of these will be sent to the official herbarium of each relevant Range State as part of the reference collection and to verify identification.

(ii) *Chemical Profiles*: Collect material from as many populations as possible to construct a database of chemical profiles (fingerprints). In so doing the possible existence of chemotypes will be investigated.
Three main study sites (one per Range State):
These populations will be used for most, if not all, of the experimental work regarding sustainable harvesting. Material will be collected on a more regular frequency than at any other experimental population.
- 10 kg wet material (approximately 1 kg dry mass are needed) will be harvested at least four times per year.
- 10 kg wet material (approx. 1 kg dry mass) will be collected of all other populations annually.

(iii) *Sustainability:* Mark individual plants for harvesting and re-harvesting over the entire period of five years to tests the possible change in concentration of active substance. Plants will be harvested using local people. The tubers on the secondary roots will be harvested and the taproot replanted. The following aspects will be investigated:

Experimental (at the three main experimental sites – one per Range State):
Harvesting time:
- Harvest in each of the seasons: summer, autumn, winter, and spring

Concentration of active substance before and after harvesting
- before harvesting
- one week thereafter
- one month later
- 1 year later

(iv) *Harvesting and Drying Methods:* Different harvesting and drying methods that are currently used in the trade will be tested and evaluated to determine the optimum methods. If possible, all available data from previous projects will be included studying these aspects. The change in concentration of the active substance will be measured during the experiment and for each treatment. The following aspects will be investigated:
Harvesting:
- 100% of each individual plant
- 50 % of each individual plant
- Harvest in each of the seasons summer, autumn, winter, and spring

Drying:
- sun dried
- shade dried
- artificially dried

(v) *Biological data:* Methods used during fieldwork to study pollination biology and phenology are standard and well described in the literature.

- Map 50 individuals per population (GIS etc.)
- Monitor the phenology of all mapped individuals per population
- Each mapped individual must be marked to enable long-term monitoring of each individual
- Annually monitor all sites, except for the main study site which should be monitored monthly or every second month after harvesting
- Biology of the species will be studied including
- Reproductive biology
- Seed bank
- Longevity of seeds in natural environment?
- Phenology (tool used to determine fitness)
  - individuals
  - populations
  - reproductive fitness
  - seed viability

(b) Laboratory work:

The Department of Chemistry at the University of the Free State has developed a rapid online enzyme based bio-assay to analyse plant extracts for biological activity. As part of this project a methodology will be developed to identify (LCMS) and elucidate the structures (NMR) of all the active ingredients in Devil's Claw. This methodology will be adapted in collaboration with the co-investigators to develop a rapid routine method to analyse all samples. This will enable us to investigate the influence of harvesting under different experimental conditions and regimes on the chemical composition and bio-activity of Devil's Claw. We will try to identify chemo types that have a higher content of the active ingredient than the average plant collected in the wild for cultivation purposes. We will also develop a "fingerprinting" protocol to determine from which plant population a given sample was collected. This can be used to establish the origin of illegally collected plant material confiscated by the authorities.

(i) *Chemical Analysis*:

This will include aspects such as

- Extract preparation,
- Development of LCMS methods to analyse crude extracts for active ingredients,
- Comparative study to establish the influence of the different experimental harvesting regimes on chemical composition
- Analysis of data to identify specific chemotypes
- Analysis of data and literature study to develop "fingerprinting methods" to identify the origin of samples.

(c) Core conservation areas

Once we have a clear indication of what is going on we will be able to identify and map core conservation areas for this species.

(d) Management Plan

Although this project will mainly focus on certain important industrial aspects, a logical outcome will be to draw up an Environmental Management Plan (EMP) involving all aspects of the industry. The impacts of harvesting activities on the environment as a whole (access roads, camps, ablution etc.) have not been determined. Increasing the awareness of local people to the detrimental effects of their actions on the sustainability of this resource might lead to an improvement in their capacity to monitor and assess the situation.

6. Project Outcomes

This proposed project is expected to achieve a number of outcomes . The main ones being:

(a) Finding a DC population with high concentrations of active ingredient.
By testing the concentration of the active ingredient of as many populations as possible, a viable chemo type might be identified for future commercial use.

(b) Plant fitness indicator.
The study of the basic biology and phenology of DC will result in the identification of an indicator (e.g. fruit set) that can be used to monitor plant fitness.

(c) Post impact survival rate
Different harvesting methods will be investigated to ensure the maximum survival of DC plants.

(d) Harvesting rotation
The effectiveness of a four-year harvesting rotation to return to a state of fitness will be tested scientifically.

(e) Drying methods
The best method of drying, resulting in the highest yield of active ingredient, will be determined.

(f) Environmental Management Plan
Existing information and accumulated data will be used to formulate an environmental management plan. If adopted and implemented this Management Plan will ensure the sustainable utilisation of DC.

7. Project Management, Reporting and Deliverables

The project is jointly funded by the RTFP and the National Museum. The RTFP has in principle approved funding for the first three years of the project as requested. However, the RTFP is committing to providing funding for the first year of the project as per the attached budget at Annex 1.

The lead researcher is responsible for managing the project and is required to report to the DCRSWG Chairperson, the Head of the National Museum and the RTFP PMU as follows:

(a) Inception Report
This report shall be produced using MS Office software and submitted in electronic format to the DCRSWG Chairperson and the Director of the National Museum and copied to the

RTFP PMU within a period of 30 days of project inception. The report will comprise of a work programme for the first year of the project that will identify the activities to be implemented as well as an outline of how and when specific activities will be undertaken. It will also outline the outputs that will be produced as a result of activities implemented and how the outputs produced would benefit members of the DCRSWG, including the National Museum and the DC industry at large.

(b) Quarterly Progress Reports

Thereafter, the Museum through the lead researcher, shall submit quarterly progress reports outlining the activities undertaken, outputs achieved and any impacts realised as a results of the outputs. Each quarterly report should contain a brief financial statement showing the utilisation of disbursed RTFP funds against the agreed budget lines and the remaining unspent funds. Subsequent financial reports should also show cumulated expenditures.

To assist the RTFP PMU to effectively undertake its monitoring and evaluation function aimed at assessing the performance of the project, the outputs and impacts achieved should be quantified where possible.

(c) End of (first) Year Progress Report

This report will provide the implementation status of the project at the time, its achievements and impacts, including a financial statement. This report should be submitted together with a work programme and budget for the second year for the RTFP to approve.

The DCRSWG and the RTFP PMU will review all reports submitted and comment on them within a period of two weeks of receipt. If no comments are received it will be assumed that the relevant group has accepted the report.