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Improving plant conservation interventions through a better understanding of human decision-making

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IMPROVING PLANT CONSERVATION INTERVENTIONS
THROUGH A BETTER UNDERSTANDING OF HUMAN
DECISION-MAKING

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Abstract

The threats to biodiversity are predominantly a result of human behaviour. Conservation interventions, from policy formulation to environmental education, often aim to foster behaviour change. But further research is needed to explore the mechanism of behaviour change in a conservation context and what interventions influence behaviour at different scales - from encouraging institutional adoption of conservation policy, to the determinates of household level decision-making. This is particularly important for plant conservation; with more than a quarter of plants species threatened, urgent action and changes in human behaviour are needed to reduce the continuing loss of plant diversity.

The purpose of my first chapter is to assess the implementation of an international plant conservation policy and identify what factors influence policy uptake. I examined how and why botanic gardens have responded to the first phase of the Global Strategy for Plant Conservation (GSPC). I surveyed 255 botanic gardens in 67 countries and carried out in-depth interviews with five gardens in five countries. I highlighted how wider policy dissemination is needed to increase global implementation, with particular focus on influencing younger global north gardens and older global south gardens. I identified environmental education as a priority by many botanic gardens and show policy targets related to sustainable plant use are often neglected.

I then assessed the effectiveness of education and training programmes implemented by botanic gardens in two different contexts. I first investigated the influence of UK botanic gardens on visitors' conservation knowledge, environmental attitudes and behavioural intentions. I surveyed 1054 people in five botanic gardens in the UK. A botanic garden visit has no impact on conservation knowledge or behavioural intention but environmental attitude was more positive when people were leaving the botanic garden than on entering. I found no relationship between attitudes and behaviour. Secondly I assessed

the effectiveness of targeted training programmes as an approach to encourage behaviour change. I investigated a training programme based at Belize Botanic Garden aiming to encourage cultivation of the over-harvested palm *Chamaedorea ernesti-augusti*. I surveyed 49 untrained and 38 trained individuals and found the training increased technical knowledge and participants' self belief, resulting in uptake of cultivation. However, access to seeds was highlighted as a potential barrier to cultivation. Future training programmes may need to consider practical barriers as well as improving technical knowledge, to encourage adoption of cultivation.

Finally, I evaluated the effectiveness of different policy interventions to encourage behaviour change at the household level. Using data from the cultivation and harvesting of *C. ernesti-augusti*, I created a bioeconomic model to identify policies capable of influencing individual decision-making and interventions likely to encourage people to change from harvesting to cultivation. Although schemes to encourage cultivation maybe an appealing conservation intervention, I have suggested caution in assuming that people will readily adopt cultivation of wild harvested species, or that this would necessarily reduce impacts on wild populations.

My research provides new insight into the predictors of human behaviour. I illustrate that behaviour may not be solely predicted by attitudes and I show additional behavioural determinants, such as knowledge and self-belief are likely to impact changes in behaviour. This thesis provides new knowledge about the factors determining human behavioural responses to conservation interventions. In this thesis I have discussed how different disciplines provide valuable insight into the process of behaviour change and also highlighted the limitations of each approach. I suggested that conservation science would benefit from further combining approaches from different disciplines to improve the implementation and effectiveness of plant conservation interventions.

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Chapter 1

Introduction

Global attempts to stem the rate of biodiversity loss have failed (Butchart et al., 2010) and extinction rates are up to 1000 times higher than background levels (May, 2009). Habitat destruction and degradation, over-exploitation, competition from invasive species and climate change are the proximate drivers of declining biodiversity (Millenium Ecosystem Assessment, 2005). Predominantly, these threats are ultimately due to human activities (Schultz, 2011). Changes in human behaviour are therefore essential to reduce biodiversity loss (Mascia et al., 2003). In this introductory chapter I first outline why an understanding of human behaviour is important for conservation science. I then discuss different frameworks used to predict human behaviour. I introduce botanic gardens as an example of institutions that can potentially be used to promote behaviour change and support plant conservation. Finally, I outline the specific aims, objectives and structure of this thesis.

1.1 Understanding human behaviour is important for conservation science

Biological science provides a theoretical framework for assessing the conservation status of biodiversity, enables the limits of sustainable use to be estimated, provides guidance in the genetic management of small populations, and gives insight into evolutionary processes (Reece et al., 2011). However a biological perspective of conservation problems may not provide adequate information to inform policy and management (Ressurreição et al., forthcoming). Indeed, it is often social factors that determine the success of conservation interventions (Saunders, 2003; Mascia et al., 2003). There is now widespread recognition that conservation biology, a discipline concerned with reducing the loss of biodiversity, is unlikely to be effective with a purely biological approach (Mascia et al.,

2003; Margles et al., 2009; Schultz, 2011). Integrating social science within a biological conservation framework has led to the emergence of conservation science, a broader and interdisciplinary approach to conservation (Balmford and Cowling, 2006). It is argued that an interdisciplinary approach (attempting to integrate different approaches from different disciplines) in conservation, benefits researchers, practitioners and produces more effective conservation outcomes (Margles et al., 2009). Although it is clear that social science needs to be fully integrated into conservation science research, further research that examines the relationships between human behaviour and ecological systems, and how conservation interventions can impact these relationships is much needed (Liu et al., 2007; Milner-Gulland, 2012). Understanding how changes in human behaviour feed back to influence wild populations, habitats and ecosystems, and how behaviour change can be achieved, is critical to measure overall success of conservation interventions (Balmford and Cowling, 2006; Vlek and Steg, 2007). Interventions aiming to foster behavioural change may involve policy formulation and implementation (Fearnside, 2003; Donald et al., 2007), education campaigns and outreach (Trehwella et al., 2005), and provision of alternative livelihoods (Entwistle et al., 2002). However, engendering behavioural change is a complex process (Monroe, 2003; Ajzen et al., 2011) and, conservation interventions may influence human behaviour but may not result in the desired reduction of pressure on natural systems. It can be difficult to quantify the effect of a conservation intervention on human behaviour (Howe et al., 2011) or attribute any changes in human behaviour to variation in natural systems e.g. Infield and Namara (2001), Waylen et al. (2009) and van der Ploeg et al. (2011). Further research is needed to explore what motivates and constrains people's behaviour, and how interventions influence behaviour at different scales - from encouraging adoption of conservation policy, to the determinates of household level decision-making.

1.2 Frameworks for understanding human behaviour

Micro-economics, one of the most widely used approaches for understanding and predicting behaviour, assumes individuals are rational and make choices to maximise their utility (goods, services and events which improve well-being) (Venkatachalam, 2008). This is the so called 'rational choice theory' (McFadden, 1999). Because of difficulties in measuring utility, money is frequently used as a proxy. The assumptions of rational

choice have been central to many studies in agriculture (Edwards-Jones, 2006), fisheries (Knowler, 2002) and the wildlife trade (Van Kooten, 2008). Research using a utility maximization hypothesis can be useful to identify what policy levers may encourage behaviour change (Clayton et al., 1997), however, in reality the assumptions of the rational choice framework are often not met (McFadden, 1999). For example, individuals are assumed to have perfect knowledge about the choices presented and so can accurately weigh up the costs and benefits of each option, choosing the option that maximises utility, yet this is rarely the case (Stiglitz, 1985). Experimental economics also demonstrates how people value gains and losses differently, influencing decision-making and violating the assumption of rational choice (Schoemaker, 1982). It has been suggested that economic models would benefit from incorporating additional factors that may influence behaviour (Persky, 1995). Although there is evidence from social science to support this proposal e.g. Schultz (2011); Ajzen et al. (2011), the majority of studies investigating individual behaviour still assume economically rational individuals (Van Den Bergh et al., 2000).

Social psychology studies how human cognition and behaviour is influenced by the environment, social roles and identities (Koger and Scott, 2007). Over the last two decades social psychologists have developed multiple theoretical models to describe determinates of individual behaviour (Ajzen, 1991; Stern et al., 2006; Fisher et al., 2008). Different proposed models contain a range of social constructs aiming to predict behaviour. One of the simplest models is known as the 'knowledge-deficit model' (Durant et al., 1989; Arcury, 1990) and assumes that increasing knowledge about a topic will influence attitudes, leading to behavioural change (Figure 1.1). In this model, knowledge is treated as a single construct, reflecting the level of accurate information an individual has about a subject (Sturgis and Allum, 2004). Attitude can be described as the tendency of an individual to assess an entity with a degree of favour or disfavour (St John et al., 2010a). This model assumes the provision of information about biodiversity will increase knowledge about biodiversity conservation, influencing environmental attitudes and leading to more environmentally positive behaviour. Environmental education and public awareness campaigns about biodiversity are based on the knowledge-deficit model (often implicitly), and aim to change attitudes and generate support for conservation through information provision (Infield and Namara, 2001;

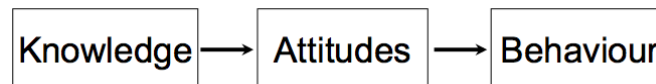


Figure 1.1: The knowledge-deficit model (Durant et al., 1989; Arcury, 1990).

Waylen et al., 2009; van der Ploeg et al., 2011). However, the knowledge-deficit model has been criticised for over-simplifying and misrepresenting the complexity of human behaviour (Brunk, 2006).

An alternative model widely used in social psychology is the theory of planned behaviour (Ajzen, 1991) which includes the following social constructs to predict behaviour (figure 1.2): attitudes (defined as above), perceived behavioural control is the self-assessment of whether a behaviour can be enacted successfully and also the availability of the resources to perform the behaviour, (Conner and Armitage, 2006) and subjective norms is the perceived pressure to perform a specific behaviour, (Rivis and Sheeran, 2003). The theory of planned behaviour has begun to generate interest in conservation science research and has been used to assess how conservation interventions, such as how awareness raising campaigns may influence behaviour. For example, Aipanjiguly et al. (2003) show how an environmental outreach programme was able to increase knowledge and support for the conservation of the Florida manatee. Using the theory of planned behaviour helped to identify the importance of peoples perceptions about social pressure to comply with rules. This led the authors to suggest normative messages highlighting the negative consequences of certain behaviours, such as ignoring boating speed limits where manatees are commonly found could be an effective conservation strategy (Aipanjiguly et al., 2003).

A criticism of social psychology approaches is that socio-demographics such as age, gender and race are often not explicitly included as predictors of behaviour (Beedell and Rehman, 2000). However, it could be argued that these factors are likely to influence social constructs, such as attitudes and are therefore implicitly included. Social psychology offers a range of potentially useful conceptual frameworks for understanding human decision-making in the context of conservation (Edwards-Jones, 2006; Milner-

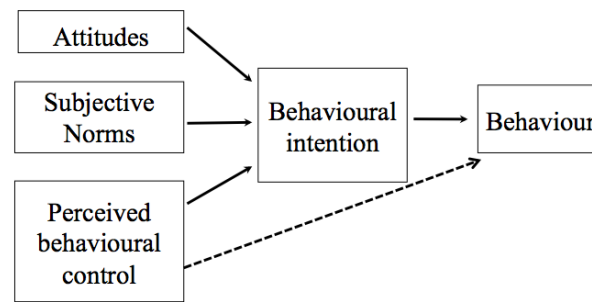


Figure 1.2: The theory of planned behaviour (Ajzen, 1991)

Gulland, 2012). However, many studies assessing human behaviour in conservation do not explicitly use a framework and most focus only on attitudes as a primary predictor of behaviour e.g. Infield and Namara (2001), Waylen et al. (2009) and van der Ploeg et al. (2011). It would be useful to have more examples of studies evaluating the success of conservation interventions, such as environmental education, using a specified behavioural framework. An increased understanding of the mechanisms underlying behaviour change, and the impact of different conservation interventions, could inform and help develop more effective interventions, targeted at changing specific behaviours.

1.3 Changing harvesting behaviour

Changing human behaviour is often the aim of conservation interventions intended to conserve over-harvested populations (Sievanen et al., 2005). Cultivation is one approach proposed as a conservation strategy for over-exploited plant resources (Schippmann et al., 2002; Canter et al., 2005). This is based on the assumption that harvesters will readily change their practices and adopt cultivation, yet there is no research indicating how conservation interventions can impact harvesters' behaviour. Encouraging people to reduce wild harvesting and initiate cultivation requires an understanding of incentives and constraints experienced by wild harvesters and how conservation interventions may influence individual's behaviour.

A theoretical model proposed by Homma (1996) describes the dynamics of plant exploitation and cultivation (Figure 1.3) and suggests cultivation will only be established when wild extraction declines (most likely due to over-exploitation). In this model it is

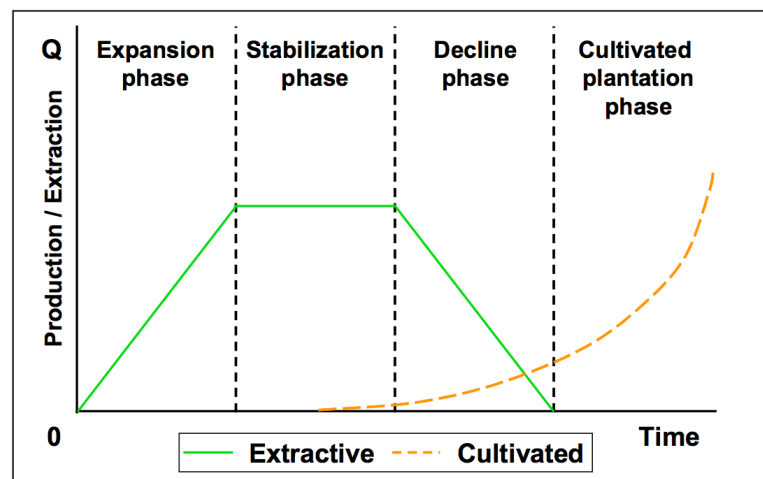


Figure 1.3: Economic dynamics of forest product extraction. As production from wild populations declines because of over-harvesting, cultivation becomes economically more feasible. Ideally cultivation could be established before the decline phase as an approach to conserve the wild population Homma (1996); Newton (2008).

assumed cultivation is unlikely to be a useful conservation strategy, as the wild population will decline considerably before cultivation becomes economically feasible. To be an effective conservation intervention, cultivation should be established before the wild population enters the decline phase of Homma's model. However, extinction risk may continue to increase when wild harvesting ceases if there are additional threats (Newton, 2008). Currently there is little evidence to suggest under which conditions cultivation can reduce pressure on wild populations. It would therefore be useful to explore what policies may encourage people to adopt cultivation and to understand the dynamics of individual's decision-making and how this could impact wild harvested populations.

1.4 The role of botanic gardens in plant conservation

Despite the fundamental ecological role and the considerable economic value of many plant species, plant conservation has received insufficient attention in both policy and practice (Wyse Jackson and Sharrock, 2011). A preliminary assessment indicates nearly a quarter of plant species across the globe are threatened with extinction (Secretariat of the Convention on Biological Diversity, 2010), with threats highest in the tropics (Giam et al., 2010). Inadequate support and funding restricts the efforts of plant conservationists. For example, over 50% of the species listed on the United States Endangered Species Act are plants, yet plants receive less than 5% of the allocated funding for con-

servation in the US (Kennedy, 2008). Even with these challenges there are organisations and institutions aiming to address plant conservation and change human behaviour (e.g. non-governmental *in situ* conservation organisations and statutory conservation bodies).

I specifically focus on botanic gardens as an example of institutions aiming to implement plant conservation interventions. Botanic gardens are generally defined as:

‘Institutions holding documented collections of living plants for the purposes of scientific research, conservation, display and education’

(Wyse Jackson and Sutherland, 2000).

Botanic gardens are frequently cited as a global network at the forefront of plant conservation (Donaldson, 2009; Pennisi, 2010; Blackmore et al., 2011), yet there are few studies critically examining the contribution of botanic gardens to conservation science. There is no single model for botanic gardens to follow, and their activities vary depending on funding sources, capacity, location, governance and size (Pennisi, 2010; Rae, 2011). There are over 2500 botanic gardens around the world and together they receive over 300 million visitors a year (Botanic Gardens Conservation International, 2010b). The diversity of botanic gardens across the globe provides an opportunity to examine how interventions have impacted botanic garden activities and also the effectiveness of this global network in implementing plant conservation interventions. Traditionally botanic gardens have focused on developing the fields of taxonomy and horticulture but have more recently begun to address wider conservation issues, with particular strengths in *ex situ* conservation (although some are also addressing *in situ* conservation) (Chen et al., 2009; Donaldson, 2009). The cultivation of plants and development of living collections is common to all botanic gardens, and with standardised criteria for acquisition of plants, these collections can be used for effective conservation (Rae, 2011).

The Global Strategy for Plant Conservation, the dominant framework guiding plant conservation activities, highlights education and public awareness as a priority activity to increase capacity for plant conservation practice and public support for plant conservation (Secretariat of the Convention on Biological Diversity, 2002). Environmental education, technical training and generating public awareness about biodiversity conservation tend to be prominent activities for botanic gardens and these institutions have the potential to communicate plant conservation to a wide audience (Donaldson, 2009; Crane et al.,

2009). Different gardens have different strategies to fulfil their educational role. Some botanic gardens offer education in the form of accredited adult qualifications (e.g. Biodiversity and Taxonomy of Plants, Master of Science at the Royal Botanic Garden Edinburgh, UK) whereas others focus on public education of both adults and children (e.g. The Eden Project, UK). Although education is within the mission statements of 80% of botanic gardens (Kneebone, 2006), the effectiveness of botanic garden education and the influence on participants or visitors has not been quantitatively assessed. As many botanic gardens are continuously developing new activities and education programmes, it would be useful to assess the relative merits of different approaches (Maunder, 2008). Ultimately botanic gardens need to engage visitors and motivate behavioural change (Havens et al., 2006). Understanding how botanic gardens are coordinating their plant conservation initiatives, how they can influence peoples' behaviour and potentially improve human well-being, could enable this global network to contribute more successfully towards plant conservation (Blackmore et al., 2011).

1.5 Aims and objectives

This thesis aims to determine predictors of human behaviour and explore the factors influencing human decision-making in response to plant conservation interventions. I use botanic gardens throughout the thesis as an example of institutions addressing plant conservation. Drawing upon both quantitative and qualitative methods, I address a number of gaps in the literature: understanding adoption and implementation of plant conservation policy; what motivates and constrains peoples' behaviour in the context of plant conservation; how education and training influences the predictors of behaviour; and whether changes in behaviour result in desired conservation outcomes. My research questions are:

- What factors predict the influence and implementation of a global plant conservation policy?
- Does passive environmental education impact knowledge, attitudes and support for conservation?
- Can training influence behaviour and encourage cultivation of over-harvested species?
- What policies can be used to encourage cultivation and reduce wild harvesting?

1.6 Thesis outline

This thesis is structured as follows:

Chapter 2 examines the extent to which botanic gardens have responded to the first phase of a multilateral conservation policy - the Global Strategy for Plant Conservation (GSPC). I identify characteristics of gardens influenced by the GSPC and highlight GSPC targets most frequently implemented. I suggest increased communication between the GSPC policy actors and additional financial support, particularly focused on gardens in the global south, would support GSPC implementation.

Chapter 3 explores the assumed empirical relationship between knowledge, attitudes and behaviour (the ‘knowledge-deficit model’) and investigates the influence of botanic gardens on visitors’ conservation knowledge, environmental attitudes and behaviour (by measuring support for conservation charities). I present evidence to suggest botanic gardens can influence environmental attitudes and highlight how botanic gardens could further impact visitors’ conservation knowledge, environmental attitudes and behaviour.

Chapter 4 assesses the impact of a botanic garden training programme aiming to encourage cultivation of an over-harvested palm species (xaté – *Chamaedorea ernesti-augusti* H.A. Wendl.) in Belize. Using a social psychology model (the theory of planned behaviour (Ajzen, 1991), I show how the training programme influences predictors of behaviour and how this influences adoption of cultivation. I discuss some of the barriers reducing uptake of cultivation and suggest how these might be overcome.

Chapter 5 investigates the socio-economic characteristics of xaté (*C. ernesti-augusti*) harvesters and estimates current harvest intensity in Belize by cross-border Guatemalan harvesters. This chapter provides the data required to parameterise the model developed in chapter 6.

Chapter 6 uses a bioeconomic model to explore what policy levers and changes in household characteristics can encourage adoption of cultivation. I show under what conditions wild harvesting pressure can be reduced and show that under some circum-

stances cultivation can increase pressure on wild populations. The model is parameterised with the case of *C. ernesti-augusti* harvesting by Guatemalans.

Chapter 7 discusses the relevance of the findings to conservation practice, policy and research. I provide a critique of the research approach adopted, highlight limitations of the research and suggest areas for future research.

Chapter 2

Policy lessons from the uptake of the Global Strategy for Plant Conservation by botanic gardens

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2.1 Introduction

The threats facing biodiversity are global in scale and increasing (Butchart et al., 2010), meaning that internationally coordinated responses are required (Donald et al., 2007). There are now over 20 global or regional conservation treaties in place, each with its own set of policies intending to influence decisions and stimulate change (Davies and Redgwell, 2011). However, policy formulation is only the first step and to have a positive impact on biodiversity, policies must be implemented. Unfortunately, policies are not always effectively implemented (Mosse, 2004), or only aspects that are in line with existing institutional aims and preferences are put into practice, so the policy stimulates little real change (Hill et al., 2011). The lack of robust evaluation of the impact of international conservation policies has been heavily criticized (Ferraro and Pattanayak, 2006). Improved understanding of the implementation of conservation policies by target institutions would be an important step in understanding, and possibly improving, the impact of such policies (Crane et al., 2009).

The Convention on Biological Diversity (CBD) is an international treaty aiming to conserve, sustainably use, and share the benefits arising from biological diversity. It was opened for signature in 1992 and has been signed by 193 Parties (Harrop and Pritchard, 2011). The CBD Secretariat is responsible for supporting the development and implementation of policies to deliver the objectives of the CBD (Siebenhüner, 2007). One programme of the CBD is the Global Strategy for Plant Conservation (GSPC), ratified by the Convention of the Parties in 2002. The GSPC provides a framework for an internationally coordinated approach to plant conservation, which can be adopted and implemented by a variety of institutions (Wyse Jackson and Kennedy, 2009). The ultimate aim of the GSPC is to halt the continuing decline of plant diversity and it contains 16 targets (Table 2.1). It has been suggested that botanic gardens should be leaders in the implementation of the GSPC and many botanic gardens have incorporated the GSPC as a core working policy document (Wyse Jackson and Kennedy, 2009). However, there has been no detailed assessment of the extent to which the GSPC has influenced botanic gardens globally, and the specific challenges to its wider adoption. We are now entering into the second phase of the GSPC: the revised targets for the period 2011-2020 were ratified at the 10th Conference of the Parties in Nagoya (Secretariat of the Convention on Biological Diversity, 2011a).

Policy implementation research often focuses on America and the United Kingdom. Studies investigating policy implementation in both the global north and global south concurrently are much needed (O'Toole Jr, 2000; Behague et al., 2009). Such global understanding is particularly important for policies formulated under multilateral agreements, such as those established by the CBD (Siebenhüner, 2007). In this chapter I critically examine the implementation of the first phase of the GSPC by botanic gardens. I first investigate the influence of the GSPC on botanic gardens and the factors that predict integration of the policy into botanic garden activities. In this study I define 'influence' as a change in the activities of the botanic garden. I then investigate the aspects of the GSPC that are being more commonly implemented. Finally, I look at what, if anything, could help promote the GSPC to target institutions, potentially resulting in increased implementation.

Table 2.1: The 2010 Global Strategy for Plant Conservation targets

Target	Convention on Biological Diversity Text
1	A widely accessible list of known plant species as a step towards a complete world flora
2	A preliminary assessment of the conservation status of all known plant species, at national, regional and international levels
3	Development of models with protocols for plant conservation and sustainable use, based on research and practical experience
4	At least 10% of each of the world's ecological regions effectively conserved
5	Protection of 50% of the most important areas for plant diversity assured
6	At least 30% of production lands managed consistent with the conservation of plant diversity
7	60% of the world's threatened species conserved in situ
8	60% of threatened plant species in accessible ex situ collections, preferably in the country of origin and 10% of them included in recovery and restoration programmes
9	70% of the genetic diversity of crops and other major socio-economical valuable plant species conserved and associated indigenous and local knowledge maintained
10	Management plans in place for at least 100 major alien species that threaten plants, plant communities and associated habitats and ecosystems
11	No species of wild flora endangered by international trade
12	30% of plant-based products derived from sources that are sustainably managed
13	The decline of plant resources, and associated indigenous and local knowledge, innovations and practices that support sustainable livelihoods, local food security and health care, halted
14	The importance of plant diversity and the need for its conservation incorporated into communication, educational and public-awareness programmes
15	The number of trained people working with appropriate facilities in plant conservation increased
16	Networks for plant conservation activities established or strengthened at national, regional and international levels

2.2 Methods

2.2.1 Quantitative data collection

I developed an online survey using Survey Monkey (www.surveymonkey.com, Appendix A) and carried out a pilot study with 10 botanic gardens before refining and improving the questions. The survey was then distributed to all members of Botanic Gardens Conservation International (BGCI) by e-mail ($n = 505$). BGCI is a global network of botanic gardens aiming to mobilise botanic gardens in securing plant diversity and to support plant conservation (Botanic Gardens Conservation International, 2010a). Botanic gardens were encouraged to respond through articles in BG Journal and

Kew On Course Magazine, and presentations at the 4th Global Botanic Garden congress 2010. I also sent the survey to contacts in botanic gardens that are not BGCI members ($n = 124$). The survey was sent to either the Director or Curator of the botanic garden. I asked this individual to complete the survey or to pass the survey on to a member of staff with suitable knowledge about the activities of the Garden and the GSPC. The survey was translated and available in five languages (English, Spanish, French, Russian and Chinese). When requested, the survey was also provided in paper format or e-mailed as a Microsoft Word document. These data were analysed and models fitted using R 2.11.1 (R Foundation for Statistical Computing, 2009). The age of the garden and regional location were compared to those of all botanic gardens using the Garden Search database, collated by Botanic Gardens Conservation International (2010a).

2.2.2 Model fitting

To assess the influence of the GSPC on the botanic garden activities, I used a proportional odds logistic model (McCullagh, 1980). The response variable was a three level ordered factor measuring GSPC influence - very, fairly or not at all influential. Explanatory variables included were BGCI membership (Yes/No), Global region (North/South), age of the botanic garden, budget and primary funding source (Private, University, Government, other). The variable 'budget' was converted to the purchasing power parity (ppp) of the country, using data from the Center for International Comparisons at the University of Pennsylvania (Heston et al., 2009). I fitted a set of 17 candidate models to the survey data using the 'polr' function in the R MASS package (Venables and Ripley, 2002). The most complex model included five explanatory variables and all two-way interactions. Candidate models were compared using Akaike's Information Criterion (AIC), where the best fitting model has the smallest AIC (Burnham and Anderson, 2002).

To investigate the implementation of the 16 GSPC targets I fitted a mixed effects model to the data, using the lmer package (Bates et al 2008). The response variable was binary and the botanic garden was specified as the random effect. The most complex model included all two-way interactions between predictors and there was a further 20 simplified candidate models. The explanatory variables tested were the targets implemented

by each garden, budget, BGCI membership, primary funding source and number of staff. The best fitting model was selected using AIC.

2.2.3 Qualitative data collection

To understand individual experiences of integrating the GSPC into botanic garden activities I conducted semi-structured interviews with seven people from five gardens in five countries (United Kingdom, Australia, Bangladesh, South Africa and USA). The case study gardens chosen cover both global north and global south countries and also gardens that stated the GSPC had, and had not, influenced their activities (Table 2.2). I carried out all interviews either in person or over the telephone and recorded each using a digital dictaphone. A semi-structured approach was used, with a list of topics to guide the conversations. The topics were: background to the botanic garden, personal experience of the GSPC, influence of the GSPC on conservation at the botanic garden, and feeding back information about the GSPC. Interviews lasted between 25 minutes and 60 minutes and were carried out between October 2010 and March 2011. Key statements, that were relevant to the four topics outlined for discussion, were extracted from the audio files and transcribed.

Table 2.2: Case study botanic gardens surveyed using semi-structured interviews

	Global north			Global south		
Influenced by GSPC	Treborth	Botanic	Garden,	Rajshahi University Botanic Garden, Bangladesh		
	UK					
	Royal	Tasmanian	Botanic			
	Garden,	Australia				
Not influenced by GSPC	Kruckeberg Botanic Garden, USA			Succulent	Karoo	National
				Botanical	Garden,	South
				Africa		

2.3 Results

2.3.1 The sample of responding botanic gardens

A total of 255 botanic gardens, from 67 countries, responded to the survey. The responses included 184 BGCI members and 71 non-BGCI members (Appendix A, table

A.1). The comparisons between age and region indicate the sample provides a good representation of the overall population of botanic gardens globally. Global north botanic gardens tended to have the largest budgets; 60% of global north responses indicated a budget greater than US \$250,000, whereas the majority (58%) of global south gardens reported budgets less than US \$250,000. 92% of the botanic gardens surveyed stated they were aware of the GSPC. 80% of the gardens stating they were not aware of the GSPC reported they had at least one conservation activity in their garden.

2.3.2 The influence of the GSPC on botanic gardens and the factors predicting influence on garden activities

From all botanic gardens included in the study, 81% indicated that their activities have been influenced by the GSPC (54% very influenced and 27% fairly influenced). Most of the semi-structured respondents suggest the GSPC is very important in guiding their activities.

Part of our role as a botanic garden is conservation, and we use the GSPC to focus our efforts

(Deputy Director, Collections and Research, Tasmania RBG)

From my point of view, it wouldn't be exaggerating to say it [the GSPC] is the raison d'être, it's the blue print for what we do

(Curator, Treborth Botanic Garden)

We've developed a plant conservation policy built around the GSPC and around local conservation priorities

(Horticultural Collections Manager, Tasmania RBG)

We initiated a discussion earlier this week just to look at the [2011-2020] targets, to see what we thought about them and how we thought they could be reached, which were achievable and how we were operating currently against them. It was very valuable to sit down and talk about what we are doing

(Deputy Director, Collections and Research, Tasmania RBG)

One respondent suggested that the GSPC has helped to gain support for plant conservation initiatives in their botanic garden.

The GSPC helps to motivate our bureaucrats to look more at plant conservation
(Prof. of Botany, Rajshahi University Botanic Garden)

The fact that not all gardens are influenced by the GSPC is supported by the interviews. For example in one garden, senior staff are not aware of its existence.

To be honest, this is the first time I have heard of it [the GSPC]
(Collections Manager, Succulent Karoo National Botanical Garden)

For the assessment of GSPC influence on botanic garden activities the best model (based on the lowest AIC) is presented in Table 2.3. Parameters included in this model show that BGCI membership, global north/global south, age, budget and two interaction terms are important predictors of the influence of the GSPC upon botanic garden activities (distribution of predictors variables presented in Appendix A). The coefficient for global north and south countries indicates that global south countries are more likely to be influenced by the GSPC. The model suggests that age is an important predictor of whether the garden is influenced by the GSPC. The interaction between the main effects, age and global region, is significant ($p < 0.05$) suggesting that older botanic gardens in the global north are mostly likely to find the GSPC very influential on their activities, whereas younger botanic gardens in the global south are more likely to find the GSPC very influential (Figure 2.1). The interviews shed more light on reasons why some gardens are more influenced by the GSPC than others. One respondent highlighted the importance of personal contact with other botanic gardens and Internet access in learning about the GSPC.

I learnt about the GSPC by e-mail from Kew and then looked more on [the] internet
(Prof. of Botany, Rajshahi University Botanic Garden)

2.3.3 Which aspects of the GPSC are being more commonly implemented and why?

Figure 2.2 shows the targets that are most likely to be implemented by botanic gardens. In this coefficient plot, estimates that are right of the dashed line are more frequently implemented than target one (target one is taken as the baseline estimate). The coefficient estimates left of the dashed line are less implemented than target one.

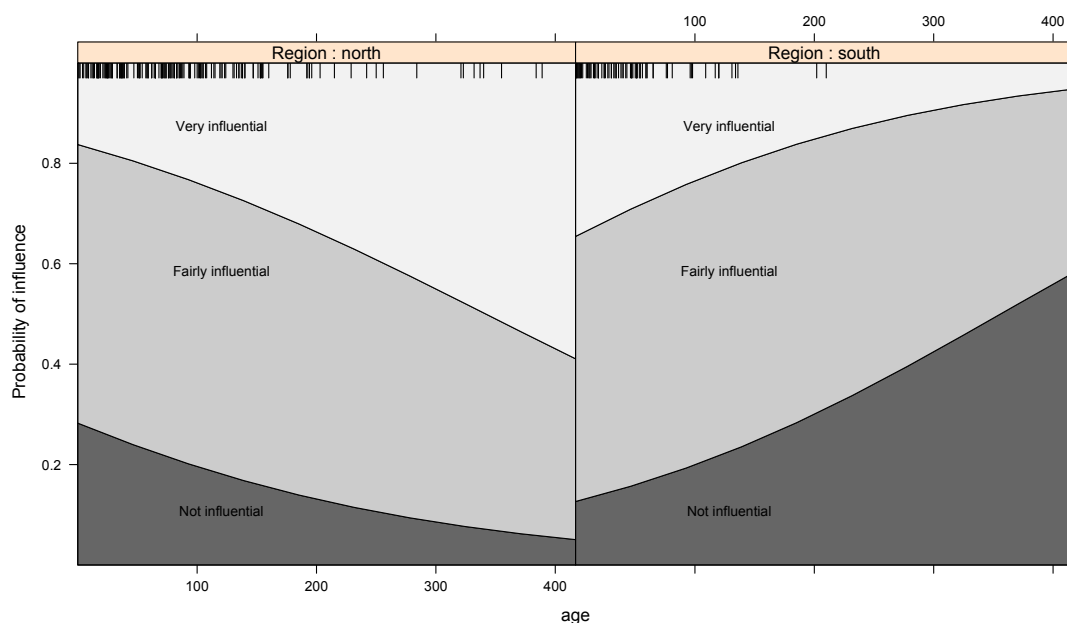


Figure 2.1: Stacked effects display of the proportional odds regression showing the probability of influence of the Global Strategy for Plant Conservation on botanic gardens in global north and global south countries as a function of age. Threshold value between not influential and fairly influential is -0.51 ± 0.41 1 standard error. Threshold value between fairly influential and very influential is 2.05 ± 0.43 1 standard error. Rug plot shows the ages of the individual gardens surveyed.

Table 2.3: The influence of the GSPC on botanic garden activities, summary of the most supported model

Variable	Coefficient	S. Erro	P Value
BGCI Member	0.51	0.36	$\ll 0.01$
North/South-south	1.69	0.55	$\ll 0.01$
Age	0.004	0.001	$\ll 0.01$
Budget (PPP corrected)	0.012	0.07	$\ll 0.01$
BGCI:North/South	-0.97	0.56	0.08
North/South:age	-0.010	0.005	$\ll 0.05$

Target 14 (The importance of plant diversity and the need for its conservation incorporated into communication, educational and public-awareness programmes) is the most frequently implemented target. Appendix A, figure A.2 displays the raw data showing implementation of the 16 GSPC targets.

We can actually contribute to the majority of these [GSPC targets] albeit on a small scale but as a University garden, education is a priority

(Curator, Treborth Botanic Garden)

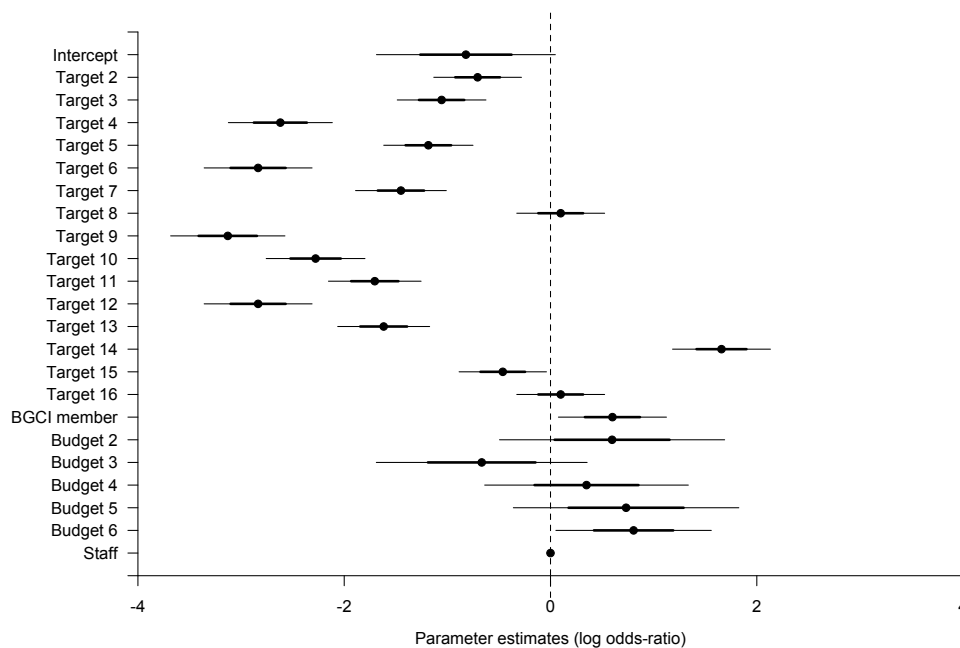


Figure 2.2: Parameter coefficient values for the mixed effects model predicting implementation of Global Strategy for Plant Conservation targets. The dashed vertical line illustrates the predicted mean parameter estimate. The central circles are the mean coefficient estimate for each parameter. Thick lines indicate 1 standard error and thin lines indicate 2 standard errors. Estimates right of the dashed line are more frequently implemented than target one (target one is taken as the baseline estimate)

Targets 6, 9 and 12, all related to sustainable use of plant resources and conservation of indigenous knowledge, are the least implemented of all the targets. *Ex situ* conservation (Target 8: 60% of threatened plant species in accessible ex situ collections) is also one of the most implemented of the GSPC targets.

From a horticulture perspective we're not just growing plants for display purpose, they [the plants] are now involved in the conservation work
(Horticultural Collections Manager, Tasmania RBG)

Gardens that are BGCi members are more likely to be implementing the GSPC targets (Figure 2.2). This may be because BGCi membership is a mechanism of disseminating information about the GSPC, as was suggested by interviews with gardens.

The Garden used to be a member of BGCi, which is how we heard of it [the GSPC]
(Director Kruckeberg Botanic Garden)

The size of a garden's budget is also important: gardens with larger budgets report that they are implementing more GSPC targets than gardens with lower budgets. Again this is supported by the qualitative data as gardens themselves often cite lack of financial resources as an important limitation on their ability to implement GSPC targets.

I realised I can do something for the GPSC and it is within my capacity....but our financial resources are very limited

(Prof. of Botany, Rajshahi University Botanic Garden)

We are a really small place and have limited resources to get involved, this is the main reason we are not involved in it

(Director Kruckeberg Botanic Garden)

2.3.4 What could improve the influence of the GSPC on gardens?

One of the problems cited by the gardens was the lack of a feedback mechanism between the gardens and the policy makers to allow them to communicate successes and failures of GSPC implementation to the CBD secretariat.

We've attended a few conferences and workshops but other than that, we don't really feedback our activities

(Curator, Treborth Botanic Garden)

There is no system for us to feedback what we are doing. People are working in isolation. That could be improved. Create a network, this is most important

(Prof. of Botany, Rajshahi University Botanic Garden)

However, such feedback processes need to be carefully designed to avoid over burdening the botanic gardens.

If there was nice simple process, like a survey or something, we would have the time to report back, it depends on the mechanism really

(Deputy Director, Collections and Research, Tasmania RBG)

2.4 Discussion

Evaluation of where and how a biodiversity policy has or has not been implemented is valuable as such information could be used to improve the design and communication of future policies to increase their conservation impact (Siebenhüner, 2002). In this chapter I have investigated the factors restricting the influence and implementation of a particular conservation policy, with the aim that this understanding can be used to improve future policy making processes.

2.4.1 Has the GSPC influenced botanic garden activities?

Ensuring implementing institutions are aware of a policy is clearly a necessity for effective implementation. One botanic garden interviewed indicated the GSPC had no influence on their conservation activities because they had not heard of the policy. My results indicate that gardens not aware of the GSPC are still carrying out conservation activities. Individual garden policies and strategies may already have conservation as an objective and so even with no knowledge of the GSPC these gardens are contributing to the GSPC targets. However, over 90% of the gardens included in the study are aware of the GSPC, indicating that the existence of the policy has been well disseminated. However, effective dissemination is about more than ensuring target institutions have heard of a policy but should provide guidance on interpreting the text and putting it into action (Hill, 2003). Accessible and concise information about how institutions can respond to a policy is important and, in the context of the GSPC, may result in increased implementation. The recent development of a concise '2011-2020 GSPC factsheet' (IUCN, 2011) should go some way to addressing the need for wider communication about the aims of the GSPC and possible responses by botanic gardens.

Approaches to promoting policy implementation have generally been developed in a western context (O'Toole Jr, 2000; Behague et al., 2009), perhaps with relatively little consideration given to differences between the global north and global south. I found strong evidence for a difference between the north and south, with younger gardens in the global south and older gardens in the global north the most likely to be influenced (garden activities impacted) by the GSPC. I suggest that these differences should be taken into account by the CBD when designing guidelines for the second GSPC phase.

2.4.2 What factors predict GSPC implementation by botanic gardens?

Aspects of policy in line with the existing abilities of institutions and other agendas are the most likely to be implemented (Spillane et al., 2002). This is logical as the barriers to such implementation are lower than for instigating entirely new activities. However if biodiversity policies result in little real change or new activities then their value is limited.

I have individually assessed the relative contribution of botanic gardens in the implementation of the 16 GSPC targets. My results show the GSPC targets most implemented by botanic gardens are those related to horticulture and education. These areas are the traditional strengths of botanic gardens (Ali and Trivedi, 2011). Target 14 (the importance of plant diversity and the need for its conservation incorporated into communication, educational and public-awareness programmes), target 8 (60% of threatened plant species in accessible *ex situ* collections, preferably in the country of origin and 10% of them included in recovery and restoration programmes) and target 16 (networks for plant conservation activities established or strengthened at national, regional and international levels) are the three targets most frequently implemented by botanic gardens. These targets can be implemented using the existing capacity and expertise held by botanic gardens. It is feasible that without the GSPC, botanic gardens would still be active in these fields of conservation. However, my interviews suggest that some botanic gardens have been encouraged to expand existing programmes in areas such as *ex situ* conservation and education.

Targets 6, 9 and 12 (all related to sustainable use of plant resources and conservation of indigenous knowledge) are the least implemented of the GSPC targets. This supports previous research indicating targets relating to conservation of socio-economic species and sustainable use of plants are the least implemented of the GSPC targets (Paton and Nic Lughadha, 2011), perhaps because these three targets are not considered traditional activities of botanic gardens (Donaldson, 2009). Other institutions and stakeholders are also involved in implementation of the GSPC at a national, regional and international level. However, it has been argued that botanic gardens could also address the sustainable use of plant resources to remain relevant to national agendas, particularly where

governments are focusing on the sustainable use of natural resources as a contribution to poverty alleviation (Pennisi, 2010; Simiyu, S, 2010). The expertise within botanic gardens could be applied to the GSPC targets relating to sustainable use of plants. For example, Aburi Botanic garden in Ghana established a project to promote conservation of over-harvested species through cultivation (United Nations Environment Programme, 2011). Initiatives such as these, using existing abilities and strengths, could enable botanic gardens to extend their traditional agendas and implement a wider array of the GSPC targets. However, financial resources may limit implementation of new programmes and funding was identified as an important barrier to implementation of the GSPC. Botanic gardens with smaller budgets are generally less likely to implement the GSPC targets. This finding was supported by the interviews where staff highlighted funding as a primary limitation to their implementation of the GSPC targets. Policy makers should consider the capacity of the institutions responsible for implementation and ensure adequate resources are available (Irvine, 2009).

My results also indicate that gardens that are members of the global botanic garden network (BGCI) are more likely to implement the GSPC than non-BGCI members. This result could be because BGCI are a conservation-orientated organisation and distribute all relevant GSPC material to members. Gardens within the BGCI network receive specific information about the GSPC and how gardens can respond to it. Such informal communication is often a key component of collective learning (Siebenhüner, 2002). In the context of biodiversity policy implementation, drawing upon the experiences of others could help the implementers become more effective. Interaction between colleagues discussing a policy can have greater impact on how it is interpreted and used than the policy text itself or guidelines provided (Kirby, 2002). GSPC policy makers should therefore consider creating opportunities for the implementers to network and discuss experiences of implementation, which may ultimately lead to increased biodiversity conservation activities.

2.4.3 What changes could improve implementation of policy?

My results indicate regional context and age are important factors to consider when promoting the GSPC. Identifying the institutions that have not been influenced by a policy

can help to tailor future promotion of a policy, directed at institutions that have not yet been influenced (Sanderson, 2002; Schofield, 2004). This result may be of use to policy makers as the North-South difference indicates these regions are influenced differently. We suggest that dissemination of the GSPC 2011-2020 includes guidelines and suggestions on how institutions can respond and implement the policy. This could help botanic garden staff understand the relevance of the GSPC to their own garden's mission and perhaps encourage aspects of the GSPC to be integrated into their activities. Particular focus could be given to influencing younger global north gardens and older global south gardens, who may have heard of the policy but are the least likely to be implementing it.

Tools that allow policy makers and implementers to share knowledge, providing opportunities to learn from shared experiences, can reduce the gap between policy and practice (Fazey et al., 2005; Willems, 2007) and potentially foster more effective implementation. In the case of the GSPC, a flexible coordination mechanism has been put in place by the CBD Secretariat, providing one channel for feedback between implementers and policy makers. The Global Partnership for Plant Conservation (GPPC), an informal grouping of organisations dedicated to GSPC implementation, including, but not limited to, botanic gardens and their networks, is part of the flexible coordination mechanism. An opportunity for feedback is also provided through the CBD national reports. All CBD Parties are required to report on progress towards the GSPC targets as part of their reporting to the CBD Secretariat. While the larger and more influential botanic gardens play an active role in the GPPC and contribute to national CBD reports, it is clear that smaller gardens are less well represented in these processes. The in-depth review of progress towards the GSPC that was carried out by the CBD Secretariat in 2008 and reported in the Plant Conservation Report (Secretariat of the Convention on Biological Diversity, 2011a) noted the need for greater engagement with all stakeholders at the national level to enhance implementation. Furthermore, while in some countries (e.g. Belgium, Canada and Ireland) botanic gardens provide the GSPC focal point, in other countries botanic garden activities are overlooked in national CBD reports. In such cases, it is clear that linkages between national policy makers and implementing agencies such as botanic gardens, need to be improved. The CBD Secretariat has recently commissioned the development of toolkit that will aim to enhance national, sub-regional

and regional implementation of the GSPC (Secretariat of the Convention on Biological Diversity, 2011b) by providing accessible information to support GSPC implementers. I recommend that the toolkit include a system for all organisations implementing the GSPC to communicate with others similarly involved and to feedback their experiences to the policy formulators, i.e. CBD Parties. This could take the form of an interactive online forum whereby individuals could add examples of projects addressing the GSPC targets and the outcomes of these projects. Improved communication through the toolkit may also encourage botanic gardens to communicate and build links with organisations outside the botanic garden community, providing a chance to discuss GSPC implementation by a variety of institutions. Additionally, a system for implementers to report on their contribution in implementing specific targets could help with measuring and monitoring progress made towards meeting the GSPC targets globally.

2.5 Conclusion

Policies such as the GSPC are unlikely to change the direction of participating institutions overnight; aspects that are inline with existing institutional capacity and agenda will be the areas most likely to be implemented. However if a policy is effectively communicated, adequate resources are available and opportunities provided for institutions to learn from one another, changes can occur over time. To widen the influence of the second phase of the GSPC, I suggest dissemination should include guidelines and ideas to support implementation. Particular focus may be given to younger global north gardens and older global south gardens, as these are currently the least influenced by the GSPC. Mobilising gardens that have either not heard of, or yet incorporated aspects of the GSPC into their work, could potentially lead to wider implementation. The next phase of the GSPC provides a second opportunity for CBD parties to increase and improve the global effort towards halting the decline in plant diversity. Increased communication between the GSPC policy actors and additional financial support, particularly focused on gardens in the global south, will help ensure the potential of the GSPC is realised.

Chapter 3

The impact of botanic gardens on visitors' knowledge, attitudes and support for conservation

3.1 Introduction

The threats to biodiversity are predominantly a result of human activities (Schultz, 2011). Global targets to reduce the rate of biodiversity loss globally have been missed (Butchart et al., 2010) so changes in human behaviour are urgently needed (Mascia et al., 2003). Environmental education is often promoted as a way of increasing knowledge about biodiversity and biodiversity loss and thus improving environmental attitudes and support for conservation (Dunlap et al., 2000; Salafsky et al., 2002). This progression from knowledge (the level of accurate information) to attitudes and behaviour is described as the 'knowledge-deficit model' (Durant et al., 1989; Arcury, 1990; Kaiser et al., 1999). Some studies using the knowledge-deficit model show a strong linear relationship between environmental knowledge and attitudes (Sturgis and Allum, 2004; Allum et al., 2008). However, a range of factors besides knowledge and attitudes can also influence behaviour, including religious beliefs (Nisbet, 2005) and feelings of responsibility (Conner and Armitage, 2006). Consequently, the knowledge-deficit model has received criticism for its simplification of the complex relationships between knowledge, attitudes and behaviour (Brunk, 2006; Heberlein, 2012). If environmental education aims to generate support for conservation through changing environmental attitudes, a greater understanding of how information provision can influence knowledge and the relationships between knowledge, attitudes and behaviour is needed (Potter, 2009; Hart and Nolan, 1999).

Attitude is the tendency of an individual to assess an entity with a degree of favour or disfavour (St John et al., 2010a). The New Ecological Paradigm (NEP) is the most widely used approach for measuring general environmental attitude (Dunlap and Van Liere,

2008), i.e. ‘the degree to which people are aware of problems regarding the environment and support efforts to solve them and/or indicate a willingness to contribute personally to their solution’ (Dunlap et al., 2000). The respondent expresses how strongly they agree or disagree with 15 statements about the environment, with higher scores indicating a more positive environmental attitude (Dunlap and Van Liere, 2008). Some studies using the NEP have found a positive relationship between attitudes and ecological behaviours (Arcury, 1990; Kaiser et al., 1999). Whether increasing positive environmental attitudes result in behaviour change can be very challenging to study, as behaviours are often difficult to observe. The amount of money that people are prepared to give towards a cause is one way of measuring behavioural intentions (stated intentions to perform an act at a later date) (Bateman et al., 2002). Some studies suggest hypothetical donations to conservation charities (Howe et al., 2011) and willingness to pay for species conservation (Kotchen and Reiling, 2000) are useful tools for assessing an individual’s support for conservation activities, and provide an indication of an individuals intended behaviour.

With over 2500 botanic gardens across the globe, attracting an estimated 300 million visitors annually (Wyse Jackson and Sharrock, 2011), botanic gardens have a clear opportunity to influence the ecological knowledge, environmental attitudes and behaviour of a large audience (Maunder, 2008). Target 14 of the Global Strategy for Plant Conservation (GSPC) outlines the importance of raising awareness and developing education programmes about plant conservation. Many botanic gardens list public education as one of their most important activities (Williams et al., 2012a), aiming to generate support for conservation efforts (Havens et al., 2006). Education activities in collections-based institutions, such as botanic gardens and zoos, can take different forms, with many gardens coordinating workshops, guided tours and activities for the public to learn about the natural world (Kneebone, 2006). Visitors that do not participate in these education activities are still likely to be exposed to information about the environment and conservation through informal exposure to signs and exhibits (Weiler and Smith, 2009). Studies have suggested that informal education provided by zoos can have a positive influence on knowledge (Penn, 2008) whereas other studies report zoo education has little impact on peoples’ knowledge and attitudes (Balmford et al., 2007). He and Chen (2012) show botanic garden visitor centres can positively influence enjoyment

and potentially increase visitors' botanical knowledge. However, the authors conclude that the influence of botanic gardens on visitors' knowledge requires further investigation. Indeed, little is known about how much knowledge botanic garden visitors acquire from their visits and how this affects environmental attitudes and support for conservation. Here I assess how ecological knowledge relates to attitudes (measured using the New Ecological Paradigm), whether botanic gardens can increase visitors' ecological knowledge and influence their environmental attitudes. I then examine the relationship between environmental attitude and behavioural intention, as measured by peoples' prioritisation of conservation charities and whether behavioural intention is influenced by a botanic garden visit.

3.2 Methods

3.2.1 Sampling Strategy

Seventeen UK botanic gardens responded to a survey about their involvement in the Global Strategy for Plant Conservation (Williams et al., 2012a). From this survey, gardens that had budgets of more than \$500,000 and had listed education as a primary aim were selected for the current research. Five (out of nine) botanic gardens were willing to be involved in a further study (Birmingham Botanical Gardens and Glasshouses, The Eden Project, Royal Botanic Garden, Kew, Cambridge University Botanic Garden and Royal Botanic Garden, Edinburgh). An *a priori* power analysis determines the sample size needed when the level of statistical power β , the effect size, ES and the significance level, α are specified (Cohen, 1992), using the following equation

$$n = \frac{s^2(1 - \beta)}{\alpha ES} \quad (3.1)$$

Using pilot study data collected from Ness Botanic Garden ($n = 50$) to specify s^2 , I carried out a power analysis to determine the sample size needed where $\beta = 0.8$, $ES = 0.3$ and $\alpha = 0.05$. This indicated 200 responses (100 arriving and 100 leaving) per garden were needed to have adequate statistical power.

Interviewers stood next to the main entrance of each botanic garden from 10:00 to 13:00 to collect responses from adults arriving. From 14:00 to 17:00 interviewers stood next the main exit of the botanic garden to collect responses from individuals leaving. For

people leaving the botanic garden, I did not survey them if they had been in the botanic garden less than one hour and included these people in our estimate of non-responses, along with individuals declining to participate. Respondents that completed the survey on arrival were not questioned again when leaving. All interviews were carried out by the lead author and three, trained research assistants between June and July 2010.

3.2.2 Questionnaire Design

My questionnaire assessed visitor ecological knowledge, environmental attitude and the degree to which visitors prioritise conservation activities in relation to other charitable causes (Appendix B). I collected socio-demographic data (age, gender, level of education, frequency of visits to the garden) for all respondents. I define ecological knowledge as ‘a general knowledge of facts, figures, concepts and relationships concerning the natural environment and major ecosystems’ (Kotchen and Reiling, 2000; Fryxell and Lo, 2003; Mostafa, 2007). Eight items were used to measure ecological knowledge and were based on the information available in all five botanic gardens. These questions were chosen to reflect different measures of ecological knowledge as suggested by Arcury (1990), including general ecological knowledge, current events in conservation and specific examples of threats and threatened plants (for full survey see Appendix B). The BGCI Botanic Garden database, the IUCN Red List and the list of Biodiversity Hotspots were used to provide objective measures as a basis for assessing answers. Where an unclear response was given respondents were asked ‘can you be more specific?’ with no further prompting.

I used the fifteen New Ecological Paradigm items with a 5 point Likert scale to measure environmental attitude (Dunlap and Van Liere, 2008). Respondents were given as much time as required to consider the statements and were assured there were no right or wrong answers.

I assessed behavioural intention by asking respondents to prioritise a range of charities. I asked respondents to vote to allocate £100 between six charitable causes; three conservation charities (WWF, Plantlife International and the Botanic Garden where the survey was conducted) and three humanitarian charities (Cancer Research UK, Amnesty Inter-

national, WaterAid). The £100 had been donated by the authors and was represented by ten £10 tokens. Six boxes (with the names, logos and mission statements of each of the charities displayed) were presented to the respondent. Each box represented a different charity and respondents allocated their tokens between the boxes (I refer to this as a vote). At the end of data collection, the £100 was divided between the charities according to the distribution of tokens between the boxes.

3.2.3 Analysis

Ecological knowledge was calculated by summing correct responses to the knowledge questions, with a maximum score of 8. I used unidirectional coding, from 1-5, for each of the NEP items with positive environmental attitude having higher scores. I then summed across the 15 NEP items to provide a measure of environmental attitude for each individual, with a maximum score of 75. Constructs, such as environmental attitude, can be difficult to measure explicitly and are often estimated from a combined score of multiple items. A positive correlation between the items indicates the measure can be used as a reliable estimate of a single construct (Tavakol and Dennick, 2011). The level of correlation between items is known as the ‘internal consistency’ (Bland and Altman, 1997). The Cronbach’s alpha is the most widely applied measure of internal consistency and provides a score between 0 (no relationship between items) and 1 (perfect correlation between items). The Cronbach’s alpha is calculated using

$$\alpha = \frac{k}{k-1} \left(1 - \frac{\sum s_i^2}{s_T^2} \right) \quad (3.2)$$

where k is the number of items, s_i^2 is the variance of the i -th item and s_T^2 is the variance of the total score, determined by summing across all items (Cronbach, 1951). To allow direct comparisons I rescaled explanatory variables to a common range. I used a series of linear models to examine variation in respondent demographics between different botanic gardens and variation in demographics of visitors arriving and leaving.

To assess the relationship between ecological knowledge and environmental attitude, I developed a candidate set of 19 generalised linear models. The global model included

ecological knowledge, age, education level, gender and frequency of visits to the botanic garden as explanatory variables. To assess whether a botanic garden visit influences environmental attitudes I include a dummy variable indicating arriving or leaving. Candidate models were ranked and weighted by AICc. There was no single model with clear support so I used model averaging to estimate the parameter coefficients. Uncertainty in parameter estimates was calculated as Burnham and Anderson (2002).

I use a mixed effects model using the lme4 package (Venables and Ripley 2002) to test the relationship between environmental attitudes and support for conservation. I included votes for charities to compare differences in the prioritisation of conservation charity, before and after a botanic garden visit whilst accounting for demographic variables. I used the votes for each charity relative to votes for the botanic garden as the response variable. The following explanatory variables were included: attitude score, arriving or leaving the botanic garden, charity bid, age, gender, education, frequency of garden visits. I also included the interaction between charity bid and arriving or leaving the garden. To account for repeated measures on individuals in the charity votes I specified individuals and botanic gardens as random effects. All analysis was carried out using R 2.11.1 (R Foundation for Statistical Computing, 2009).

To examine the impact of a botanic garden visit on ecological knowledge (as a continuous variable) I developed a candidate set of 18 generalised linear models. The global model had the following explanatory variables: a dummy variable indicating arriving or leaving, age, education level, gender, frequency of visits to the botanic garden. I used corrected AIC (AICc) to rank the candidate models and calculate the relative weight of each model. Following Burnham and Anderson (2002) I chose the most supported model as the one with $\Delta\text{AICc} > 2$.

3.3 Results

I had a mean response rate of 77% ($\pm 10\%$, 95% Confidence interval) providing a sample of 1054 completed questionnaires: 523 people arriving and 531 leaving (Table 3.1). I sampled 616 females and 438 males, and over 60% of respondents were aged 46 or above. Forty-five percent of respondents had a university level education (including

bachelors, Masters degree and doctorate degree), 22% had college education (A levels or equivalent), 6.2% were educated to GCSE level or equivalent and 25% had other training qualifications. There was no significant difference between gardens in the number of respondents interviewed arriving or leaving, age, gender, ecological knowledge and environmental attitude ($p < 0.05$, $df = 1049$). The Cronbach's Alpha test indicates a high internal consistency (0.87) for the measure of environmental attitude. My NEP results show a similar distribution across items to that of previous studies carried out on the general public (Kotchen and Reiling 2000) supplementary material 2). I therefore assume our respondents have a representative environmental attitude of the general public.

Table 3.1: Summary of respondents in the five study botanic gardens. Mean ecological knowledge scores and mean environmental attitudes scores are shown with 95% confidence intervals in brackets. There are no significant differences between gardens in respondent age, ecological knowledge and environmental attitude ($p \geq 0.05$, $df = 4$).

Botanic Garden	Number of responses	Response rate (%)	Mean knowledge score (max = 8)	Mean NEP score (max = 75)
Birmingham	204	72	3.5 (0.29)	58.1 (0.97)
Cambridge	207	87	3.9 (0.25)	57.6 (0.96)
Eden	215	86	3.5(0.20)	57.1 (0.91)
Edinburgh	204	66	3.7(0.22)	57.3 (0.92)
Kew	224	72	4.0 (0.24)	58.1 (0.99)
Total	1054	77	3.7	57.6

3.3.1 Does ecological knowledge predict environmental attitude?

Table 3.2 summarises the ten models with the most support, ranked by $\Delta AICc$. As no single model had clear support when assessing the predictors of environmental attitude, Figure 3.1 presents parameter averages over 19 candidate models. There is a strong positive relationship between ecological knowledge and environmental attitude. Coefficients for age, gender, education and frequency of garden visits are also positive, suggesting women that are leaving the botanic garden, with higher levels of formal education and visit the garden frequently, have a more positive environmental attitude.

Table 3.2: Summary of 10 candidate models ranked by AICc developed to assess the effect of ecological knowledge and a botanic garden visit upon environmental attitude, controlling for demographic variables.

<i>Leaving</i>	<i>Know</i>	<i>Age</i>	<i>Gender</i>	<i>Education</i>	<i>Freq. visits</i>	<i>Know:education</i>	<i>Age:education</i>	<i>Know:age</i>	<i>AICc</i>	<i>ΔAICc</i>	<i>Weight</i>
✓	✓	✓	✓						6939	0.0	0.32
✓	✓	✓	✓	✓					6940	1.5	0.15
✓	✓		✓						6940	1.8	0.13
✓	✓	✓	✓	✓		✓			6941	1.8	0.13
✓	✓	✓	✓	✓	✓				6941	2.0	0.12
✓	✓		✓	✓	✓				6942	3.3	0.06
✓	✓		✓	✓					6942	3.8	0.05
✓	✓	✓	✓	✓	✓				6843	4.2	0.04
✓		✓	✓	✓	✓	✓		✓	6985	46.1	0.0
✓		✓	✓						6987	48.5	0.0

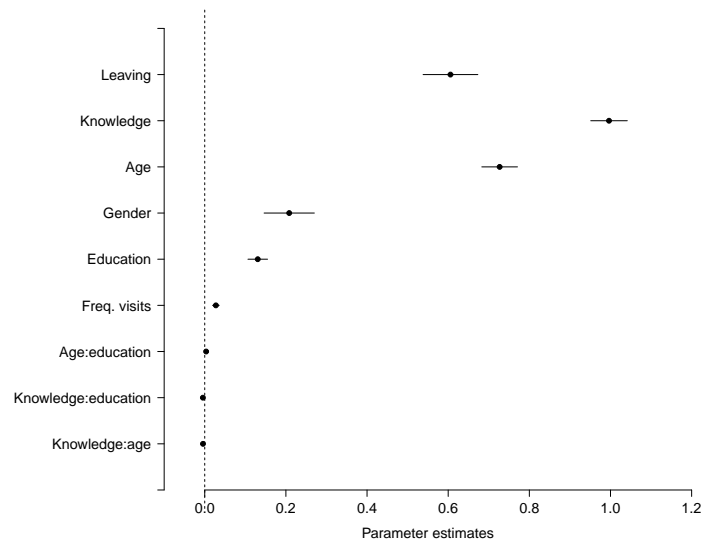


Figure 3.1: Parameter estimates predicting environmental attitude. Intercept = 52.02 (± 0.06). Central circles are coefficient estimates averaged across the candidate set of models. The lines indicate 95% confidence intervals. The further right the estimate, the greater the positive relationship with environmental attitude i.e environmental attitude is likely to be higher on the way out of the garden and there is positive effect of ecological knowledge, age, gender and education level. This suggests that women, that are older, with higher levels of formal education and have visited the garden, have a more positive environmental attitude.

3.3.2 Does environmental attitude predict behaviour?

Environmental attitude, as measured by the NEP, has little effect on prioritisation of conservation charities, whereas the coefficient estimate for formal education level suggests people with higher education will give more to the botanic garden. The results show there is little difference in the prioritisation of conservation charities before and after a visit to a botanic garden. Table 3.3 illustrates how people on the way in and on the way out, will give mostly to Cancer Research, Wateraid and WWF (Appendix B provides displays the plotted raw data showing the difference between ecological knowledge, environmental attitude and votes for charities, before and after a botanic garden visit).

Table 3.3: Summary of the mixed effects model testing the differences in prioritisation of charities before and after a botanic garden visit, where individual and botanic garden are specified as the random effects. To calculate the response variable for each individual I subtract the number of tokens given to the botanic garden from votes to other charities and use the relative votes for each charity. The intercept represents votes for Amnesty International when arriving at the botanic garden (relative to votes for the botanic garden). The coefficient estimates suggest Wateraid, Cancer Research and WWF receive the most votes on the way in and out. Environmental attitude (NEP) has no effect on votes.

	Coefficient	Standard error	<i>t</i> value
Intercept	0.172	0.379	0.455
Leaving	−0.207	0.116	−1.779
NEP	0.011	0.005	2.025
Age	−0.102	0.026	−3.812
Gender	0.049	0.082	0.606
Education	−0.021	0.026	−0.810
Freq visit	−0.067	0.028	−2.368
Cancer	0.600	0.094	6.355
Plantlife	0.056	0.094	0.594
Wateraid	0.813	0.094	8.610
WWF	0.383	0.094	4.059
Cancer:leaving	0.145	0.132	1.094
Plantlife:leaving	0.195	0.132	1.464
Wateraid:leaving	0.218	0.132	1.640
WWF:leaving	0.215	0.132	1.613

3.3.3 Does a botanic garden visit impact ecological knowledge, environmental attitude and support for conservation?

Table 3.4 shows a summary of the 10 most supported models developed to assess predictors of ecological knowledge. I present the most supported model in Figure 3.2. There is no impact of a single visit to a botanic garden on ecological knowledge. The effect of a single visit was retained in the second most supported model, but the coefficient estimate was small (-0.007 ± 0.1) and the delta AIC is more than 2 suggesting weak support for the model. Our results suggest more frequent visits to the botanic garden are positively related to ecological knowledge. The level of formal education also indicates people with higher levels of education are likely to have higher ecological knowledge. Figure 3.1 shows environmental attitudes are more positive when leaving the botanic garden and Table 3.3 shows that there is no difference in support for conservation before and after a botanic garden visit.

Table 3.4: Summary of 10 candidate models ranked by AICc developed to assess the impact of botanic garden visits on ecological knowledge. Botanic garden visit was retained in the second most supported model with a coefficient of $-0.007(\pm 0.1)$.

<i>Leaving</i>	<i>Gender</i>	<i>Education</i>	<i>Age</i>	<i>Freq. visits</i>	<i>Age:education</i>	<i>Leave:education</i>	<i>Leave:age</i>	<i>AICc</i>	<i>ΔAIC</i>	<i>Weight</i>
	✓	✓		✓				3948	0	0.59
✓	✓	✓		✓				3950	2.0	0.22
✓	✓	✓	✓	✓				3952	3.5	0.09
✓	✓	✓		✓				3953	5.1	0.04
✓	✓	✓	✓	✓	✓	✓	✓	3955	7.0	0.01
✓	✓	✓	✓					3955	7.1	0.01
✓	✓	✓	✓					3956	7.8	0.01
✓	✓	✓	✓					3958	9.9	0.00
✓	✓	✓		✓		✓		4003	55.4	0.00
✓		✓	✓	✓	✓			4007	58.8	0.00

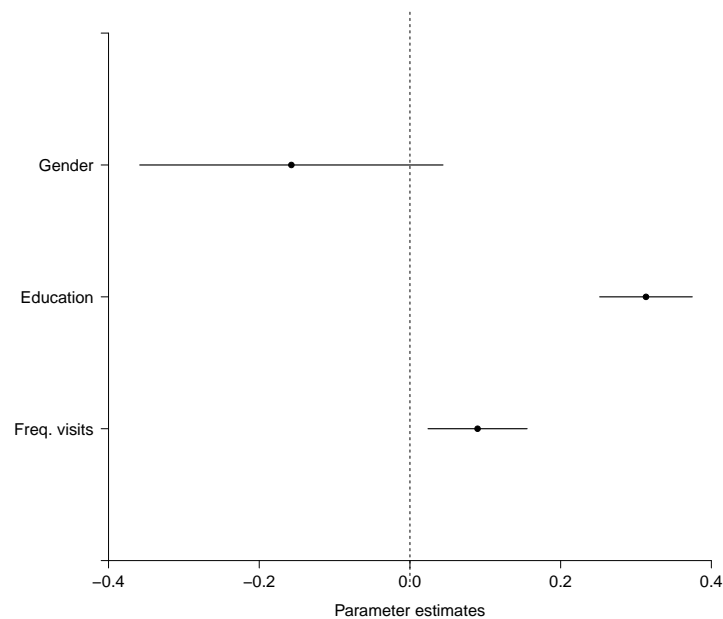


Figure 3.2: Coefficient estimates for the most supported model predicting ecological knowledge. Intercept = $2.28(\pm 0.02)$. Central circles are average coefficient estimates for each parameter and lines indicate 95% confidence intervals. People with higher levels of formal education and visit the garden frequently are likely to have higher ecological knowledge.

3.4 Discussion

The provision of information forms an important component of informal education activities for many collections-based institutions, such as botanic gardens (Miller et al., 2004). The effectiveness of this approach relies upon the assumption that providing information will influence peoples' knowledge and potentially change attitudes and behaviour. Although there are educational activities within botanic gardens that involve interaction between visitors and botanic garden staff or volunteers, I focus specifically on passive informal education, that is, aiming to change visitor's ecological knowledge through signs, exhibits and displays.

3.4.1 The relationship between knowledge, attitudes and behaviour

The knowledge-deficit model suggests higher levels of ecological knowledge would lead to more positive environmental attitudes and support for conservation (Arcury,

1990). My results show a strong positive relationship between ecological knowledge and environmental attitude, but I am unable to identify whether knowledge predicts attitude or vice versa (i.e. to separate correlation from causation). However, previous research does show provision of environmental information plays an important role in promoting positive environmental attitudes (Sturgis and Allum, 2004; Havens et al., 2006; Allum et al., 2008). Although not explicitly using the knowledge-deficit model as a framework, Trehwella et al. (2005) demonstrate how increasing knowledge resulted in more positive attitudes towards fruit bat conservation in the Comoros Islands. My result showing a positive relationship between ecological knowledge and environmental attitude suggests informal education could play an important role in communicating conservation and environmental issues to the public and generating positive environmental attitudes. However, changing behaviour is a complex process (Monroe, 2003; Heberlein, 2012) and the knowledge-deficit model may be overly simplistic in assuming improving environmental attitudes will result in positive environmental behaviour (Heberlein, 2012). Most studies using the knowledge-deficit model focus on the relationship between knowledge and attitudes, without testing the assumption that attitudes predict behaviour (Hansen et al., 2003; Sturgis et al., 2010). I used hypothetical bids for charities as a measure of behavioural intention but were unable to detect any relationship between attitudes and behavioural intention. St John et al. (2010a) highlight the importance of linking a measure of attitude with a specific behaviour. For example, if I am interested in understanding how people prioritise conservation charities, the attitudes measured need to be specifically about prioritisation of conservation charities. I measured general environmental attitudes using the New Ecological Paradigm and it is possible that this measure does not match directly with the measure of behavioural intentions, as measured by hypothetical bids for a range of charities. Furthermore, there is a well-documented discrepancy between behavioural intention and actual behaviour (Balmford et al., 2007; Steg and Vlek, 2009). Because of the difficulty in many situations of directly observing behaviour of interest, most studies rely on self-reports of behaviour e.g (Kaiser et al., 1999; Waylen et al., 2009; Weiler and Smith, 2009) or indicators of behavioural intention (Kotchen and Reiling, 2000; Howe et al., 2011). My study relies on a measure of behavioural intention rather than actual behaviour and I recognise this is a limitation in the study.

3.4.2 Impact of botanic gardens on knowledge, attitudes and support for conservation

My results suggest a single visit to a botanic garden is unlikely to substantially impact visitors' ecological knowledge. However, I find regular visitors have higher ecological knowledge, indicating botanic gardens can potentially increase ecological knowledge over time. Alternatively, this result could indicate that people with higher levels of ecological knowledge are more likely to frequently visit the botanic garden, or that interest in botanic gardens predicts both acquisition of knowledge and visits to gardens. I expect the latter two options are most likely, as the visitor profile of UK botanic gardens is often quite limited and not representative of the general public. Indeed my results show the majority of respondents (45%) have university level education whereas less than 30% of people in the UK have qualifications from University or equivalent (Office of National Statistics, 2011). A challenge faced by UK botanic gardens is the public perception of being for an elite group of older, middle class people (Dodd and Jones, 2010; Schultz, 2011). Many botanic gardens have recently begun coordinating community outreach projects, specifically targeted to encourage new audiences and to attract a broader spectrum of visitors. For example, the Winterbourne House and Garden, part of the University of Birmingham, set up community based urban vegetable growing project, aiming to encourage cultural exchange and learning experience for the Islamic communities of Birmingham and the Garden (Botanic Gardens Conservation International, 2012). To evaluate the impact of these community projects it would be useful to incorporate measures of participants' ecological knowledge and ecological environmental attitudes. Measuring the impact of longer-term projects may be more likely to show any impact of botanic gardens on ecological knowledge, particularly if the project involves frequent visitor contact.

My results do indicate botanic gardens can have a positive effect on environmental attitudes. However, I am unable to directly attribute this change to the informal education efforts of the botanic garden. I suggest that future studies employ a quasi-experimental design when investigating knowledge, attitudes and behaviour. Including a control group (i.e. people that are not exposed to educational material) may provide greater insight into the casual relationships between knowledge, attitudes and behaviour. The

change in attitude I observed may be due to the pleasure of visiting the garden itself, as the majority of people visit gardens for enjoyment and relaxation (Ballantyne et al., 2008; Maunder, 2008). As my measure of environmental attitude was taken directly after a visit to the botanic garden, I am unable to suggest whether there is a longer-term impact. Although environmental attitudes may be positive after a botanic garden visit, attitudes are dynamic constructs and may need reinforcement to be maintained (Stern et al., 2006). It would be useful to have research where respondents are surveyed again at a later date to estimate if botanic gardens have a longer-term impact on environmental attitudes. It is likely education programmes where visitors interact with botanic garden staff and volunteers will have greater impact than hoping visitors read the signs and absorb the conservation messages from interpretation boards (Miller et al., 2004). Research on zoo education programmes suggests high levels of visitor participation has the greatest positive impact on ecological knowledge and attitudes (Penn, 2008).

Havens et al. (2006) suggest an understanding of conservation is necessary to engage public support for conservation and that botanic gardens are well placed to generate this support. However, my results indicate botanic gardens have little impact on how visitors prioritise conservation. If botanic gardens are aiming to influence behaviour and generate more public support for conservation, it is likely they will need to address these additional predictors of behaviour. Social psychology research indicates that messages focusing on a specific and achievable goal are more likely to succeed at changing behaviour, while broad requests to 'save the planet' have little chance of being effective (Schultz, 2011). Botanic gardens could tailor their messages to address a specific behaviour and frame the message to indicate the benefits of behavioural change (Pelletier and Sharp, 2008).

3.5 Conclusion

Botanic gardens apply a wide range of activities to educate and inspire the public, often aiming to generate support for conservation. Here I have focused on the impact of passive informal education in botanic gardens. Although botanic garden visits do not seem to influence ecological knowledge, my findings suggest visits have a positive influence on environmental attitudes. I have used this study to investigate the underlying assumption in many environmental education programmes: that increasing people's ecological

knowledge will affect their environmental attitudes and that this will translate into positive environmental behaviours. With over 300 million visitors a year globally, botanic gardens have an excellent opportunity to educate the public and promote positive environmental attitudes. However, successfully achieving this outcome may require a more sophisticated approach than suggested by the simple knowledge-deficit model. I suggest future research should use a quasi-experimental design to provide greater insight into the casual relationships between knowledge, attitudes and behaviour.

Chapter 4

Training programmes can change behaviour and encourage the cultivation of over-harvested plant species

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4.1 Introduction

Humans have carried out wild harvesting of plant species for subsistence and trade for thousands of years (Diamond, 2002). However, over-exploitation now threatens many wild plant populations (Millenium Ecosystem Assessment, 2005). There has been increasing interest in the cultivation of harvested plant species as a method to reduce over-exploitation of wild populations (Schippmann et al., 2002; Ticktin, 2004) and also to improve human livelihoods (Hamilton, 2004). The assumption is that increasing domestic supply will reduce the pressure on wild populations (Endress et al., 2004a; Trauernicht and Ticktin, 2005; Canter et al., 2005). It is likely that multiple factors determine an individual's decision to begin cultivation, including socio-economic characteristics (Byg and Balslev, 2006), land tenure (Zubair and Garforth, 2006), risk preference (Ibanez and Carlsson, 2010) and technical knowledge about cultivating a novel species (Godoy, 1992). Training programmes have been initiated to encourage cultivation of over-harvested species (Chukwuone, 2009; United Nations Environment Programme, 2011). Such programmes implicitly assume that lack of technical knowledge is the barrier to cultivation. However few studies have explicitly considered individuals' decision-making processes concerning whether to engage in cultivation or not, and how this may be influenced by a training programme (Pattanayak et al., 2003; Mercer, 2004).

Understanding the drivers of human decision making and behaviour is important for improving the design of effective conservation interventions (St John et al., 2010a). The theory of planned behaviour (Ajzen, 1991) provides a useful framework to analyse individual behaviour. This social psychological theory uses three factors: attitudes, subjective norms and perceived behavioural control, as predictors of behavioural intention, the antecedent to behaviour (Figure 4.1). Attitudes can be conceptualised as what an individual thinks about a behaviour and can be favourable or unfavourable. Subjective norms describe what individuals perceive others to think of a behaviour (Ajzen, 1991). Perceived behavioural control (PBC) is a self-assessment of whether a behaviour can be enacted successfully and also the availability of the resources to perform the behaviour (Conner and Armitage, 2006). Some studies suggest knowledge is also an important predictor of behaviour, however a personal assessment of knowledge may not necessarily reflect the accuracy of the knowledge (Ajzen et al., 2011). Technical knowledge can be described as factual, accurate information about a specific behaviour (Schultz, 2002) and can be included as a predictor of behaviour (Pooley and O'Connor, 2000; Schultz, 2002; Fisher et al., 2008). Recent work has examined the relative predictive power of technical knowledge on behavioural decisions compared to the other factors traditionally included in the theory of planned behaviour (Ajzen et al., 2011).

Training programmes aiming to initiate cultivation of a new plant species can address a perceived lack of technical knowledge in cultivation methods, and may also influence attitudes, subjective norms (Zubair and Garforth, 2006) and perceived behavioural control (McGinty et al., 2008). Previous research evaluating changes in behaviour frequently rely on self-reports of behavioural intentions; actual behaviour is often difficult to measure (Baruch-Mordo et al., 2011; St John et al., 2012). In this study I assess the impact of a training programme that aimed to promote the cultivation of an over-harvested palm species (xaté -*Chamaedorea ernesti-augusti* H.A. Wendl.) among forest-edge communities in Belize. The leaves of xaté are used in the floricultural industry in a global trade worth approximately US \$4 million annually (Bridgewater et al., 2006). This case study offers an excellent opportunity to investigate the relative importance of the various predictors of behaviour on actual behaviour as whether a participant went on to cultivate xaté is easily documented and readily verifiable. I use a modified

theory of planned behaviour as a framework and combine qualitative and quantitative research methods to address 1) the impact of training on the participant's attitudes, subjective norms, perceived behavioural control and technical knowledge (whilst accounting for socio-economic variables), 2) whether attitudes, subjective norms, perceived behavioural control and technical knowledge predict xaté cultivation behaviour (again controlling for socio-economic variables), and 3) other barriers to xaté cultivation in Belize.

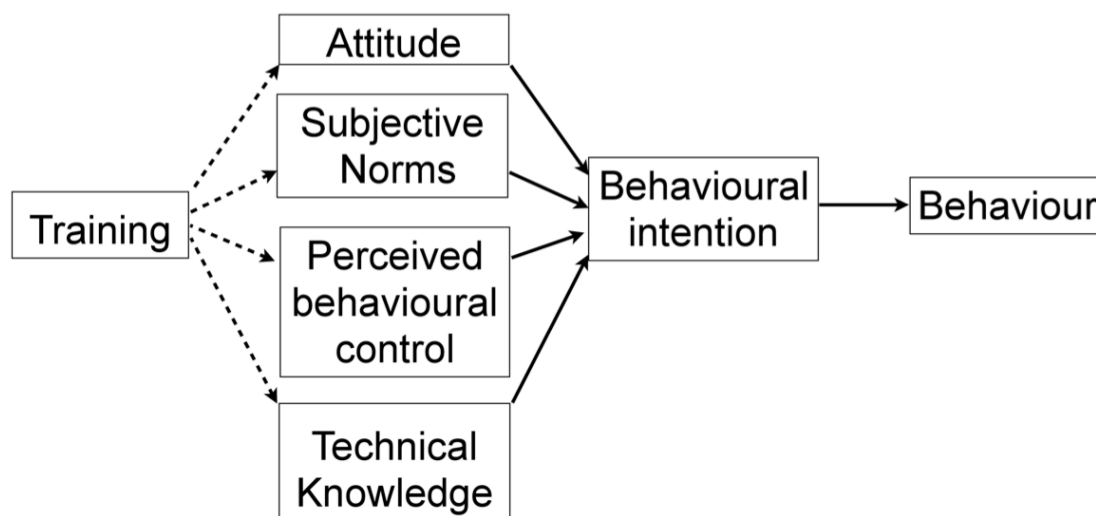


Figure 4.1: In this conceptual model I include the additional variable of technical knowledge as a predictor of behavioural intention and training as a potential method of influencing the four predictors of behavioural intention.

4.2 Methods

4.2.1 Study site

Belize is a small country on the Caribbean coast of Central America with a population of approximately 300,000 (Belize Central Statistical Office, 2010). This work was carried out in the district of Cayo from December 2010 to February 2011 (Figure 4.2). Small scale farming is the main occupation for the majority of the villagers and the inhabitants primarily speak Yucatec Mayan, but most people are also fluent in English

and Spanish (Belize Central Statistical Office, 2010). As part of a Darwin Initiative Project (UK government funding), Belize Botanic Garden prepared a xaté cultivation training programme which was delivered to 50 farmers from four villages in 2005 and provided participants with xaté seedlings to encourage cultivation. The botanic garden also planted a demonstration plot to promote xaté cultivation. Our study was carried out in these four villages (not named to preserve respondents' anonymity). The training programme aimed to teach people in Belize how to cultivate the xaté, as a method of increasing the supply from cultivated sources and improving local farmers' livelihoods. Creating a xaté market is a relatively new initiative in Belize, whereas Guatemala has a long established system and infrastructure for sorting, packing and exporting xaté leaf (Bridgewater et al., 2006). Wild harvesting of xaté is uncommon among Belizeans, and it is suggested that wild harvesting in Belize is carried out illegally by Guatemalans crossing the border (Bridgewater et al., 2006).

4.2.2 Questionnaire development and design

Belize Botanic Garden provided the training participants with information about xaté cultivation; I used this to develop our questions assessing technical knowledge (Table 4.1). Our measure of technical knowledge is distinct from the assessment of the attitudes, subjective norms and perceived behavioural control as I specifically examine the amount of accurate information an individual has, whereas the three other behavioural predictors do not measure the amount or accuracy of information held (Ajzen et al., 2011). To develop the statements measuring attitudes, subjective norms and perceived behavioural control I held discussions with key informants to help us to understand the range of perceptions within the communities about xaté cultivation (Table 4.2). The questionnaire was adapted following discussion with two key informants to reflect local context. Responses were initially measured on a five-point Likert scale. A pilot study ($n = 10$) found that people either agreed or disagreed with statements and it was difficult to elicit variation in the strength of opinion. For this reason, I simplified the survey to use a three-point scale. In the pilot study I constructed the individual attitude, subjective norms and perceived behavioural control statements to include target, action, context and timeframe (Conner and Sparks, 2008). For example, I could ask an individual their attitude towards cultivating xaté on a farm in the next five years. In this example cul-

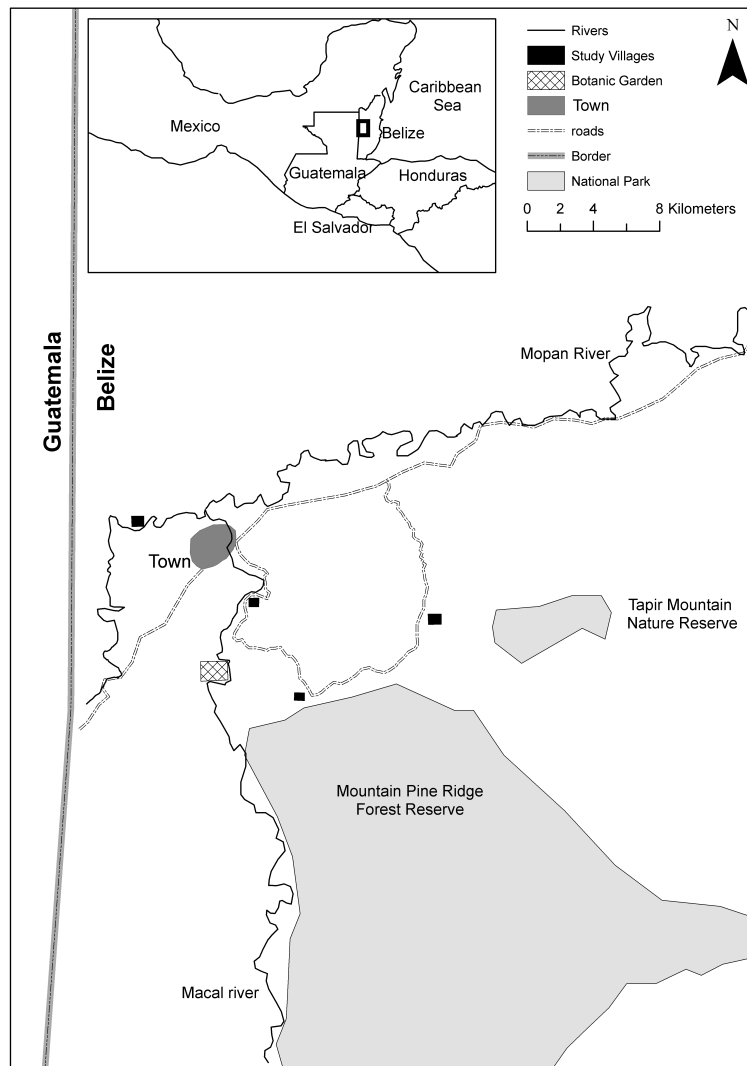


Figure 4.2: The location of study villages in Belize.

tivation is the action, xaté is the target, the farm is the context and five years is the timeframe. However, the detail in these statements was confusing for respondents. As the context and timeframe remained the same for each statement, I outlined these two components at the beginning of the attitude statement section of the questionnaire (Table 4.2). The target and the action were defined individually for each statement. After these revisions, I carried out a second pilot study ($n = 10$) and no further changes were made and so these data were included in the final analysis. Respondents were also asked their

Table 4.1: Statements used to measure technical knowledge with answers based on information provided during training at Belize Botanic Garden.

Question	Correct Answer		Rationale
What is xaté used for in the US?	Decoration, ornament, flower arranging		The only known use of the plant
How long do xaté seeds take to germinate?	Between 9–12 months		Based on tests at the Belize Botanic Garden
What colour are xaté seeds when ready to harvest?	Black/purple		Distinct colour change from green when seeds are ripe
Have there been any changes in the numbers of xaté in the forests of Belize in the last ten years?	Yes, decline		A decline in xaté in Belize has been documented in the Darwin Initiative project
Does xaté require full sun or shade to grow?	Shade		Xaté is not tolerant of direct sun
How many xaté leaves can you take each year without harming the plant?	2 or <2		Based on research during DI project. Training programme taught 2 leaves per year maximum to be harvested.

age, length of time living in the village, amount of forest land owned, number of financial dependents, number of children, years of schooling and the length of time they had been a farmer (Appendix C). Following the questionnaire I carried out semi-structured interviews to gain a more nuanced understanding of farmers' perspectives of xaté cultivation. The following topics were discussed with informants: what are the barriers to cultivation of xaté? Is xaté cultivation a good investment of land and effort? Why don't Belizeans wild harvest xaté?

4.2.3 Sampling strategy and data collection

The xaté cultivation training coordinated by Belize Botanic Garden targeted farmers: i.e. those people dependent on cultivating crops for their primary source of income. I aimed to contact all participants of the training programme through three key informants (Curator of Belize Botanic Garden, Chairman of the local Farmers Association and a local agroforestry non-government organisation (NGO) representative). From the total

of 50 people trained in xaté cultivation, I was able to interview 38. The people not interviewed had either moved away from the village or were not available for interview. To provide a random sample of the farmers who were not involved with the training programme, I compiled a comprehensive list of all the farmers in the villages through discussions with three key informants independently (Chairman of the local Farmers Association, the agroforestry NGO representative, a farmer that had lived and farmed in the village for 45 years). I assume that this list of 122 farmers is reliable as there was excellent agreement in the names provided by the three informants (117 names were the same on each informant's list with an extra 4 or 5 provided by two informants). From this list, 50 farmers were randomly sampled using numbers generated at random by R (R Foundation for Statistical Computing, 2009). All farmers interviewed, except two, were male. Interviews were arranged by visiting the house of the farmer and organising a time that would be suitable to conduct the survey. Interviews were carried out in English at the houses of farmers or on their farmland, whichever was more convenient for the informant. An ethics checklist, as required by Bangor University, was completed prior to data collection and indicated that the research did not require further review. Oral consent was obtained from all study informants and all data were stored anonymously.

4.2.4 Data Analysis

The quantitative data measuring attitudes was assessed for internal consistency using the Cronbach's Alpha (Santos, 1999). The four items measuring attitude showed moderate internal consistency at the level 0.68 and so could be used as a single measure of attitude. Items were coded so positive answers towards cultivating xaté had higher scores. The scores for attitude, subjective norm and perceived behavioural control were a simple calculation in accordance with Ajzen (2006). To provide a single attitude measure the four statement scores were summed. Scores of the two items measuring subjective norms were summed, as were the scores of the PBC statements. In a Theory of Planned Behaviour framework, where possible, evaluation statements should correspond directly to belief statements (Ajzen, 1991). In this case indexes can be constructed by multiplying the scores together (Ajzen, 2006). In this study, a direct link was not

possible for statements so I use a simpler approach of adding scores together. This alternative construction did not substantially affect the results. Xaté technical knowledge scores were calculated by adding all the correct answers for the technical knowledge questions to provide a measure between 0 and 6. These four variables (attitude, subjective norms, PBC and technical knowledge) were then rescaled to a common range between 0 and 40 to allow direct comparisons. The higher scores represent positive attitudes, social norms, PBC and higher technical knowledge. Socio-demographic variables were re-scaled to allow direct comparison between all variables. Demographic and socio economic characteristics of the trained and untrained informants were compared using a Student's *t* test. I then used proportional odds logistic models (McCullagh, 1980; Venables and Ripley, 2002) to assess the impact of training on the participants' attitudes, subjective norms, perceived behavioural control and technical knowledge. This method allows for ordinal response variables to be fitted in the model. I controlled for socio-demographics by including the amount of forest owned, years at school and age in the models. For each response variable I developed a candidate set of 8 models, which were ranked by Akaike information criterion (AIC), a method used to measure the goodness of fit of a model. I use the corrected AIC (AICc) to account for our small sample size. For each candidate set there was no single model with clear support so I used model averaging to estimate the parameter coefficients. Uncertainty in parameter estimates was calculated as according to Burnham and Anderson (2002).

To assess whether attitudes, subjective norms, perceived behavioural control and technical knowledge predict behaviour I used a generalised linear model with xaté cultivation as the binomial response variable and a logit link function. I developed a candidate set of 24 models *a priori* and included the following predictor variables: age, years at school, amount of forest owned, attitude, subjective norms, perceived behavioural control and knowledge (table 4.3, Appendix C, figure C.1 displays the distribution of predictor variables). The quadratic functions of age and school were included to allow for a potential non-linear response to these variables. Because of the limited sample size ($n = 87$), interactions between variables were not included in the models. The AICc was used to rank the candidate models and to calculate the relative weight of each model. The predicted probability of xaté cultivation was estimated under scenarios of varying technical knowledge and perceived behavioural control. Uncertainty in parameter val-

ues was incorporated by drawing 1000 times from a multivariate normal distribution with coefficient mean and covariance estimates from the best model (Gelman and Hill, 2007). Other variables were set at the sample medians. To analyse the qualitative data, key statements relevant to the topics outlined for the semi-structured interviews were extracted from the audio files and transcribed.

4.3 Results

4.3.1 Summary of the sample

The mean duration of the interviews was 24 minutes, with a maximum of 55 minutes. A total of 87 people were interviewed (trained = 38, untrained = 49). No significant differences in socio economic variables between the trained and untrained informants were found ($p < 0.05$, $df = 86$). Twenty-six people were actively cultivating xaté (trained = 22, untrained = 4). Mean scores for the four attitude and two subjective norm statements indicate the majority of farmers have positive attitudes and subjective norms towards xaté cultivation (Table 4.2), irrespective of training (Appendix C provides a summary of the data to illustrate calculations of attitude, subjective norms and perceived behavioural control scores). The responses for perceived behavioural control indicates that untrained participants have less confidence in their abilities and less access to resources for cultivation.

4.3.2 What does training influence?

Whilst controlling for socio-demographic variables, I found training had a small positive impact on attitudes (Figure 4.3a) and no evidence of influence upon subjective norms (Figure 4.3b). Training influenced perceived behavioural control (self belief in their abilities to cultivate xaté) and also access to resources needed to cultivate (Figure 4.3c) and technical knowledge i.e. the amount of accurate information an individual has about cultivation of xaté (Figure 4.3d).

Table 4.2: Statements used to measure attitudes, subjective norms and perceived behavioural control, including a summary of responses from trained and untrained participants. Informants were told each statement was based in the local area, in the next five years, to include target, action, context and timeframe in the statements. Statements were coded so positive attitudes, subjective norms (SN) and perceived behavioural control (PBC) likely to favour xate cultivation had higher values. Values are rescaled to range between 0–10; all items were re-coded so high values indicated a positive view of xaté cultivation.

Predictor	Measurement	Trained participants	Untrained participants
Attitude 1	Growing xate is good way for farmers to earn money	8.6	8.6
Attitude 2	Growing xate isn't a worthwhile use of land	7.6	7.2
Attitude 3	It is very difficult to earn money from growing xate	6.3	6.7
Attitude 4	The risk of theft in this area is too high to make growing xate worthwhile	9.6	7.8
SN 1	My friends think it is a bad idea to grow xate	7.4	7.0
SN 2	It is important to grow the same crops as my friends	7.5	8.0
PBC 1	I know how to grow xate	4.7	2.8
PBC 2	I don't have the money to buy what I need to grow xaté	9.2	4.5

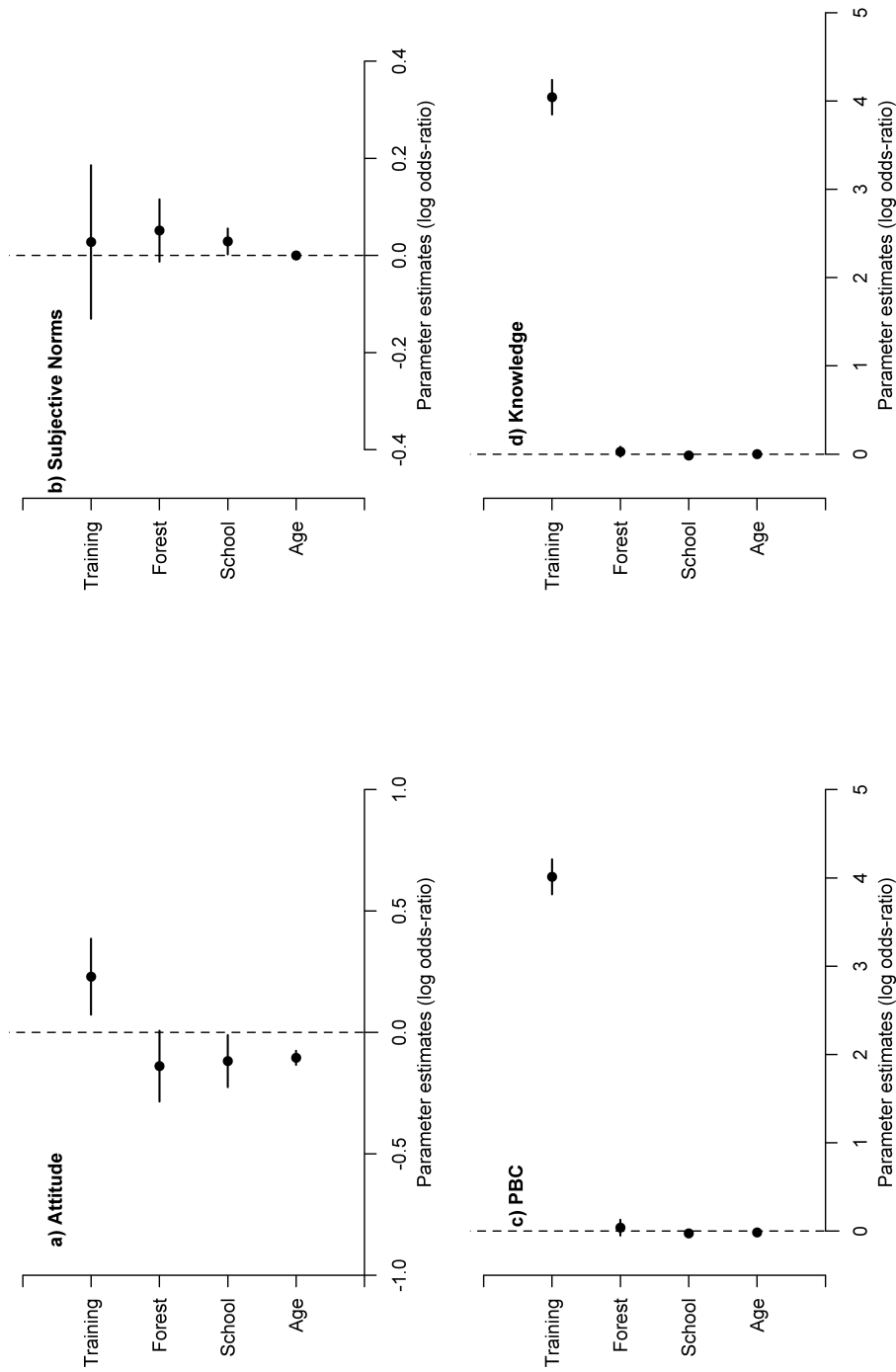


Figure 4.3: Model averaged parameters estimates. Illustrating the influence of training upon attitudes (a), subjective norms (b), perceived behavioural control (c) and technical knowledge (d), controlling for the socio-demographic variables forest ownership, years at school and age. The central circles are the mean coefficient estimate for each parameter. Lines indicate 95% confidence intervals. Socio-demographic variables were rescaled to allow direct comparison with the training variable.

4.3.3 What predicts cultivation?

Table 4.3 presents a summary of 10 (of the 24) candidate models with the lowest AICc, developed to predict xaté cultivation. Three models are <2 AICc but as the model with the lowest AICc also has the lowest number of parameters, I present this as the most supported model. This model retains the amount of forest land owned, age, technical knowledge level and PBC as predictors of xaté cultivation. Figure 4.4 presents the coefficient estimates for the most supported model. This illustrates that older farmers with technical knowledge about xaté cultivation and positive perceived behavioural control are the most likely to cultivate xaté. I used the best model to predict the impact of these two predictors on the probability of cultivating xaté. Figure 4.5 presents the simulations of different levels of technical knowledge (Figure 4.5a) and perceived behavioural control (Figure 4.5b). These illustrate that even with the highest level of knowledge or perceived behavioural control, the probability of cultivating xaté is less than 50%. However, when both perceived behavioural control and knowledge are increased to the highest levels simultaneously, the probability of cultivation rises to over 80% (Figure 4.5c) (Endress et al., 2006).

Table 4.3: Summary of 10 candidate models with lowest AICc developed to assess the predictors of xaté cultivation

<i>forest</i>	<i>age</i>	<i>age²</i>	<i>school</i>	<i>school²</i>	<i>know</i>	<i>attitude</i>	<i>Social Norm</i>	<i>PBC</i>	<i>AICc</i>	Δ <i>AICc</i>	<i>Weight</i>
✓	✓				✓			✓	67.75	0.00	0.21
✓	✓				✓		✓	✓	68.21	0.46	0.17
✓	✓	✓			✓	✓	✓	✓	69.76	2.01	0.08
✓	✓		✓	✓	✓	✓	✓	✓	69.98	2.23	0.07
✓	✓	✓	✓	✓	✓	✓		✓	69.98	2.23	0.07
✓	✓				✓	✓	✓	✓	70.18	2.43	0.06
✓	✓	✓	✓		✓	✓	✓	✓	70.70	2.96	0.05
✓	✓	✓	✓	✓	✓	✓	✓	✓	71.29	3.55	0.04
✓	✓		✓		✓	✓	✓	✓	71.29	3.55	0.04
✓	✓				✓	✓			71.83	4.09	0.03

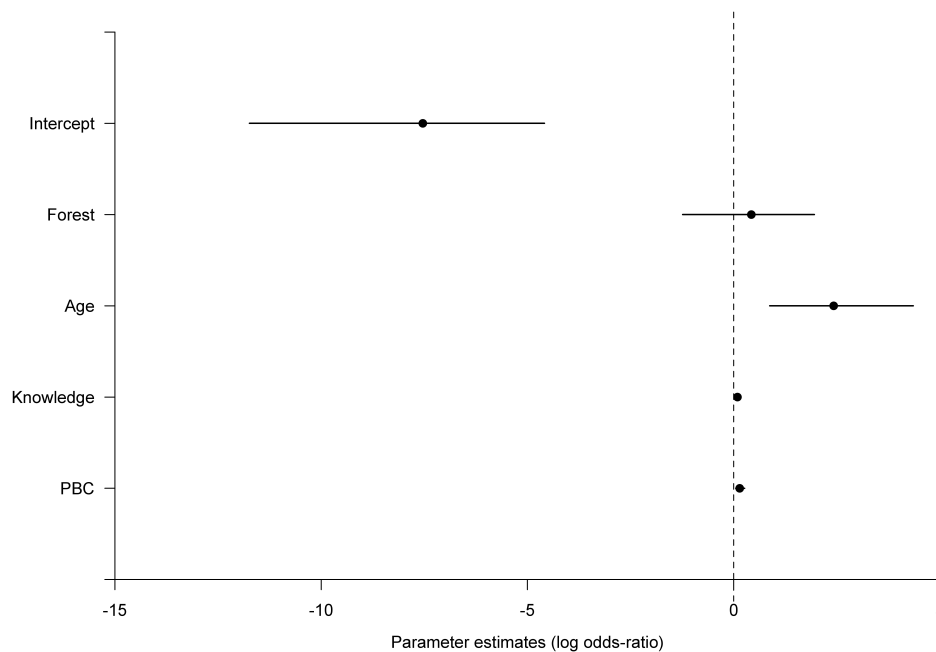


Figure 4.4: Parameter coefficient estimates for the most supported model predicting xaté cultivation. The central circles are the mean coefficient estimate for each parameter and lines indicate 95% confidence intervals. The further right the estimate, the more likely xaté cultivation will occur e.g. older people are more likely to cultivate xaté.

4.3.4 Additional barriers to cultivation

Farmers reported two additional perceived barriers to xaté cultivation through the semi-structured interviews: the lack of market to sell the leaves in Belize and access to xaté seeds.

There is an export market in Guatemala, but in Belize I don't have it. I don't know why there is no market here (Not xaté farmer, not trained)

We don't have the seed, we don't have the financial support or government support to start xaté. I don't think there is a company in Belize to buy seed. I think to get seed we will have to go to the jungle

(Not xaté farmer, trained)

In addition to the two reported barriers, farmers in the village closest to the Guatemalan border stated that theft was a problem when cultivating xaté. It was generally believed

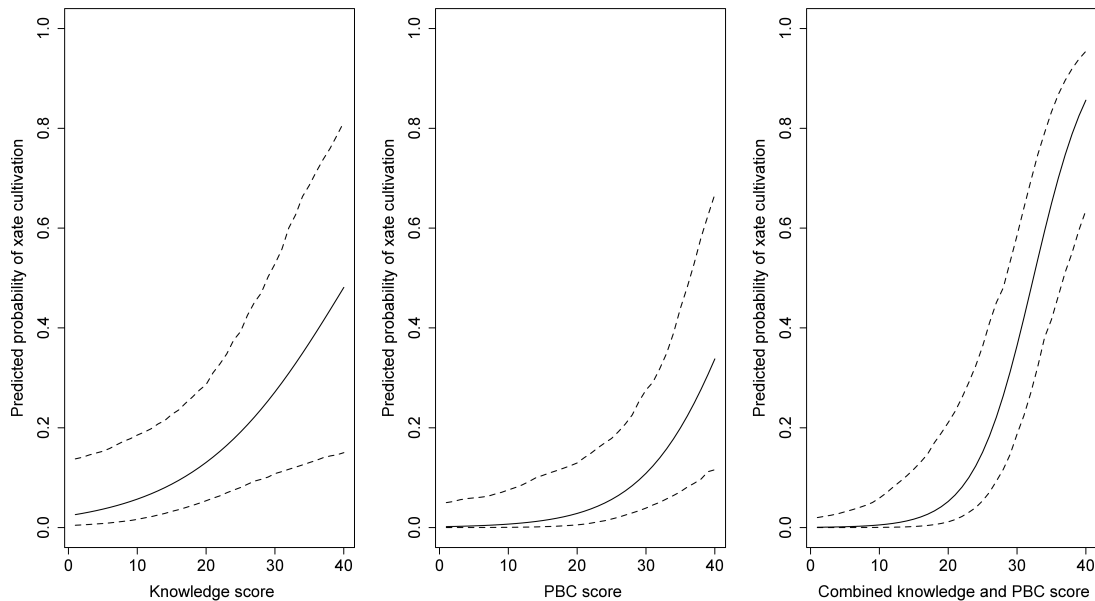


Figure 4.5: Influence of changing technical knowledge and perceived behavioural control on predicted probability of xaté cultivation. a. Technical knowledge scores, b. Perceived behavioural control (PBC) scores and c. Combined technical knowledge and perceived behavioural control score. Solid lines are the mean estimate and dashed lines are the 95% confidence intervals. Parameters were held at their median values whilst varying the parameter of interest.

that Guatemalans illegally crossing the border carry out these occurrences of theft.

Guatemalans are entering our country and they go into our land. They cut the xaté and they take it. When we are not there, they take it

(Previously a xaté farmer, trained)

They come in from Guatemala and come in Belize, take our xaté from the forest. In the future we will have nothing to show what is xaté

(Xaté farmer, trained)

4.4 Discussion

Training programmes are widely used to influence behaviour and have been found to be useful in a range of fields, including improving driving behaviour (Walker et al., 2009), improving health worker practices (Opiyo et al., 2008) and increasing the use

of malaria prevention techniques (Hwang et al., 2010). By targeting the factors known to influence behaviour, training programmes can potentially encourage the adoption of new behaviours. Here I discuss the impact of a cultivation training programme on the four proposed predictors of behaviour, and the impact of training on behaviour. I recognise that a limitation of this study is that participants in the initial training programme were self-selecting and differences between the trained and untrained group may have existed before the training programme. I found no difference in the measured socio-demographic characteristics between the trained and untrained groups, suggesting the differences may be relatively small. However, without random assignment of participants to the training programme a possible bias is unavoidable it is therefore not possible with complete confidence to conclude that the training programme caused the differences observed.

4.4.1 The effect of training

I found training had a small positive impact on attitudes and no evidence of influence upon subjective norms, in the context of xaté cultivation. Before the training programme the Belize government had been promoting xaté cultivation (Seven News Belize, 2004), which may have resulted in universally positive attitudes and subjective norms among farmers in the study area. Alternatively, training may have influenced attitudes and subjective norms of the participants and these perceptions were then, over time, transferred to other farmers in the area. Such peer to peer transfer of information is commonly a stated objective of agricultural development interventions (Roling, 1988; Warren, 2003) and could explain the small difference in the attitudes and subjective norms of trained and untrained informants. There is a strong contrast between this lack of difference and the clear difference between trained and untrained individuals in their technical knowledge and perceived behavioural control. It is remarkable that this division has been maintained in the 5 years since the training course. This finding suggests that training did have a positive influence on technical knowledge and positive beliefs about the ability to cultivate xaté but this did not diffuse through the community. Previous studies have demonstrated training programmes can result in a transfer of knowledge within a community (Ballantyne et al., 2001; Damerell, 2009). However, these studies focus on general knowledge about environmental issues whereas our study examines technical knowledge, which may be more difficult to transfer. Despite the lack of transfer of

knowledge through the community, it is encouraging to find our results show training can influence technical knowledge and this knowledge is retained over five years. As perceived behavioural control was also increased, I assume the training programme addressed both of the facets of perceived behavioural control: training has influenced an individual's self belief in their ability, perhaps indirectly influenced through increasing technical knowledge. Secondly, to increase perceived behavioural control, training programmes need to address the resource access to help individuals implement a behaviour (Conner and Sparks, 2008).

4.4.2 Requirements for cultivation

A lack of knowledge in silvicultural and agroforestry practices is thought to hinder adoption of cultivation practices (Walters et al., 2005) and high confidence is thought to increase the intention to cultivate a novel species (McGinty et al., 2008). The predicted simulations highlight the importance of technical knowledge and perceived behavioural control as predictors of cultivation behaviour. Simultaneously increasing both knowledge and perceived behavioural control substantially increases the probability an individual will cultivate xaté. Training programmes are more likely to result in behavioural change if they can address the technical knowledge needed to cultivate a new species and also generate self confidence in individuals with the provision of resources needed to initiate cultivation. By providing seedlings to participants, the Belize Botanic Garden addressed the need for resources to establish xaté plantations. However, even if prospective cultivators have technical knowledge, self confidence in their abilities and seedlings, additional constraints may restrict implementation of cultivation (Walters et al., 2005). There may be barriers to cultivation that training programmes are not able to address. I identify three factors that people perceive as important considerations before initiating xaté cultivation: access to seeds, lack of market and theft of xaté. There are no xaté nurseries selling seedlings or seed and our study found evidence of seed harvesting from wild populations. It has been suggested that harvest of palm seeds can be more detrimental than harvesting leaves (Oyama, 1992). I therefore suggest caution should be taken when promoting cultivation of a new species if there is no sustainable source of seeds or seedlings after the training programme has been completed. The lack of an established xaté market in Belize discourages farmers from investing in xaté cultiva-

tion. Although it may not be the responsibility of the training coordinators to establish the market, it is perhaps important for the organisation to consider this important factor before encouraging individuals to cultivate a new crop. With high value plant products, theft is a potential risk for farmers. Our study shows how this risk can be high enough to deter farmers from cultivating a new species such as xaté. Training programmes are unlikely to alter behaviour if theft of the plant is likely and this needs to be considered before expecting individuals to invest in cultivation of a new species.

4.5 Conclusion

The theory of planned behaviour has provided a useful framework for examining factors that can predict behaviour. My study illustrates how training programmes can influence behaviour and how this can encourage cultivation of over-harvested plant species. I show that training programmes can influence participants' technical knowledge and their self assessment of whether a behaviour can be enacted successfully (perceived behavioural control) and that these variables are important in predicting whether people take up cultivation. It is interesting to note that technical knowledge and perceived behavioural control did not appear to transfer between participants and non-participants over the five year period between the training programme and our research. Future training programmes aimed at increasing cultivation of over-harvested plants therefore need to target both individuals' technical knowledge and perceived behavioural control, which may be influenced by providing the seeds or seedlings needed for cultivation. Whether cultivation is an effective approach for reducing pressure on wild populations still requires further research.

Chapter 5

Who harvests and why? Characteristics of Guatemalan households harvesting xaté (*Chamaedorea ernesti-augusti*)

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5.1 Introduction

Many people across the globe depend on harvesting plants and animals, for direct use or income, yet the over-exploitation of these resources is a major threat to many species (Milner-Gulland et al., 2003; Ticktin, 2004). Effective management is therefore needed for both biodiversity and human well-being. Cultivation of harvested species has frequently been proposed as a conservation strategy to reduce pressure on wild plant populations and improve local livelihoods (Schippmann et al., 2002; Canter et al., 2005). A number of projects have been initiated worldwide, to encourage cultivation of socio-economically important species e.g. Entwistle et al. (2002). These projects implicitly assume that wild harvesters will readily switch to cultivation as an alternative livelihood strategy. The socio-economic characteristics of people are likely to impact the success of such conservation projects (Chukwuone, 2009). However, resource extraction is often carried out illegally, making it a challenge to study and develop locally relevant conservation initiatives. Gavin and Solomon (2010) recently highlighted the global extent of illegal resource use and the need for more accurate data to support monitoring of conservation interventions aiming to reduce the biological impacts of over-exploitation.

I focus on the harvesting of the palm *Chamaedorea ernesti-augusti* (H. Wendl.). *Chamaedorea* is the largest genus of palms in the neotropics, with many species of high socio-economic importance (Hodel, 1992). *C. ernesti-augusti* is distributed in the seasonal forests of Mexico, Guatemala, Belize and Honduras and is locally known as xaté. The leaves of xaté are traded internationally for use in floriculture and the annual value of exports from Guatemala was estimated to be US \$4 million in 2006 (Bridgewater et al., 2006). The leaf is cut above the base of the petiole and only leaves that are unblemished with no fungal or insect damage are suitable for export. However, harvesters tend to be paid by the quantity they collect and it is estimated that over 60% of harvested leaves are discarded during processing (Radachowsky, 2003). Once harvested leaves stay green for up to four weeks, making them particularly attractive for use in the floristry industry. Harvesting wild xaté in Belize is illegal (Belize Forest Act 2000) whereas xaté harvesting in Guatemala is legal when carried out within a licensed forest concession or from licensed cultivated xaté, but is otherwise illegal (Palacios Aldana, 2012). The industry is an important income source for many communities in the Petén region of Guatemala, although it is thought harvesters predominantly harvest illegally across the border in the Greater Maya Mountains, Belize (Bridgewater et al., 2006). Belizeans largely do not wild harvest xaté themselves, although within the last five years xaté cultivation has been encouraged in Belize (Bridgewater et al., 2006; Williams et al., 2012b). In Guatemala, conservation initiatives coordinated by international and national organisations have focused on the development of sustainable harvesting management plans for community concessions and establishing xaté community cultivation projects (Wilsley and Radachowsky, 2007; Taylor, 2010). The level of illegal harvest that continues to supply the market is not known. In this chapter I aim to estimate the current intensity of harvesting carried out by Guatemalans in the Greater Maya Mountains and assess the socio-economics of xaté harvesting. I identify the characteristics of xaté harvesting households in Guatemala and assess local perceptions about the enforcement laws concerning xaté harvesting in Belize.

5.1.1 Study area

My study focuses on the Greater Maya Mountain area defined by Penn et al. (2008) which covers 3291² km in Belize and is located between the longitudes 89° 15° W and 89° 35° W and the latitudes 17° 15° N and 16° 15° N (Figure 5.1). This area is one of the largest relatively untouched tropical forest zones in Central America, with the Belize/Guatemala international border as the western boundary (Penn et al., 2004). It is likely that Guatemalan harvesters cross this boundary to harvest, as xaté has declined in Guatemala due to over-harvesting and high levels of deforestation (Radachowsky, 2003; Bridgewater et al., 2006). Xaté is found throughout the Greater Maya Mountains and has not been historically exploited. Some evidence suggests xaté is declining across the Greater Maya Mountains due to over-harvesting (Porter Morgan, 2006; Penn et al., 2008). The Belizean Defence Force patrols the border and harvesters risk a \$1000 fine and six-month imprisonment (Belize Forest Act 2000). There has previously been gunfire exchange between harvesters and the Belize Defence Force, which creates an additional risk to harvesters (Bridgewater et al., 2006; Prensa Libre, 2012).

I focus my research on villages in Guatemala within 10 km of the Belize/Guatemala border. Guatemala has previously claimed sovereign rights over Belize and this border remains disputed (Perez, 2010). In recent years xaté cultivation projects have been initiated in forest edge communities in both Belize and Guatemala.

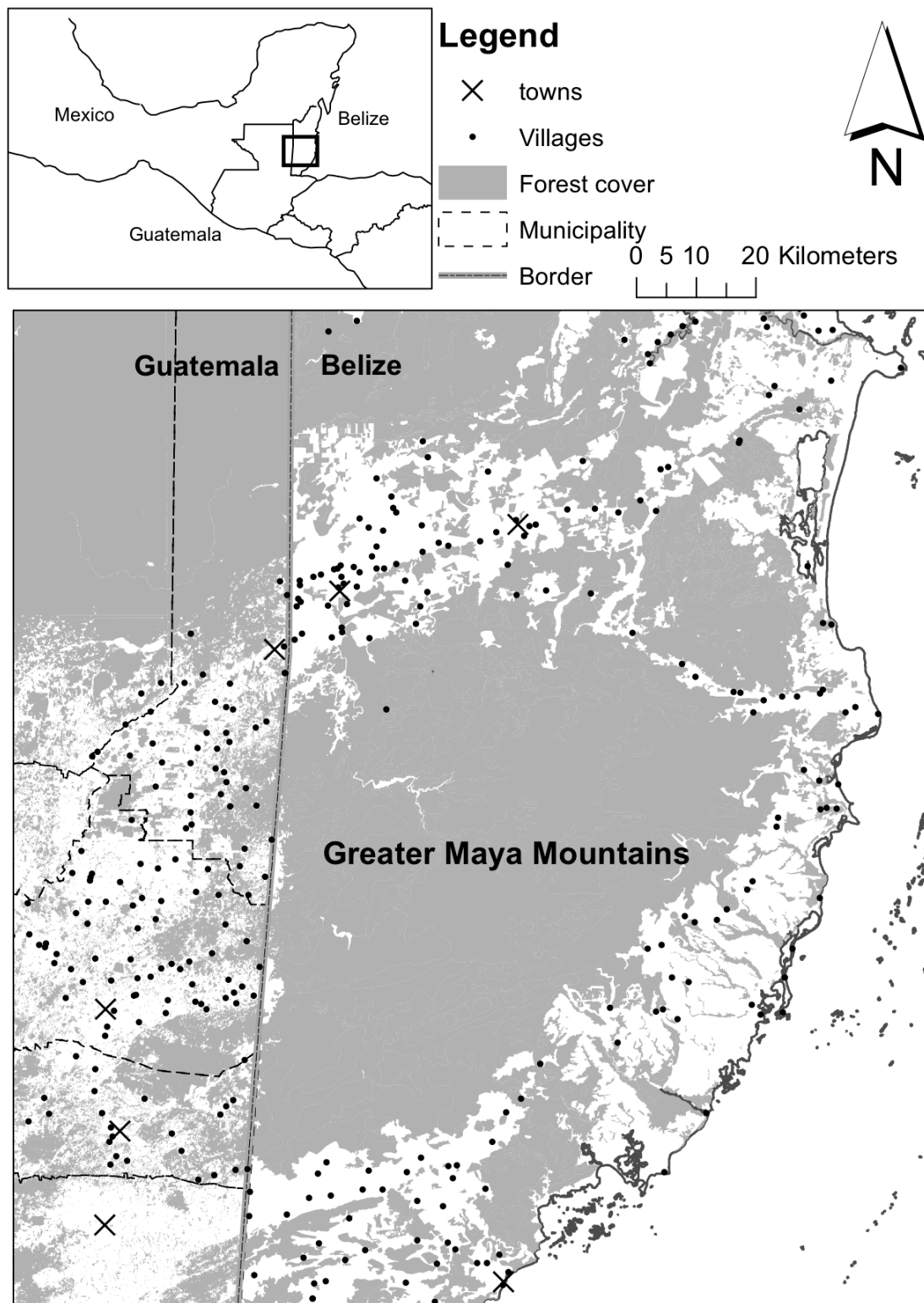


Figure 5.1: Data layers provided by GIZ Guatemala (GIZ, 2012) and the Belize Environment Resource Data System (Belize Environment Resource Data System, 2011)

5.2 Methods

Asking questions about illegal activities presents ethical challenges as researchers have a responsibility not to cause harm to informants (Society for Economic Botany, 1995). There are also challenges in terms of data quality, as informants may not reveal their behavior truthfully (St John et al., 2010b). Both of these issues are best addressed by ensuring informants understand that responses will be used for research only and that individuals or communities will not be identifiable from the data. I therefore do not name the villages I visited, recording only the names of municipalities. Prior to starting the study, I visited local leaders in each village to discuss the research and to ask them to communicate my intentions to the villagers. This ensured that potential informants knew I would ask questions about wild harvesting of xaté before agreeing to be interviewed. At the start of each interview I stated the purpose of the research and that I would not record the names or identify individuals. Informants were reminded that taking part in the interview was voluntary and they were allowed to discontinue the interview at any time (Appendix D).

5.2.1 Sampling strategy

To estimate harvest intensity by Guatemalans and the characteristics of Guatemalan harvesters, I focused my sampling efforts on the western boundary of the Greater Maya Mountains (Figure 5.1). I used detailed maps to develop a sampling frame of all villages within 10km of the western boundary (GIZ, 2012). Using a random number generator in R (R Foundation for Statistical Computing, 2009), I randomly selected nine villages from a total of 40, stratified by the three municipalities bordering the Greater Maya Mountains. After gaining permission to carry out the study from local leaders I used a systematic sampling strategy and a randomised starting point based on census data for each village (Petén Municipality Health Census, 2011). I sampled every n th house, dependent on the size of the village to ensure widespread coverage of the entire village. I defined a household as people living together and sharing regular meals. My aim was to sample a minimum of 30 households in each village. In villages that had less than 30 houses I sampled as many houses as possible.

5.2.2 Data collection

Data were collected during 8 weeks from December 2010 and 7 weeks from January 2012. I developed a questionnaire to ask about household livelihoods activities. One of the research assistants translated it from English to Spanish and it was back translated to English by a different research assistant to check for consistency in the meaning of the questions. All interviews were carried out in Spanish, except for one village where I required Q'eqchi' translators. I arranged interviews by asking the head of household if they would participate in our study. If the head of the household was not available, I would ask the next appropriate person in the household. I carried out a pilot study of ten interviews in a single village within the study area. No major revisions of the questionnaire were needed although I altered the wording of some questions to reflect local terminology and so I do not include the pilot study data in the analysis.

I asked questions about the number of people in the household, length of time lived in the village, amount of land owned or rented, the main livelihood activities of the household and whether anyone in the household harvested xaté or cultivated xaté. At the beginning of the interviews I did not specifically ask if people from households harvest across the border. If individuals said they harvested, without a specific location, I later asked them if they ever crossed the border. I asked all respondents to estimate the number of harvesters in their village and whether they knew anyone that had been caught illegally harvesting. If they knew someone who was caught I asked what was the penalty received. If the respondent indicated members of the household were harvesters, I asked an additional set of questions about the costs and income generated from harvesting. I asked about the current price paid for xaté leaf, how long it takes to walk to a good harvesting location, the length and frequency of harvesting trips, the amount collected per trip, the number of leaves harvested per plant and the equipment used. At the end of the questionnaire all survey respondents were asked open-ended questions to investigate perceptions about the risk and penalties for harvesting across the border.

To triangulate our estimates of harvest intensity and quantities harvested I identified key informants through discussions with Belize Botanic Garden and CONAP (Consejo Nacional de Areas Protegidas, the government organization responsible for managing

protected areas). I interviewed 7 people involved in the buying, exporting, management or monitoring of xaté. These semi-structured interviews provided information about quantities of xaté sourced from cultivation and the wild, and estimated monthly exports. I also visited a xaté leaf processing factory to estimate the number of leaves prepared for export.

5.2.3 Analysis

One respondent reported to have over 100 times the average amount of land owned. Discussions with local respondents suggested this was unrealistic, so I excluded this respondent's data from our analysis. I used a binomial response mixed effects model to estimate variables predicting households harvesting xaté. I first developed a global model with the following predictors: number of people living in household, length of time living in the village, amount of land owned, amount of land rented, distance to the Belize border, distance to the nearest town (defined as a settlement with >1000 inhabitants). Table 5.1 shows a summary of variables modelled. The corrected AIC (AICc) was used to rank the global model and 22 candidate simplified models and to calculate the relative weight of each model. Following Burnham and Anderson (2002), I selected the best-supported model as the model with the lowest AICc score.

To estimate the harvesting intensity in the study area I extrapolated from the results by multiplying the percentage of respondents identifying themselves as harvesters in each municipality, with the total number of houses in each municipality. My data from harvesters allows me to extract mean estimates and standard errors for the costs and income generated from harvesting. I calculate these estimates for the following measures: time spent harvesting, number of leaves collected per day, frequency of harvest trips, length of harvest trips, time required to reach a good harvesting area and the equipment needed for harvesting. To estimate the number of leaves annually extracted per individual, I multiply the number of leaves harvested per day by the length of harvesting trip, multiplied by the number of trips per year. From our open-ended questions I am able to extract key statements to investigate the perceived risk of harvesting. These were transcribed during the interview in Spanish and translated into English.

Table 5.1: Descriptions of variables included as predictors of harvesting households. Sample size = 222. The mean, median and 95% confidence intervals of the mean are presented.

Variable	Type	Median	Mean	95% CI	
				lower	upper
People in household (number)	Continuous	6	6.65	6.23	7.05
Time lived in village (years)	Continuous	17	18.41	16.89	19.92
Land owned (hectares)	Continuous	0	8.13	5.96	10.30
Land rented (hectares)	Continuous	0.69	1.42	1.17	1.67
Distance to border (km)	Continuous	3.5	4.71	4.36	5.06
Distance to market (km)	Continuous	24.7	24.02	23.02	24.61

5.3 Results

Of my sample of 222 households, 58 identified their household as harvesting xaté (Table 5.2). Not all respondents were happy to discuss harvesting in detail and so I collected the detailed harvesting survey from 45 respondents. I had a high response rate, with 3 people or less in each village declining to answer the questions.

5.3.1 Estimating harvesting intensity

Our study estimates that 26% (58 of 222 surveyed) of households are engaged in xaté harvesting. All harvesters that agreed to answer questions about their activity (45 of the 58 harvesting households) said that they predominantly harvested across the border in the Greater Maya Mountains. Assuming the sample is representative of the total number of households in the study area (Table 5.2) there are approximately 494 harvesting households in the three municipalities. Harvesting households have a mean of 2 (± 0.4 , 95% CI) people regularly harvesting. I therefore estimate roughly 1000 people illegally harvesting across the border in the Greater Maya Mountains. All respondents were asked if they knew anyone from their village that harvested across the border; 53% said they did. However, I cannot determine whether harvesters focus their efforts exclusively in the Greater Maya Mountains.

My estimate of the total number of active harvesters is close to the estimates provided by the exporters, government officials and xaté middle-men I interviewed. One exporter interviewed provided the highest estimate and suggested approximately 1400 people

Table 5.2: Sample sizes and estimates of harvesting households in three municipalities bordering the Greater Maya Mountains. In each municipality 3 villages were sampled. I present the data at municipality level to retain village anonymity.

<i>Municipality</i>	<i>Total houses in Sample villages</i>	<i>Sampled houses in sampled villages</i>	<i>Harvesting houses in sample villages</i>	<i>% of sample harvesting</i>	<i>Total houses in municipality</i>	<i>Estimated households harvesting in municipality</i>
1	310	93 (30%)	23	24.7	841	207.7
2	132	48 (36%)	12	25.0	805	201.89
3	247	82 (33%)	23	28.0	301	84.28
Total	689	223	58	25.9	1947	493.87

are harvesting across the border in the Greater Maya Mountains. The lowest estimate was from a government official who estimated 800 active illegal xaté harvesters in the Greater Maya Mountains. The interviews indicate that illegal harvesters collect a mean of 921 (± 155) leaves per day (Figure 5.2). Each harvesting trip lasts on average of 7.2 days (± 1.7), with an average of two trips in every month of the year. Based on the estimate of each harvesters extracting 921 leaves per day, harvesting for approximately 14 days per month with trips in every month of the year, and assuming all harvesting effort is within the Greater Maya Mountains, each harvester extracts $\approx 160,000$ leaves per year. Multiplying this with my estimate of harvesters active in the Greater Maya Mountains (1000), I estimate ≈ 160 million leaves are extracted each year. As the interviews provide only a snapshot of the xaté trade at one point in time, a high level of uncertainty is to be expected for the annual total harvest. Nonetheless, the amount extracted from the Greater Maya Mountains is likely to be substantial. Harvesters reported demand for xaté throughout the year, with an increase in February and March, corresponding with Valentine's Day and Mother's Day. The exporter interviewed also reported increased demand in February and March. During one interview with an exporter at a processing factory an order of over 2 million leaves was being prepared for export to Miami. The exporter indicated there is a regular export most weeks of the year and that he aims to source 50% of what he exports from cultivation. However, I am unable to verify this claim.

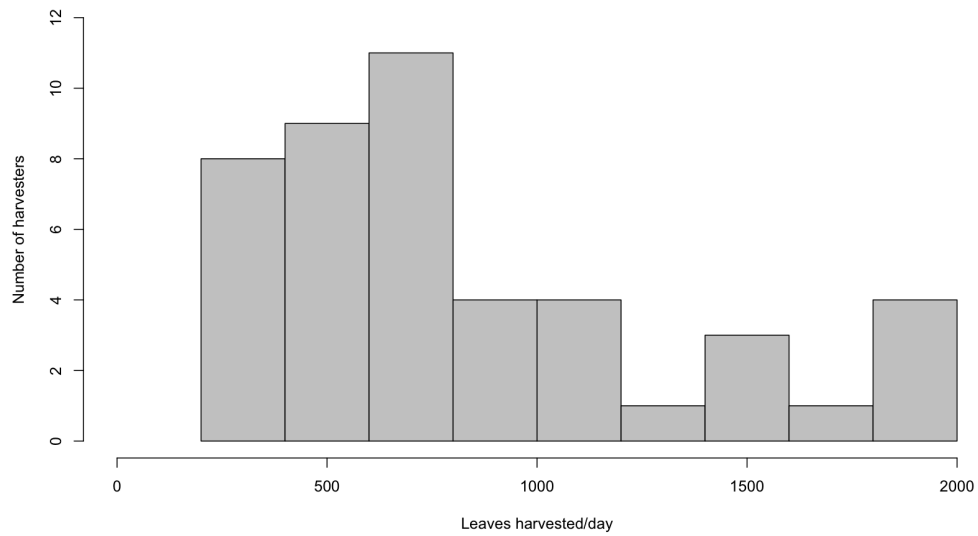


Figure 5.2: Estimated distribution of number of xaté leaves harvested per day by a single harvester ($n = 45$, mean = 921.7)

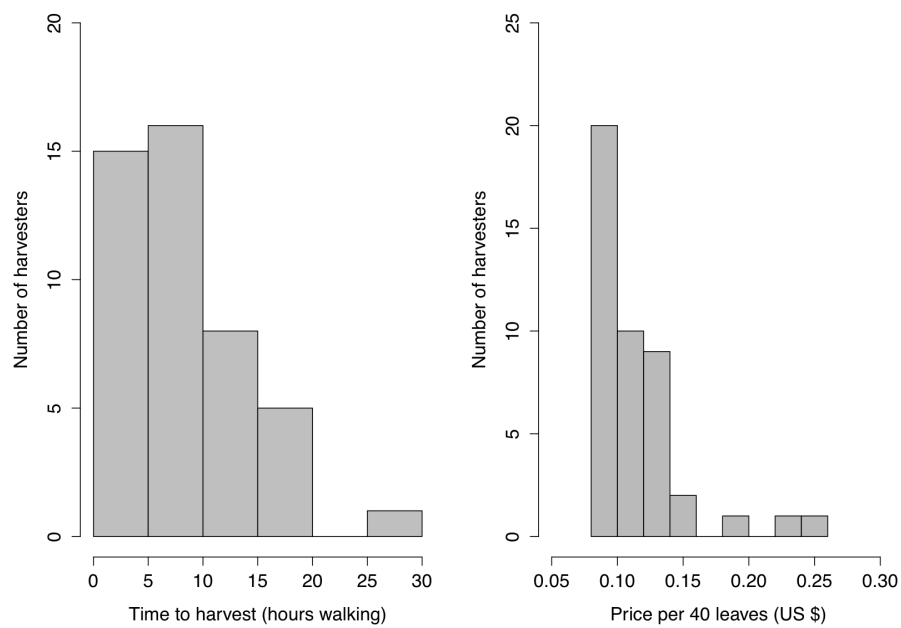


Figure 5.3: The time taken to walk to a good harvest location and price paid to harvesters per 40 leaves ($n = 45$).

5.3.2 Socio-economics of wild harvesting

Harvesters generally walk for 8 hours before collecting xaté (Figure 5.3) and only require basic equipment for harvesting; a machete and a bag for harvested leaves. Harvesters often get paid per bundle of 40 leaves (locally known as a ‘grusa’). I estimate the mean payment for 40 leaves is US\$0.12 (± 1.2) (Figure 5.3). Assuming harvesters extract $\approx 160,000$ leaves per year, harvesting can provide an annual income of $\approx \$480$. As harvesters generally go on harvesting trips twice a month, which last 7 days, there is time available to also earn income through other sources. Agricultural work is one of the few alternative sources of income in the region. The minimum daily wage for agriculture workers has recently been set to \$8 per day (QIL Abogados, 2011). However, it is unlikely that consistent work is available to rural villagers. The per capita Gross National Income of Guatemala is \$2740, however this is not evenly distributed through the population of Guatemala. Over 80% of the population in our study region are classed as ‘poor’ or ‘extremely poor’ and living on less than US \$1.25 per day (World Bank, 2004b,a).

5.3.3 What are the characteristics of harvesting households?

Table 5.3 presents a summary of 10 (of the 22) candidate models with the lowest AICc, estimating the characteristics of xaté harvesters. Although 2 models are within 2Δ AICc I present the model with the lowest value and the fewest number of parameters. Figure 5.4 shows the parameter estimates for the model with the lowest AICc. The predictors retained in this model are the number of people in the household, years lived in the village and amount of land owned. This model indicates that the longer someone has lived in the village the more likely they are to harvest. The negative coefficient for the amount of land owned suggests that people with less land are more likely to be harvesters.

Table 5.3: Summary of candidate models with the lowest AICc, ranked by delta AICc

house size	lived in village	own land	rent land	distance market	distance border	AIC	AICc	Δ AICc
✓	✓	✓				243.98	244.17	0.00
✓	✓	✓	✓	✓		245.36	245.75	1.59
✓		✓			✓	246.65	246.83	2.67
		✓				246.90	246.96	2.79
		✓	✓			247.13	247.24	3.07
		✓		✓		247.62	247.73	3.57
		✓		✓	✓	247.87	248.05	3.89
		✓	✓	✓	✓	247.87	248.05	3.89
✓		✓	✓			248.44	248.72	4.55

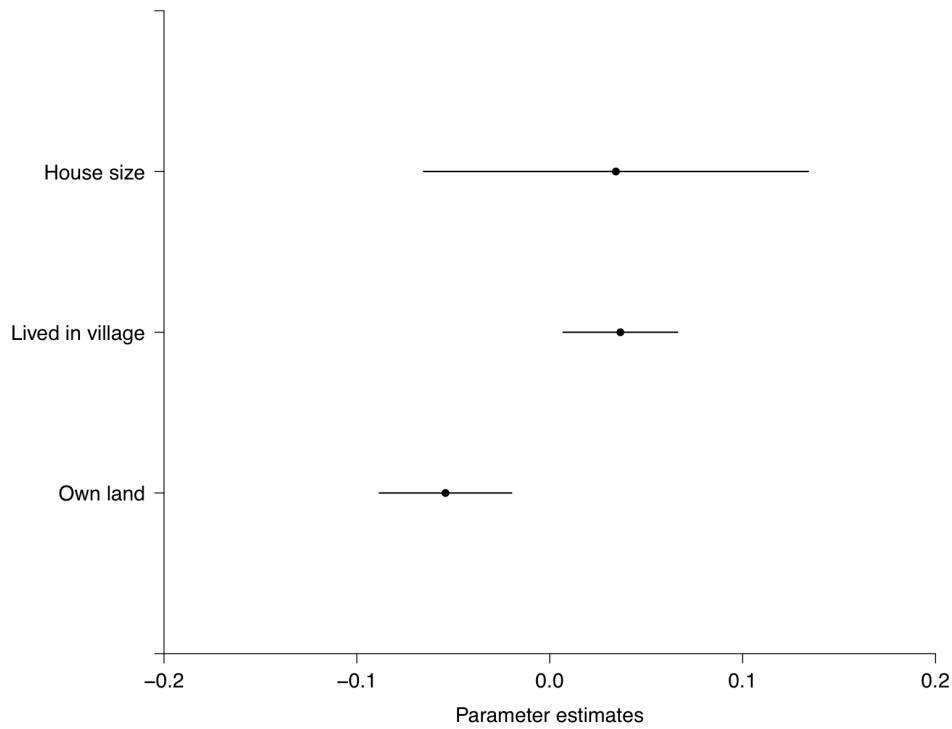


Figure 5.4: Coefficient plot showing estimates for the best supported model (Δ AIC=1.59) predicting harvester characteristics. Intercept = -2.30. The central circles are the mean estimate for each parameter and the lines indicate 95% confidence intervals. The further right the estimate, the more likely xaté harvesting will occur i.e. people that have lived in the village for longer and do not own land are more likely to harvest

5.3.4 Perceptions concerning enforcement of xaté harvesting laws in Belize

From my sample 76% of harvesters indicated they were either 'worried' or 'very worried' about getting caught. Many stated that there are no alternative sources of income and so they continue to harvest.

I was beaten when they caught me but they let me go, regardless, we have to go [harvesting] (Anonymous 1)

One individual indicated that he did not believe he was harvesting illegally when in Belize. The respondent made a political statement when asked "do you harvest across the line [border]". Although clearly aware of the national border he replied:

What line? (Anonymous 2)

Another respondent stated:

there is no border, so I am still harvesting in Guatemala (Anonymous 3)

Some harvesters indicated that the chances of getting caught were very low, however others suggested they would not harvest xaté because of the risk of getting caught. Respondents reported that there had been a recent incident where a harvester was shot and killed in Belize.

It is a big forest and there is little chance of seeing people, but now we have to walk further to collect (Anonymous 1)

I do not go, since the person was killed a month ago (Anonymous 4)

5.4 Discussion

5.4.1 Harvesting intensity in the Greater Maya Mountains

My results suggest xaté harvesting is a common source of income for Guatemalan households located near the Guatemala/Belize border. Harvesting households make up approximately 26-28% of the villages within 10km of the border and are geographically widespread along the length of the border region. All harvesters I spoke to reported crossing the border to harvest xaté in the Greater Maya Mountains. I acknowledge that a limitation of our study is that some respondents may be unwilling to discuss illegal harvesting (St John et al., 2010b), suggesting that the estimate should be taken as a lower bound. My research therefore suggests that the quantity of xaté leaf harvest from the Greater Maya Mountains is substantial, despite efforts to encourage cultivation to take pressure off the wild populations. I have shown that the costs of harvesting are relatively low, with little equipment needed and an open access resource. However the cost of getting caught harvesting is potentially high. My interviews suggest that harvesters are walking further into Belize, increasing the risk of getting caught and increasing the costs of harvesting. Harvesters are concerned about the risk of getting caught but feel that there are few options for generating income. The risk of capture in Belize is enough to deter some harvesters and suggests that increased enforcement may reduce wild harvesting efforts. However, some of the respondents stated they did not recognise the border and will continue to harvest.

To assess the level of sustainability of this harvest, detailed data on reproductive rates and the impact of harvesting on leaf production is needed. Previous studies on closely related *Chamaedorea* species indicate that harvesting can have a negative impact on reproductive rates (Endress et al., 2006; Martinez-Ramos et al., 2009). It appears that *Chamaedorea* species can initially withstand leaf harvest by producing more leaves that are smaller than average, but if harvest is sustained over longer periods leaf production rates eventually decrease (Endress et al., 2004b). This is an important consideration for xaté exploitation, as only leaves above a certain size are marketable and declines in the leaf size will reduce profitability of harvesting. Xaté harvesters generally walk a full day before harvesting and are reportedly having to walk further than previously.

Similar trends have been observed for other harvested species and is often an indication of declining population levels. However, the rate of deforestation is also high in the region (Bray et al., 2008) and is likely to contribute to the decline of xaté.

5.4.2 Alternatives to harvesting

The provision of alternative livelihoods is often proposed as a method to reduce unsustainable resource use (Sievanen et al., 2005; Hill et al., 2011). However, there are few examples of both biological and development success as a result of alternative livelihood programmes (Milner-Gulland, 2012). Understanding opportunity costs of the resource users, and the benefits they derive from a resource, can provide valuable information to ensure alternative livelihoods programmes can meet the financial needs of harvesting households. The Convention on Biological Diversity 6th technical report recommends cultivation of non-timber forest products as an alternative to wild harvesting (Secretariat of the Convention on Biological Diversity, 2001). Recently there has been substantial investment from international and national organisations into xaté cultivation projects in both Belize and Guatemala (Williams et al., 2012b). The success of these projects to meet local livelihood needs and reduce pressure on wild populations is yet to be assessed. Recent research on a closely related xaté species, *Chameadoreia seifrizii* Burret, has suggested that establishing cultivation is unlikely to reduce harvesting pressure on wild populations (Lopez-Toledo et al., 2011). The biological characteristics of a species, and potential profit from cultivation, are factors that also need to be considered when promoting cultivation as an alternative livelihood strategy (Jones et al., 2007). Those without secure land tenure are unlikely to invest in cultivation (Godoy, 1992), and our results indicate xaté harvesters are overwhelmingly without secure tenure. Encouraging cultivation may therefore have limited impact on peoples's livelihood decisions.

5.4.3 Policy implications

In 1989 the Convention on International Trade in Endangered Species (CITES) rejected a United States proposal to list xaté on Appendix 2 (Convention on International Trade in Endangered Species of Wild Fauna and Flora, 1989). The Guatemalan government forestry department responsible for managing protected areas (CONAP) is now considering proposing xaté for CITES listing (Palacios Aldana, 2012). This policy will

help to control and monitor the trade of xaté but may create a disincentive for people considering starting xaté cultivation. If CITES is not applied to cultivated sources of xaté, plantations could provide an opening for laundering illegally harvested leaf. This situation has been observed within the international trade of other species, such as the green python exported for the pet trade (Lyons and Natusch, 2011). My results indicate the quantity currently illegally harvested from the Greater Maya Mountains is approximately 160 million leaves annually. This finding can contribute towards an assessment of the impact of trade on the wild population - as required by CITES. To support the CITES assessment I suggest that a formal conservation classification in accordance with the Red List criteria is also needed. One of the aims of the IUCN Palm Specialist Group is to identify priorities for assessing palm species conservation status (IUCN, 2012). Because of the substantial extraction levels of xaté in Belize, I suggest that *C. ernesti-augusti* should be a priority for Red Listing. However, additional fieldwork would be needed to assess the area occupied by xaté across Central America and to determine the scale of additional threats, such as deforestation.

Target 11 of the Global Strategy for Plant Conservation (GSPC) aims to have no plant threatened by international trade by 2020 (Secretariat of the Convention on Biological Diversity 2012). The related target 12 states that all plant products should be sustainably sourced by 2020. These two targets are often the least implemented of all the GSPC targets (Paton and Nic Lughadha, 2011; Williams et al., 2012a) and to achieve these ambitious aims the conservation community needs to develop insight into the motivations and constraints on harvesters. Policies that aim to encourage adoption of cultivation must provide incentives to ensure it is an attractive alternative source of income. Xaté harvesting can provide an important income, relative to local alternative livelihoods, and has few barriers to entry because of the ease of collecting and the lack of specialist equipment needed. Increasing the costs of harvesting through increased risk of getting caught could potentially encourage people to switch from harvesting to cultivation. However, this assumes that harvesters have the technical skills needed for cultivation and the resources available to establish plantations (Williams et al., 2012b). Other policies that could result in sustainable xaté exploitation, such as a premium price for cultivated leaf or increased penalties for illegal harvesting, could be explored to understand under what conditions cultivation could reduce pressure on the wild population.

5.5 Conclusions

My study shows that many Guatemalan households living close to the Belizean border harvest xaté and it is a relatively profitable activity. The quantities of xaté extracted are substantial, but further research would be needed to examine the sustainability of extraction. Cultivation is often proposed as an alternative to wild harvesting to reduce pressure on wild populations and improve local livelihoods. I have demonstrated that households without secure land tenure are more likely to wild harvest. Individuals, with no secure land tenure may be unlikely to be in a position to invest in cultivation; casting some doubt that cultivation will take pressure of the wild population unless land tenure issues are solved. I suggest that conservation interventions promoting cultivation need to understand harvester motivations and constraints. Further research could focus on understanding under what conditions cultivation could reduce pressure on wild populations and what incentives would encourage harvesters to adopt cultivation.

Chapter 6

When can cultivation reduce pressure on wild harvested plant populations?

6.1 Introduction

Overexploitation of socio-economically important plant species is a major threat to biodiversity (Ticktin, 2004; Millenium Ecosystem Assessment, 2005). However, despite global targets (Secretariat of the Convention on Biological Diversity, 2002), little progress has been made in promoting sustainable use (Secretariat of the Convention on Biological Diversity, 2009; Williams et al., 2012a). The domestication of valued wild species is frequently proposed as a method to reduce pressure on wild harvested populations while potentially improving local livelihoods (Sarasan et al., 2011; Nogueira and Nogueira-Filho, 2011). Many projects have been initiated to supply animals or their parts from captive sources, including the production of bear bile medicine (Dutton and Hepburn, 2011), tiger skins (Kirkpatrick and Emerton, 2010) and pythons for the pet trade (Lyons and Natusch, 2011). Although appealing, evidence supporting such wildlife farming as a conservation strategy is scarce (Bulte and Damania, 2005). Cultivation of wild-harvested plant species has similarly been promoted as a conservation approach (Entwistle et al., 2002; Schippmann et al., 2002; Canter et al., 2005). There are few studies which evaluate the success of programmes encouraging people to take up cultivation, and none that I know of which explore whether increased cultivation does improve the status of over-exploited plants.

People may be encouraged to switch from wild harvesting to cultivation by increasing the costs of wild harvesting through increased enforcement (Keane et al., 2008), or increasing the benefits from cultivation such as and providing incentives such as price

premiums (Wilsey and Hildebrand, 2010). Biological characteristics of species are also likely to influence the costs and benefits of cultivation, and therefore affect cultivation uptake. Factors such as growth rates (Jones et al., 2007) and the resilience to frequent harvesting (Lopez-Toledo et al., 2012) will vary from species to species, meaning some are more suitable for cultivation than others (Diamond, 2002). The socio-economic characteristics of communities are likely to determine whether households can adopt cultivation (Chukwuone, 2009). Land tenure has also been highlighted as a key constraint in the adoption of cultivation of new species (Godoy, 1992). To predict when cultivation could be an effective conservation strategy, an integrated understanding of peoples' socio-economic characteristics and the biology of the over-harvested species is therefore needed.

Bioeconomic models integrate biological and socio-economic components to explore the dynamics of a system and provide a useful tool for understanding natural resource exploitation (Ling and Milner-Gulland, 2006). This approach requires explicit consideration of the components of a system and can identify key factors driving dynamics and determine how individuals in the system respond to changes (Grimm et al., 2006). Research into fisheries and bushmeat exploitation have widely applied bioeconomic models (Knowler, 2002; Damania and Bulte, 2007). There are currently no examples of bioeconomic models investigating over-exploitation of plant harvesting systems. Here I draw upon methods developed in the fisheries and bushmeat literature and apply these to the harvesting and cultivation of a socio-economically important, wild harvested plant species. My aim is to investigate under what conditions cultivation can reduce pressure on wild harvested populations. I assess what changes could encourage people to cultivate and how increased cultivation might impact wild populations. Firstly I examine different policy levers that could be used to encourage cultivation; increased enforcement to deter wild harvesters and a premium price for cultivated plant material. I then investigate a biological characteristic: the time from planting to harvesting and assess how this impacts peoples' decision to cultivate. Finally I examine the influence of land ownership and opportunity costs of labour on decision-making.

6.2 Methods

6.2.1 Model structure

I model a community of n individuals who can choose from wild harvesting, cultivation or alternative livelihood activities to provide a portion of their livelihood. All individuals have the same options for livelihood activities, but differ in the amount of land owned. I am assuming that the demand for the plant material is unchanged through time (i.e. that the market is always large relative to the supply from the source considered) and the two sources (wild and cultivated) are perfect substitutes. The three livelihood options differ in the impact on the wild population (Figure 6.1). If an individual chooses to wild harvest they will take plant material from the wild population, influencing the number of wild plants and reproductive capacity. If individuals choose to cultivate, in the first year of cultivation they remove seeds from the wild population to establish plantations with the amount taken proportional to the amount of land an individual owns. If an individual chooses alternative income there is no impact on the wild population. The income an individual can earn from cultivation is based on the amount of land they own. An individual's choice between the three options (wild harvesting, cultivation or alternative income) is based on maximizing income (Figure 6.2). The model runs on an annual time step with individuals choosing their livelihood activity each year. Table 6.1 describes the model parameters and Table 6.2 summarises the model outputs.

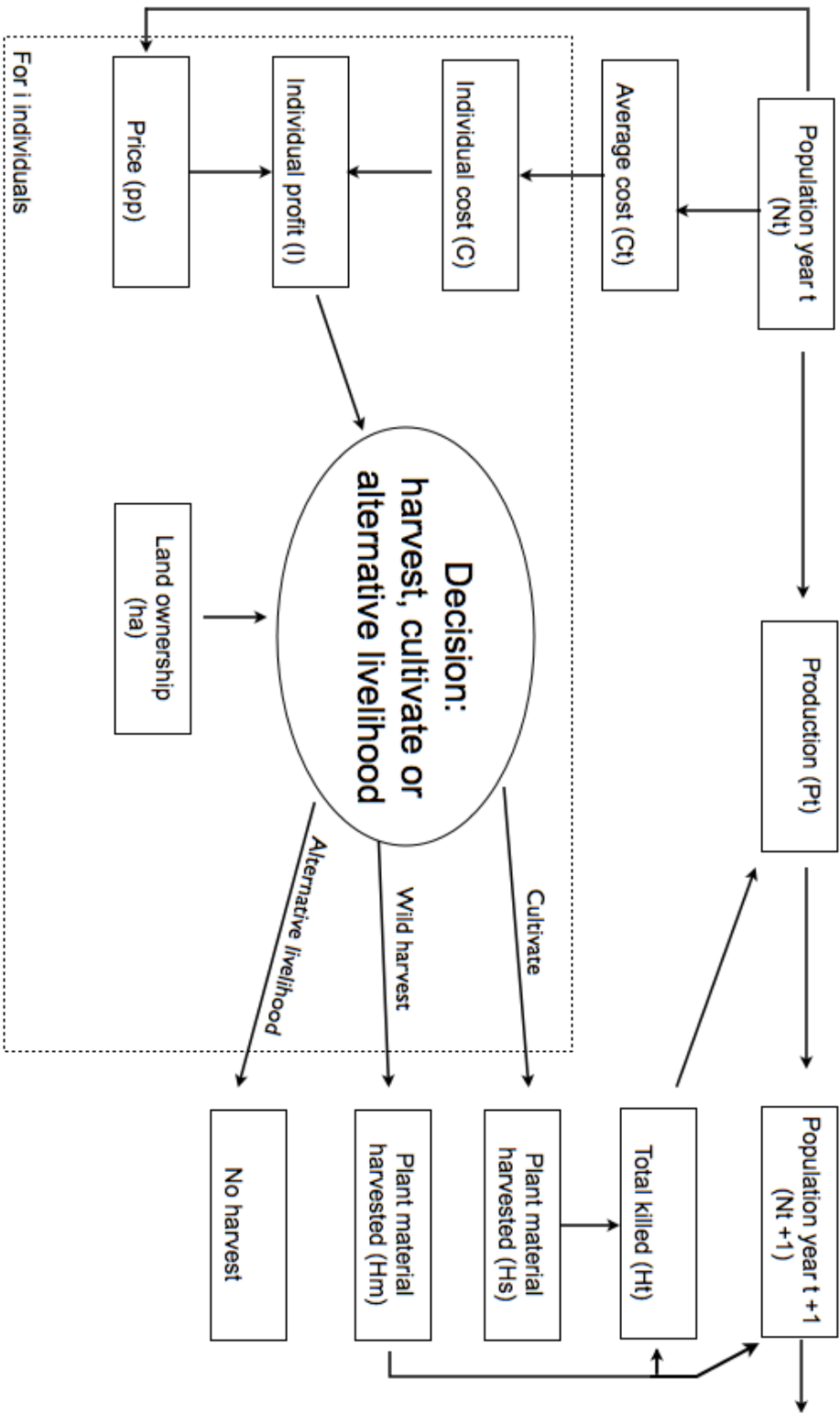


Figure 6.1.: Conceptual diagram summarising the decision to wild harvest, cultivate or find alternative livelihoods. The rectangles represent variables and constants, the oval is a decision point, and the arrows are causal links. Adapted from Milner-Gulland and Rowcliffe (2007)

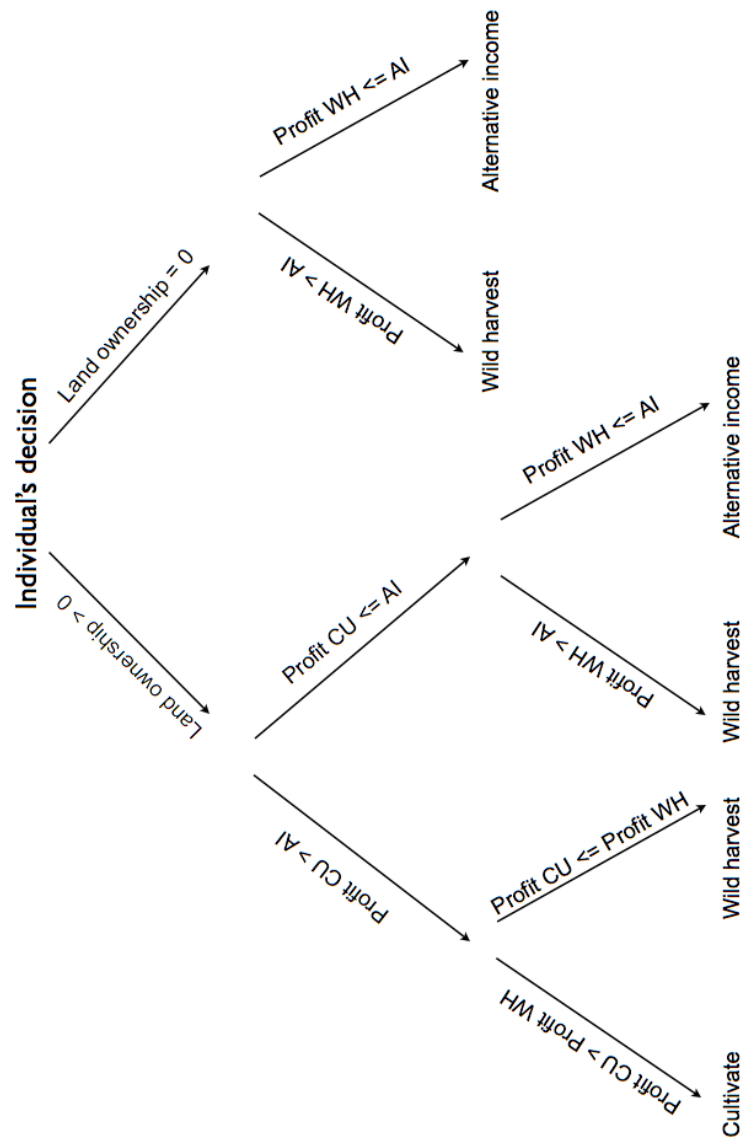


Figure 6.2: Decision tree for individuals. If individuals have no land there is no option of cultivating. Individuals will choose either wild harvesting or alternative livelihoods. If individuals own land they choose between cultivation, alternative livelihoods. Comparing livelihood options is based on maximising net profit. AI= Alternative income, CU = cultivation, WH = wild harvesting.

Table 6.1: Model parameters and descriptions, illustrated with estimates and sources for the chosen case study of xaté, a harvested and cultivated palm in Central America (Williams et al., forthcoming)

Parameter	Description	Units	Estimate	Source
N_0	Population at time 0	[-]	58768850	Penn et al. (2008)
K	Carrying capacity	[-]	58768850	Penn et al. (2008)
λ	Intrinsic rate of increase	[-]	1.147	Endress et al. (2006)
M_j	Mortality rates		Fig.6.3	Endress et al. (2006)
ν	Seed viability	[%]	30	Endress et al. (2006)
A	Land cultivated	[ha]	0.1 ± 0.01	Williams et al. (forthcoming)
C_w	Opp cost for minimum distance walked	[\$/day]	1.25	World Bank (2004b)
C_{opp}	Opportunity cost	[\$/year]	456.25	World Bank (2004b)
C_{setup}	Set Up Cost	[\$]	50	Interviews with cultivators
C_{maint}	Maintenance cost	[\$/year]	10	Interviews with cultivators
t_c	Time spent cultivating	[days/year]	24	Interviews with cultivators
t_h	Time spent harvesting	[days/year]	160	Williams et al. (forthcoming)
D	Probability of detection	[-]	0.01	Williams et al. (forthcoming)
F	Fine	[\$]	1400	Belize Forest Act (2011)
p_{Ph}	Price for WH plant material	[\$/leaf]	0.003 ± 0.002	Williams et al. (forthcoming)
p_{Pc}	Price for CU plant material	[\$/leaf]	0.003 ± 0.002	Interviews with cultivators
h_{tot}	Total amount of plant material harvested	[1/year/person]	160000 ± 20000	Williams et al. (forthcoming)
Q	Plants cultivated	[1/ha]	20,000	Interviews with cultivators
Y	Yield	[1/year/ha]	60,000	Interviews with cultivators
r	Discount rate	[%]	10	Haggard et al. (2005)
t_w	Time from planting to harvest	[years]	4	Interviews with cultivators

Table 6.2: Model outputs

Parameter	Description
P_t	Productivity
N_t	Population at time t
H_t	Total plant death due to harvest
H_m	Number of plants killed due to wild harvest activity
H_s	Number of Plants killed due to cultivation activities
C_H	Costs of wild harvesting
C_C	Costs of cultivation
I_H	Net profit from harvesting
I_C	Net profit from cultivation
WH	Number of wild harvesters
CU	Number of cultivators
AL	Number in alternative livelihoods

Biological model

Unlike most animal harvesting systems, a plant may not be totally removed from the population when harvested, so can still contribute to next year's population. The impact on productivity can vary depending on the plant part harvested (Ticktin, 2004). Harvesters can directly kill a plant by increasing the probability of plant mortality e.g. removing leaves, (Lopez-Toledo et al., 2012) and indirectly impact the total population by reducing reproductive capacity e.g. harvest of seeds, (Bernal, 1998). I model the impact of harvesting on the reproductive population by modifying a logistic density dependent population growth model to provide

$$P_t = \lambda \left(1 - \frac{H_t}{N_t}\right) \left(1 - \frac{N_t}{K}\right) N_t \quad (6.1)$$

where λ is reproduction rate, N_t is this year's population, K is carrying capacity. H_t is the total number of plants removed from the population due to harvesting. Using $1 - H_t/N_t$ enables us to calculate the proportion of the total population remaining after harvesting and allows us to scale population growth rate accordingly. H_t is a function of H_s , the number of plants removed from the total population due to harvesting seeds to establish plantations and H_m , the number of plants killed through increased mortality

due to harvesting. By combining H_s and H_m I impact the population growth rate and therefore indirectly impact the total population

$$H_t = H_s + H_m. \quad (6.2)$$

where H_s is the number of plants removed due to cultivation activity and represents the number of seeds harvested to establish plantations translated into the equivalent number of plants removed from the total population

$$H_s = \sum_i \frac{A_i \cdot Q}{v} \quad (6.3)$$

where A_i is the individual amount of land cultivated, Q is the number of plants that can be cultivated per hectare (I assume every individual will cultivate Q the maximum density of plants per area) and v is the ratio between reproductive success of cultivated seeds compared to wild seeds. The reproductive success describes the transition from seed to plant. If the reproductive success is equal for both cultivated and wild seeds, cultivation and wild harvesting have equal impact. I expect the seeds harvested for cultivation to have higher success in becoming mature plants, compared to seeds in the wild.

H_m is the number of plants killed through increased mortality due to harvesting. I calculate H_m from the probability of plant death, dependent upon h the amount of plant material harvested per plant. For each individual harvesting I assign how much plant material they harvest in total h_{tot} , and their collection pattern. Each individual's collection pattern is randomly assigned from a Poisson distribution and is h , the amount of plant material harvested per plant, until the total amount plant material harvested cc is met. Each amount of plant material harvested per plant h impacts the mortality rate of the plant M_j

$$H_m = \sum_{j=1}^n f_j M_j \quad (6.4)$$

where j represents wild plants and f_j denotes the frequency of h amount of plant material harvested per plant, M_j is the mortality of a plant for h amount harvested, and n is the maximum amount of plant material harvested per plant.

Next year's total population N_{t+1} is calculated from the current year's population N_t plus the productivity P_t and minus the amount directly killed through harvesting H_m

$$N_{t+1} = N_t + P_t - H_m. \quad (6.5)$$

Socio-economic model

I model i individuals, each maximising net income based on the costs and benefits calculated for three livelihood options. This determines the total number of people wild harvesting, cultivating or finding an alternative livelihood each year. The number of people wild harvesting determines H_m and the number of people cultivating determines H_s .

Harvester costs are a linear function of the plant population N_t . Total costs C_H includes the individual's opportunity costs C_{opp} per day multiplied by the time spent harvesting t_H , scaled by N_t to reflect population density. The total costs accounts for the minimum distance needed to walk to a harvest location, expressed in US \$ to reflect opportunity costs of the time taken. I also include E , the cost of getting caught illegally harvesting. Variability between individuals, due to differences in harvester skills and abilities is estimated as a normally distributed random variable $N(0, sd)$ with a standard deviation sd . The total cost for harvesting yields

$$C_H = (C_w + C_{opp} + E) \left(1 - \frac{N_t}{K} \right) + N(0, sd). \quad (6.6)$$

where E is the cost of getting caught, since wild harvesting may be an illegal activity. E is a calculated from the probability of detection D and the fine incurred F if caught harvesting and E is 0 if harvesting is legal

$$E = D \cdot F. \quad (6.7)$$

An individual's payment B_H from harvesting is the amount of plant material harvested h multiplied by the price received for the plant material pp_H

$$B_H = h_{\text{tot}} \cdot pp_H.$$

The net profit I_H is the total payment B_H minus the costs of harvesting C_H for each individual.

$$I_H = B_H - C_H \quad (6.8)$$

Each individual is randomly assigned an amount of land from a Poisson distribution and this remains fixed for the individual for each year simulated. The land an individual owns must be >0 to initiate cultivation. They can cultivate up to a fixed proportion of their land ensuring each individual still has land available for growing crops for subsistence. When an individual decides to cultivate I include the harvesting of plant material s to set up the plantation. This occurs only in the first year of cultivation and is based on Q , plant density per hectare, scaled according to A , the individual amount of land allocated for cultivation. Cultivation incurs a cost for set up and maintenance. The set up costs are paid only in the first year of deciding to cultivate, even if they later choose to wild harvest and then return to cultivation. Each year there is a maintenance cost for cultivation, which is based on the time investment and materials needed for the plantation. To represent variability between individuals due to differences in cultivator skills and abilities, I also include a random variable N in relation to costs

$$C_C = \begin{cases} C_{\text{setup}} + C_{\text{maint}} + C_{\text{opp}} \cdot t_C + N(0, sd) & \text{for } t = 1 \\ C_{\text{setup}} + C_{\text{opp}} \cdot t_C + N(0, sd) & \text{for } t \geq 1 \end{cases} \quad (6.9)$$

Individual annual payment from cultivation B_C is based on Y , the yield of the area cultivated, A and pp_C the price paid per unit of plant material.

$$B_C = YA \cdot pp_C \quad (6.10)$$

The net profit I_C is discounted using r (which includes risk discounting as well as pure time preference). This accounts for the time from planting to harvest t_w , where individuals wait for a return on investment and attempts to express the potential income in the future at a present day value. The cost of cultivation C_C is subtracted from the discounted payment to give net profit I_C

$$I_C = \frac{B_C}{(1+r)^{t_w}} - C_C \quad (6.11)$$

6.2.2 Case study

I explore the model using the case study, *Chamaedorea ernesti-augusti* (H.A. Wendl.) a palm species distributed in the seasonal forests of Guatemala and Belize and locally known as xaté (refer back to chapter 5 for further details about xaté).

In this model I assume people are rational profit maximisers, making livelihood decisions purely by estimating the relative time discounted costs and benefits of alternative livelihoods. Many studies have shown that other factors are likely to impact people's behaviour including attitudes, social norms and cultural significance (St John et al., 2010a), however as xaté has no local use and the harvest only started in Guatemala in the late 1970's (Bridgewater et al., 2006), people are likely to make harvesting or cultivation decisions based primarily on economic benefits rather than cultural or social influences. Xaté is a typical example of proposed cultivation schemes. The population is thought to be declining due to over-harvesting (Porter Morgan, 2006) and cultivation has been promoted by local conservation organisations aiming to improve livelihoods of the forest edge communities (Williams et al., 2012b). The xaté population has been estimated in a relatively discrete area (Penn et al., 2004) and patrols along the border occur to deter illegal harvesters, providing the opportunity to explore how changes in enforcement may influence uptake of cultivation.

6.2.3 Model parameterisation

Biological parameters

Penn et al. (2008) predict xaté abundance for different vegetation types in the Greater Maya Mountains and estimate the number of hectares covered by each vegetation type. To estimate the total xaté population in the Greater Maya Mountains, I multiply the estimated abundance for each vegetation type by the area covered by each vegetation type. Exploitation of *C. ernesti-augusti* in the Greater Maya Mountains has started within the last 10 years (Bridgewater et al., 2006). I assume that the population estimate by Penn et al. (2008) represents carrying capacity for the study site. I use a six year study conducted to investigate the impact of defoliation on demography of the closely related species *Chamaedorea radicalis* (Endress et al., 2006). I use this study to provide estimates of mortality under different harvesting regimes. Adult *C. ernesti-augusti* plants have a mean of 3.8 (± 0.1 standard error) leaves per plant and plants rarely have more than 5 leaves per plant (Williams unpublished data). Therefore I estimate mortality rates varying from 0 to 1 as the number of leaves taken increases from 0 to 5 leaves per plant per year (Figure 6.3). I use an intrinsic rate of increase (λ) of 1.14 (± 0.057) for population growth in the absence of harvesting (Endress et al., 2006), indicating an increasing population in the absence of density dependence.

Economic and household parameters

I sampled 45 wild harvesters (all Guatemalan) and 45 cultivators (26 from Belize and 19 in Guatemala) to provide estimates of the socio-economics of xaté harvesting and cultivation (sampling methods described in (Williams et al., forthcoming). As Belizeans largely do not wild harvest (Williams et al., 2012b) I parameterise the model to reflect socio-economics of Guatemalan people living within 10km of the Greater Maya Mountains, as these are the people whom interventions to encourage cultivation with the objective of reducing wild harvesting effort would be aimed at.

I simulate 2500 people, based on an estimate of the number of adults within the study region (Petén Municipality Health Census, 2011). Approximately 1000 people harvest at the outset of a model run, 20 people cultivate and the rest find alternative livelihoods. I use a Poisson distribution with a mean of 0.2 ha to assign land ownership per indi-

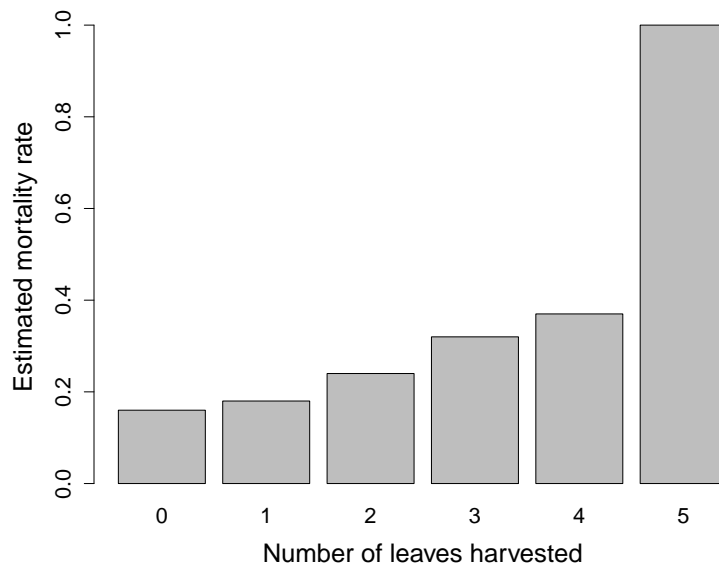


Figure 6.3: Estimated mortality rates for *Chamaedorea ernesti-augusti* under different harvesting regimes. Based on *C. radicalis* mortality rates from Endress et al. (2006)

vidual. Over 75% of households in the study region are subsistence farmers, renting small parcels, on a short-term lease, from the municipality (Fuentes et al., 2003; Shriar, 2011). As this land is on short-term rental I do not include it as land available for cultivating xaté.

Trends for Guatemala indicate an increased proportion of people working in formal employment over the last 10 years; however in my study region there remain few alternative livelihood activities and the proportion of people living in poverty has remained stable since the 1990's (Shriar, 2011). In 2003 it was estimated sixty-eight percent of the population in the Petén were living in poverty on less than \$1.25 a day (Fuentes et al., 2003; World Bank, 2004b). Recent figures indicate Guatemala's human development index has been increasing over the last 10 years, although the country still ranks amongst the lowest 30% of countries (United Nations Development Programme, 2011). My study region focuses on a remote area of the Petén, with little transport infrastructure and high dependency on subsistence agriculture (Fuentes et al., 2003). As consistent employment is difficult to find in my study region, I use the estimate of \$1.25 as a measure of daily opportunity cost. Opportunity costs are used to calculate the forgone income for the time spent harvesting or cultivating.

I estimate 160,000 leaves are harvested annually per individual (Williams et al., forthcoming) and harvesters report removing a maximum of 2 leaves per plant. I assume harvesters take a mean 2 leaves per plant and use a Poisson distribution to represent that a higher number of leaves could also be harvested from a plant. I specify a \$1000 fine if harvesters are caught wild harvesting (based on existing fines under the Belize Forest Act (2011)). Reports from the respondents in Guatemala indicate that detection is unlikely. I do not have accurate data for patrol rates along the border and so conduct a sensitivity analysis on how the probability of detection influences harvesters' decision-making.

Interviews with cultivators in Guatemala (chapter 5) indicate households plant xaté under forest canopy and most households are unlikely to have access to shade netting; only three out of 26 had used artificial shade netting. I therefore model plantations with minimal set-up costs that are established under forest cover. The interviews indicate that xaté leaf production is higher in cultivation than in the wild, and individuals harvest on average 3 leaves per plant per year from cultivated plants. There were reports of up to 6 leaves harvested per plant per year from cultivation, however the biological data on other *Chamaedorea* species suggests high harvest rates are likely to be unsustainable over the longer term (Endress et al., 2004a). I therefore model 3 leaves harvested per plant per year. I use an estimate from cultivation trials at Belize Botanic Garden to estimate approximately 20,000 plants can be cultivated per hectare, providing a yield of 60,000 leaves per hectare per year. I specify the price for cultivated leaf is the same as wild harvested (US \$0.003). Cultivators have to wait four years before receiving any return on investment. I include a discount rate of 10%, which is based on previous studies carried out agriculture economic analysis in Mexico (Haggar et al., 2005) and the forestry industry in Costa Rica (Kishor and Constantino, 1993). I also carry out a sensitivity study on the discount rate used (described below). In both Belize and Guatemala, xaté plantations are only legally established using seed from a certified source; however, 45% of the respondents indicated they collected seedlings from the wild to initiate cultivation. I include \$50 for cultivation set up costs to account for people buying equipment or supplies such as fertiliser. Respondents indicated that annual maintenance costs were low. Once a plantation is established, the majority of cultivators spend less than \$10 per year for materials need for maintenance. I include this \$10 into the total annual costs of cultivating. Individuals would on average spend 8 hours (± 2.7) per month maintaining the plantations (based on 1 hectare) and so I include 8 hours opportunity costs per month per hectare into the total costs of cultivating.

Sensitivity Analysis

To test the model sensitivity to the intrinsic rate of increase (λ) I simulate a range of λ values based on Endress et al. (2006). This study suggests a λ of 1.14 (± 0.057), in the absence of harvesting. I test five values within the 95% confidence intervals of the mean estimate (Figure 6.4a). Under default harvesting level and at $\lambda = 1.15$, the population reaches equilibrium at $\approx 55\%$ of carrying capacity. Figure 6.4b illustrates the livelihood choices of individuals under different scenarios of λ rate. The number of people cultivating does not change with different rates of population growth but the number of people wild harvesting increases with higher population growth rate. Overall, livelihood choices do not appear to be very sensitive to changes in λ . Under all λ values tested the majority of people find alternative income, between 30% and 35% of people choose to wild harvest and $\approx 5\%$ cultivate.

The discount rate is a parameter which expresses the future value of an item at a present day value (Anderson et al., 2004). Discount rates are likely to vary depending upon the cultural, social and economic context of the study. Experimental research in the USA found farmers have discount rates between 28% (± 7.3) and 43% (± 3.3) for decisions associated with payments for adopting conservation practices on farms (Duquette et al., 2012). I use the discount rates from this study to guide the upper bound in the sensitivity analysis. I vary the discount rate from 1% to 50% to assess how this influences uptake of cultivation. The sensitivity analysis shows at higher discount rates fewer people cultivate. Haggard et al. (2005) suggest a discount rate of 10% for farmers in Mexico when examining adoption of agroforestry strategies. As I am unable to determine the discount rate specifically for Guatemalan subsistence farmers considering cultivating xaté, I use the rate from Haggard et al. (2005) as the default value. I carry out a sensitivity analysis to estimate the proportion of land individuals cultivate, assuming all individuals cultivate the same proportion (Figure 6.5). I test values from 20% to 80% of individual land available for cultivation (Figure 6.6). Less than 5% of the people interviewed cultivated and so I specify 50% of an individuals land available for cultivation as the default estimate.

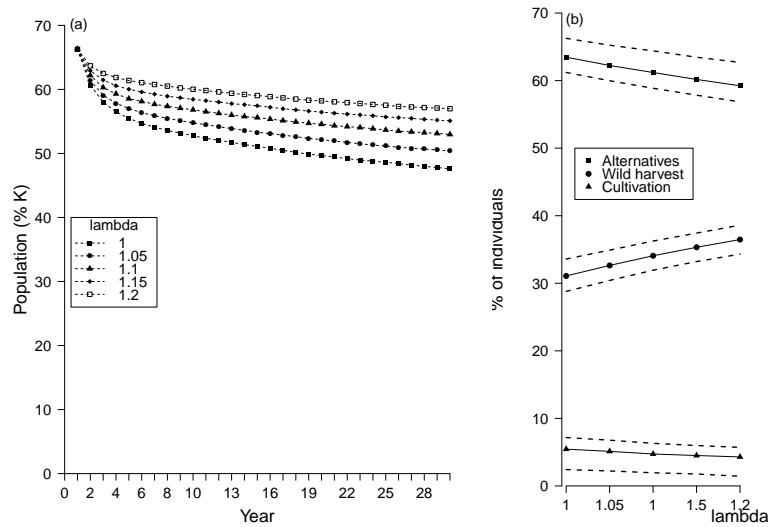


Figure 6.4: Sensitivity of the wild population to different λ values over 30 years (a). Data points are the mean of 1000 iterations for each year. At $\lambda = 1$ the population reaches equilibrium $\approx 48\%$ of carrying capacity whereas at $\lambda = 1.2$ the equilibrium is reached at 60%. Panel b illustrates the livelihood choices of individuals under different scenarios of λ rate. Livelihood choices do not appear to be considerably sensitive to changes in λ . Under all λ values tested the majority of people find alternative income, between 30% and 35% of people choose to wild harvest and $\approx 5\%$ cultivate.

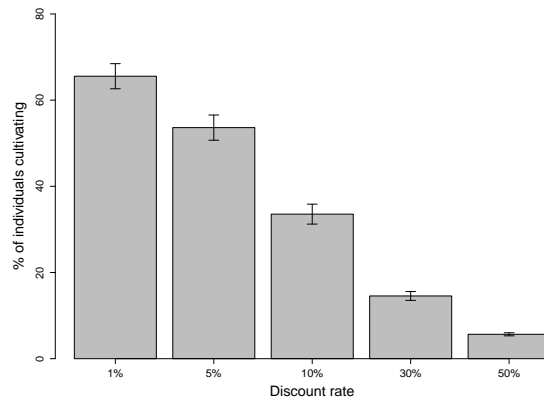


Figure 6.5: Sensitivity of individuals' decision making to the discount rate used. The percentage of individuals cultivating is calculated as a proportion of those that can cultivate (i.e. those with land). At higher levels of discount rate fewer people cultivate. The estimates showed are means of 1000 iterations with 95% confidence intervals.

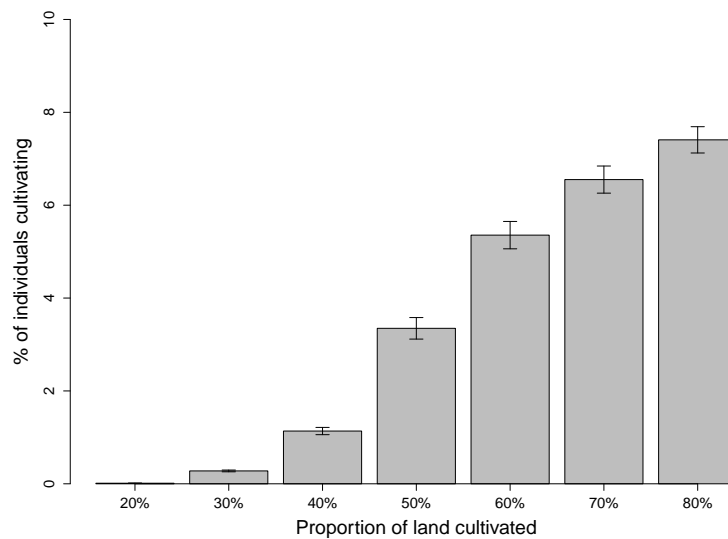


Figure 6.6: Sensitivity of the proportion of an individuals land available for cultivation. The percentage of individuals cultivating is calculated as a proportion of those that can cultivate (i.e. with land). The estimates showed are means of 1000 iterations with 95% confidence intervals.

Scenario Simulations

The model is stochastic so I run 1000 iterations, over a 30-year time horizon. Firstly, I simulate the default scenario where there is no conservation intervention (i.e. where price for cultivated leaf is the same as wild, the probability of detection and opportunity costs are low and few people have land ownership). Then I simulate a range of scenarios: policy levers that may influence harvesters incentives, variation in time to first harvest and changes in peoples' socio-economic characteristics (Table 6.3 summarises the scenarios simulated).

Policy levers to influence harvesters incentives

Increasing enforcement increases harvester's costs. The Belize Defence Force could increase the number of patrols along the Guatemala/Belize border to deter harvesters, which I model by increasing the probability of being caught. I refer to this as the 'enforcement' scenario. Certification for cultivated xaté leaf has been proposed as a method to encourage people to establish cultivation. I model this 'price premium' scenario with increases in price for cultivated.

Variation in species biology

Species with high growth rates and early maturity are more likely to be suitable for cultivation. I assess how changes in the time people have to wait from planting to harvest impacts decisions. I would expect that species providing a quick return on investment will encourage more people to cultivate. I refer to this scenario as ‘time to first harvest’.

Changes in socio-economic characteristics

The amount of land owned by individuals determines whether they can invest in cultivation. Securing peoples land tenure is often highlighted as possible solution to habitat loss and over-exploitation (Holden et al., 1998; Mercer, 2004). Here I simulate how changes in land ownership influence adoption of cultivation. This is the ‘land ownership’ scenario. Increasing opportunity costs of harvesters by improving wages elsewhere could reduce harvesting incentives. Currently, the individuals I model have very low alternative income as the majority of people in the study area live on less than \$1.25 per day. I run a series of scenarios with increasing opportunity costs and investigate how this influences decision-making. I call this scenario ‘alternative income’.

Table 6.3: Summary of scenarios simulated and parameter values.

Scenario	pp_i^C (\$/year)	E	C_{opp} (\$/year)	A (ha)	t_w (years)
Default	0.003	0.01	500	0.22	4
Alternative livelihoods	0.003	0.01	500-1250	0.22	4
Land ownership	0.003	0.01	500	0.1-1	4
Enforcement	0.003	0.01-0.8	500	0.22	4
Premium price	0.003-0.02	0.01	500	0.22	4
Waiting time	0.003	0.01	500	0.22	2-10

6.3 Results

6.3.1 Default model

Under default model conditions the population reached equilibrium at 66% of carrying capacity. Over 50% of people choose alternative livelihoods with 45% wild harvesting and less than 5% of people cultivating xaté. Over time the number of people cultivating

does increase slightly reflecting a decline in the wild population. The area of land cultivated increases over time whereas the harvesting of seeds to establish plantations is high at the outset and declines. This is because people harvest seed only in the first year of cultivation to establish plantations (Figure 6.7).

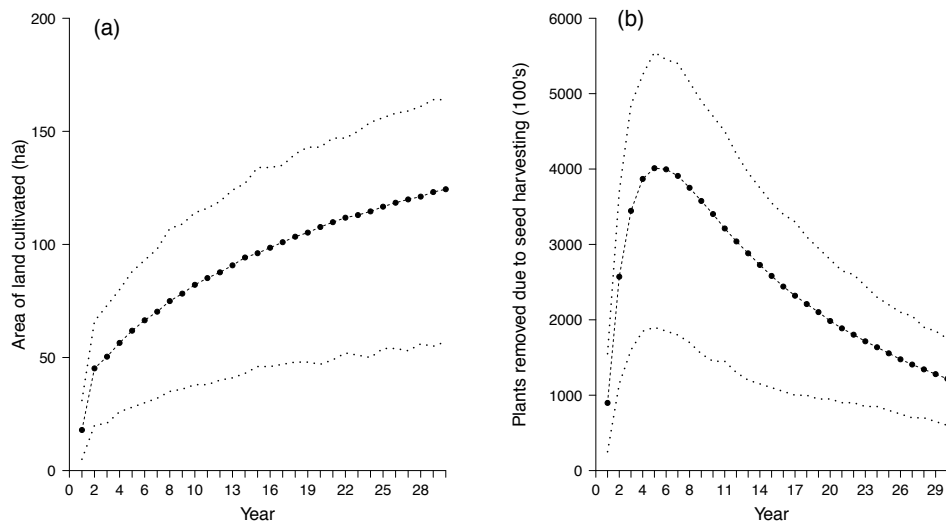


Figure 6.7: The area of land cultivated and number of plants harvested to establish cultivation (100's) under default conditions. The harvesting of seeds to establish plantations is high at the outset and declines. This is because people harvest seed only in the first year of cultivation to establish plantations.

6.3.2 Policy levers to influence harvesters incentives: enforcement and price premium scenarios

Increasing the probability of detection does encourage people to move from wild harvesting into alternative livelihoods and cultivation (Figure 6.8). With less people harvesting the plant population begins to recover. However, with a high probability of detection (70% chance of getting caught) more people move into cultivation, which results in a decline of the wild population. This is because of the number of plants collected to establish plantations.

A price premium for cultivated leaf can encourage people to adopt cultivation and reduce pressure on the wild population. As the majority of the people are still constrained

by the amount of land they own, when the price for cultivated leaf increases by 600%, a maximum of 20% of people cultivate. Figure 6.8 illustrates how this can reduce the number of people wild harvesting and the wild population recovers to 80% of carrying capacity.

6.3.3 Variation in species biology: time to first harvest scenario

Increasing the waiting time from planting to harvest reduced the number of people in cultivation. I changed the time from 2 years up to 10 years (Figure 6.9). People moving from cultivation entered alternative livelihoods and the number of people wild harvesting remained constant. In all the cases the wild population reached equilibrium at 60% of carrying capacity.

6.3.4 Changes in socio-economic characteristics: land ownership and alternative income scenarios

Increasing the amount of land owned by individuals does encourage people to move into cultivation, however increased land ownership increases pressure on the wild population (Figure 6.10). When individuals own on average 1 hectare of land the population declines to 60% of carrying capacity. The number of wild harvesters stays relatively constant and people move into cultivation from alternative livelihoods.

Increased alternative income creates an incentive for people to stop harvesting, resulting in reduced wild harvesting pressure (Figure 6.10). With a 50% increase in alternative income people move to alternative livelihoods and the wild population reaches over 90% of carrying capacity. The number of people cultivating does not change with alternative livelihoods.

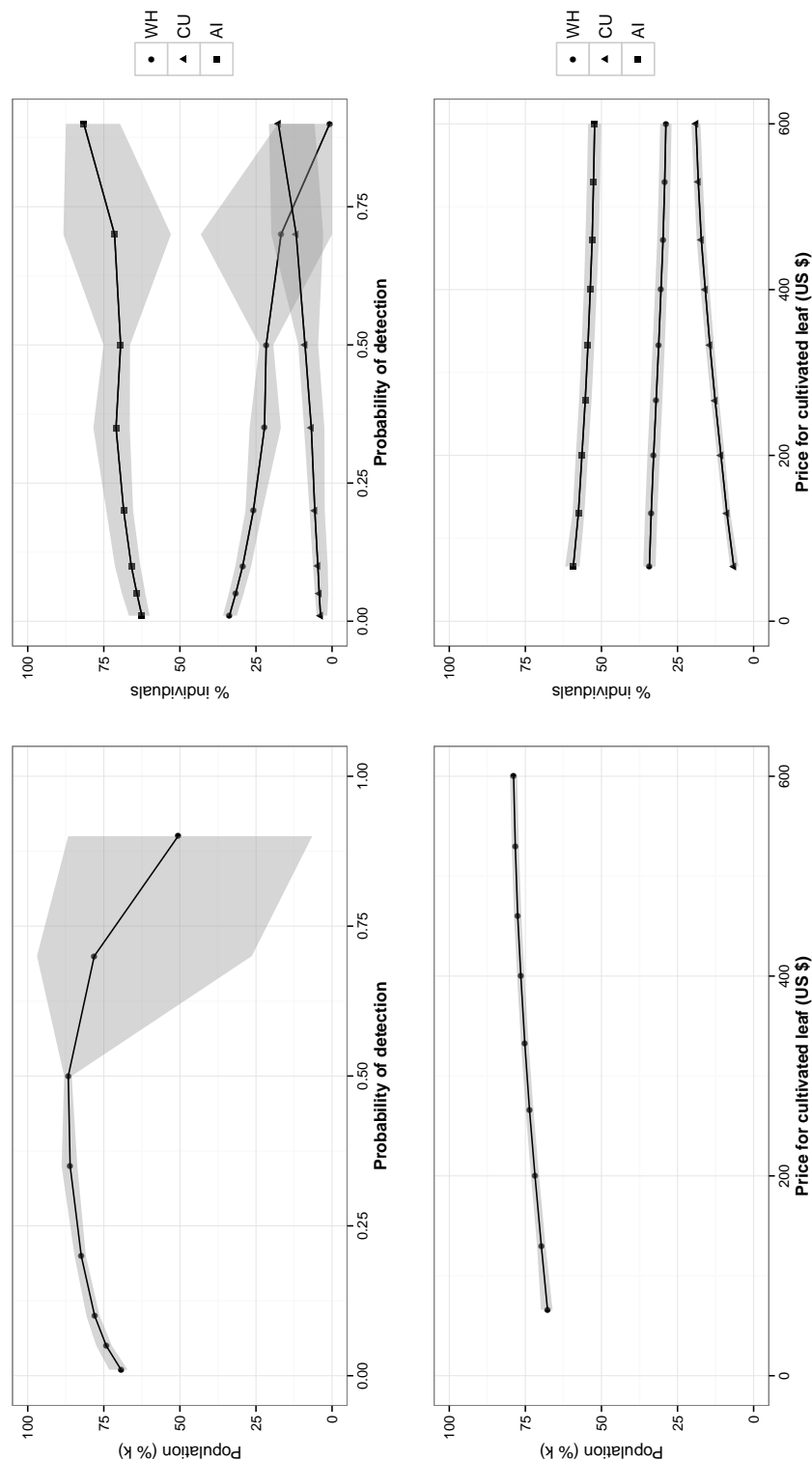


Figure 6.8: Upper figures show the impact of changing the probability of detection in the wild population and on livelihood choices. Lower figures show the impact of increasing the price for cultivated leaf on the wild population and livelihood choices. Increasing detection reduces the number of wild harvesters. Increasing the price can encourage people to move into cultivation and reduce pressure on the wild population. All points are mean values for the last 10 years simulated over 1000 iterations and a 30-year time horizon.

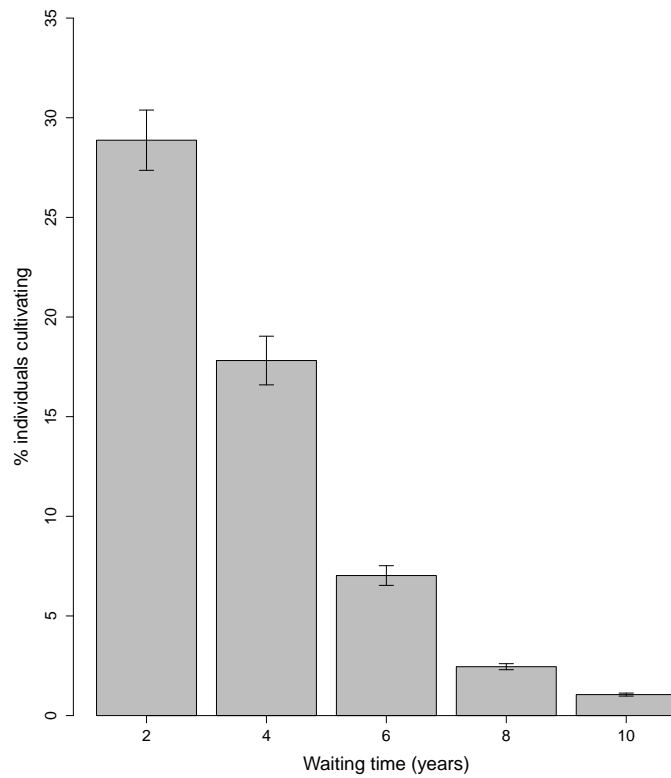


Figure 6.9: Proportion of people cultivating under different scenarios of waiting time from planting to harvest (out of those that can cultivate). The number of people cultivating declines as the waiting time increases. Estimates are means for the last 10 years simulated over 1000 iterations and a 30-year time horizon. Error bars show 95% confidence intervals. In all cases the wild population reaches equilibrium *approx*60% carrying capacity.

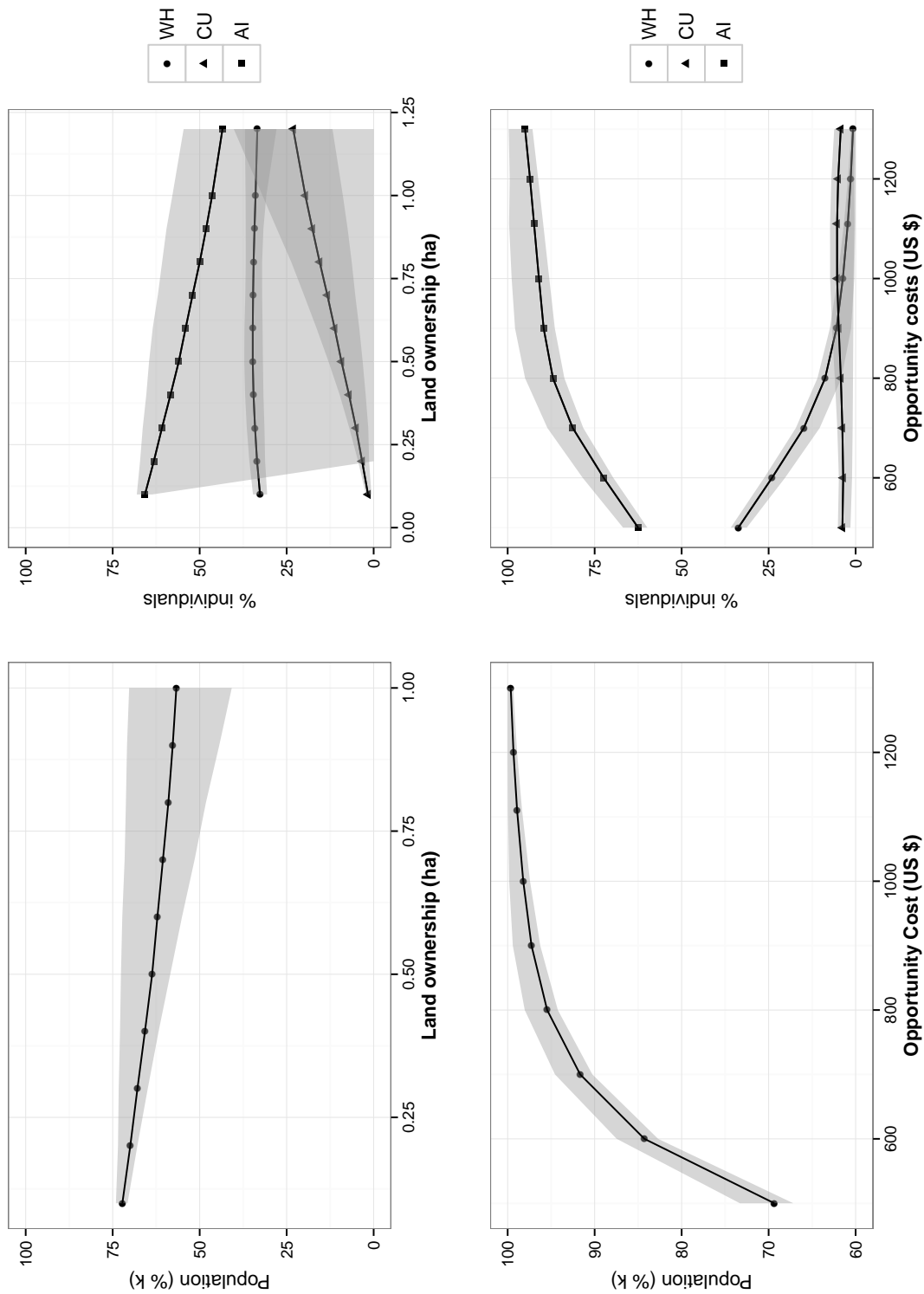


Figure 6.10: Upper figures show the effect of increasing land ownership on the wild population and livelihood choices. Lower figures show the impact of increasing alternative income on the wild population and livelihood choices. Increasing land ownership encourages people to move into cultivation but increases pressure on the wild population. Increasing alternative income reduces pressure on the wild population. The number of wild harvesters declines and more people move into alternative livelihoods. Points are mean values for the last 10 years simulated over 1000 iterations and a 30-year time horizon. Shaded areas are the 95% confidence intervals. WH = wild harvesting, CU = cultivation, AI = alternative income.

6.4 Discussion

Although cultivation of plant species is frequently proposed as a conservation strategy (Schippmann et al., 2002; Canter et al., 2005), there is little supporting evidence to suggest cultivation reduces wild harvesting pressure. Given that the model is a significant simplification of reality, the absolute values for population trends should not be used as guidelines for management. However I argue that the model has value in exploring the relative impact of conservation interventions aiming to reduce harvesting pressure of over-exploited species.

6.4.1 Reducing the number of wild harvesters

Fostering behaviour change is the basis of many conservation interventions. Enforcement of conservation laws is one approach to reduce the incentives of harvesting and encourage people to change behaviour (Rowcliffe et al., 2004). Increasing the probability of detection (and thus increasing harvesters costs) is thought to be more successful at deterring harvesters than raising the penalty for non-compliance (Leader-Williams and Milner-Gulland, 1992). However, increasing detection is costly, and requires training, equipment and salaries for law enforcers (Keane et al., 2008). Moreover, the results suggest high levels of enforcement are needed to reduce the number of wild harvesters. Ensuring a 50% chance of capturing illegal harvesters may be difficult for the case study of xaté, as harvesters enter Belize along a 60 km stretch of dense continuous forest cover. Without additional funding and capacity to ensure a higher frequency of patrols along the Belize/Guatemala border, it is unlikely enforcement will have an impact on the decision making of xaté harvesters.

An alternative approach to reducing the number of wild harvesters could be to supply a premium price for cultivated plant material. Certification, through schemes such as Fair Trade, can provide an incentive encouraging adoption of cultivation; however this does rely on the assumption consumers are willing to pay sufficiently higher prices for certified material to justify the certification costs and leave a premium to be passed on to producers (Taylor, 2005). Many exported species, including xaté, can be considered luxury items and are prone to fickle markets that may change depending on fashions and trends (Belcher and Schreckenberg, 2007). Consumer preferences can change and

cultivated material may no longer fetch a premium price. Certification also requires a high level of organisation to ensure producers receive an economic benefit for meeting criteria and standards of certification to counter the additional costs of participating in the scheme (Blackman and Rivera, 2011). My results indicate price premiums may be a useful conservation tool for promoting adoption of cultivation and may be worth exploring. Unfortunately there are few empirical examples where certification has resulted in economic benefits at the producer level (Ebeling and Yasue, 2009). A certification scheme for xaté harvested from community forest concessions in Guatemala has already been established and it is possible the scheme could be extended to cultivated xaté (Wilsey and Radachowsky, 2007). I suggest that the organisations promoting cultivation include monitoring and socio-economic data collection in their activities to clarify any benefits received from participating in the scheme.

The growth rate of a species has been highlighted as an important factor determining whether people will invest in cultivation (Jones et al., 2007). My results support this and show more people will adopt cultivation if the time from planting to harvest is short. This is likely to be especially the case when the land availability is a constraint (Zubair and Garforth, 2006).

Land ownership has been highlighted as a key barrier for people wanting to invest in cultivation of crops, particularly when long-term investment is required (Godoy, 1992). However, land reform is often a complex, long-term process where an administrative body is required to map, title and register land in a given region, and often in a highly politicised context (Ybarra, 2009). Then identifying who has legitimate rights to parcels of land, and what these rights encompass can be complicated (Bridgewater et al., 2006; Monterroso and Barry, 2012). In my study region, land ownership is uncommon, with most households renting land (Williams et al., forthcoming) and municipalities may actively prohibit long-term cultivation, allowing only 6 month or annual rental contracts (Katz, 2000; Penn et al., 2008). I suggest that under these circumstances it is unlikely that households will adopt cultivation of xaté, as it takes four years to receive any benefits.

Assuming harvesters are economically rational, the provision of alternative livelihoods can increase opportunity costs of harvesting and reduce the number of people participating in wild harvesting. I show that with even a small increase in the income from alternative livelihoods, there is a considerable decrease in the number of people wild

harvesting. The development of alternative livelihoods is an attractive approach to encouraging behaviour change; however there may be risks in promoting alternative livelihoods (Milner-Gulland, 2012). For example, Sievanen et al. (2005) show fisherman were encouraged to set up seaweed farms in the Philippines and Indonesia, as an approach to reduce fishing effort. However, overall fishing effort may not decrease and seaweed farming could potentially subsidise fishing i.e. through increased financial resources to buy fishing equipment. Introducing alternative livelihoods in one particular region could also lead to increased migration to the area as people in nearby communities want to benefit from the availability of new livelihood activities (Milner-Gulland and Rowcliffe, 2007).

From the scenarios I have explored, provision of alternative livelihoods was the only management option resulting in a considerable decline in the number of wild harvesters and an increase in the wild population. Cultivation could be promoted as an alternative livelihood but I have shown under default conditions relatively few people are likely to adopt this strategy. I suggest locally relevant, alternative livelihoods should be investigated further, in partnership with local communities. However, it is important to note that introducing alternative livelihoods may not be a substitute for other management options and it is perhaps better viewed as a component of diversifying livelihoods (Hill et al., 2011). Nonetheless, I believe this would be a useful avenue for future investigation.

6.4.2 Reducing pressure on wild populations through cultivation

It is often assumed that encouraging people to stop wild harvesting will reduce pressure on the wild population (Sievanen et al., 2005). However, I have shown that under some circumstances encouraging people to cultivate instead of wild harvesting can increase pressure on the wild population. Indeed, when individuals have increased land ownership, cultivation can potentially intensify harvesting pressure when plant material is wild harvested to establish plantations. Once plantations are established and plants are mature, seeds or seedlings could be harvested from cultivated sources rather than the wild. This may mitigate some of the wild harvesting pressure and provide a sustainable source of plant material for initiating cultivation. The Fauna and Flora International bulb cultivation project in Turkey is the only example I could find where cultivation has suc-

cessfully reduced wild harvesting pressure. In this project bulbs were supplied to help establish plantations (Entwistle et al., 2002) and may have eased incentives to harvest wild material. Access to seeds has previously been highlighted as a barrier to adopting cultivation (Williams et al., 2012b) and I suggest organisations encouraging cultivation should ensure access to seeds or seedlings to avoid adverse impacts on wild populations.

In addition to my results suggesting cultivation can increase pressure on wild populations, there is evidence indicating there can be unintended impacts when promoting cultivation. For example, Clayton et al. (2000) show captive breeding of babirusa pigs in Indonesia led to increased illegal wild harvesting, as hunters falsely assumed all trade was officially sanctioned. Cultivation may therefore create confusion about the legal status of wild harvesting. Furthermore, cultivation could create an avenue for laundering illegally harvested material through plantations. A premium price for cultivated leaf could provide an additional incentive to launder wild harvested material through plantations, as seen in the trade of green pythons in Indonesia (Lyons and Natusch, 2011). For the specific case of xaté, I believe there is a risk of laundering through plantations, given the high level of corruption and money laundering in the region (Brands, 2011). It is possible that with funding and good governance, the provenance of cultivated material could be assured through monitoring. However, until additional financial resources are available to increase capacity for monitoring and enforcing trade regulations, I suggest cultivation of xaté could potentially increase harvesting intensity.

Cultivation of non-timber forest products within a forest understory potentially offers an economic alternative to other land uses such as forest clearance for cattle ranching or agriculture. However, altering the forest understory to cultivate a single economically valuable species can decrease the biodiversity of the local area (Trauernicht and Ticktin, 2005). Agroforestry practices (i.e. managing trees as well as crops) could provide opportunity for designing and managing plantations that maintain local biodiversity levels (Jose, 2012; Bardhan et al., 2012). If plantations of xaté are developed for multiple economically viable species in a more complex landscape, this may help maintain biodiversity levels. However, as the wider impacts of cultivation are unclear, I suggest further research at a habitat scale is needed before assuming cultivation will be a useful conservation intervention.

6.5 Conclusion

Promoting cultivation of over-harvested species may not always be an effective conservation strategy and it may be challenging to encourage wild harvesters to switch to cultivation when there is little secure land tenure. If people do establish cultivation this could lead to increased harvesting pressure, due to demand for seeds or potentially by creating an avenue for laundering wild harvested material. If cultivation is promoted as an alternative or component of diversifying livelihoods, access to plant material to establish plantations may help to reduce wild harvesting pressure. Although schemes to encourage cultivation maybe an appealing conservation intervention, I urge caution in assuming that people will readily adopt cultivation of wild harvested species, or that this would necessarily reduce impacts on wild populations.

Chapter 7

Discussion

7.1 Background

Conservation of biodiversity is complex, and requires an interdisciplinary approach drawing upon both biological and social sciences (Mascia et al., 2003; Balmford and Cowling, 2006). The drivers of biodiversity loss are ultimately due to human behaviour and many conservation interventions intend (often indirectly) to foster behavioural change (Schultz, 2011). In recent years the conservation science community has increasingly called for a greater understanding of how coupled human and natural systems respond to interventions (Liu et al., 2007; Milner-Gulland, 2012) and there is a clear need for research that examines both theoretical and practical questions regarding how conservation interventions may effectively change human behaviour.

My research provides new insight into the predictors of human behaviour. In chapter 3 I illustrate that behaviour may not be solely predicted by attitudes and in chapter 4 I show additional behavioural determinants, such as knowledge and self-belief are likely to impact changes in behaviour. This thesis provides new knowledge about the factors determining human behavioural responses to conservation interventions. In chapter 2 I show that the geographical location and age of an institution, such as botanic garden, is likely to impact the influence of global conservation policy. Finally, in chapters 5 and 6 I suggest socioeconomic factors are likely to affect behavioural change and response of people to conservation policies. In this thesis I use both qualitative and quantitative methods to examine conservation interventions at different scales; from institutional policy adoption to determinates of household level decision-making. By drawing upon social psychology and economic behavioural frameworks my thesis has advanced understanding about how conservation interventions may influence behaviour and the potential implications of behavioural change.

In this next section I will first discuss the strengths and limitations of the behavioural frameworks I have used in my thesis. Secondly, I describe some of the problems in researching human behaviour in conservation and outline how conservation interventions can influence human behaviour. I then discuss the implications of my research for policy and practice and provide a critique of the research approach I have used in this thesis. Finally I highlight the limitations of my studies and suggest avenues for future research.

7.2 Strengths and limitations of behavioural frameworks

Different approaches, taken from a range of disciplines, can be used to explore the process of behavioural change in different contexts. I have applied three behavioural frameworks to examine how conservation interventions may influence peoples' behaviour (chapters 3, 4 and 6) and each of the frameworks has strengths and limitations (Table 7.1).

Table 7.1: Strengths and limitations of the frameworks used to understand the process of behavioural change

Framework	Discipline	Strengths	Limitations
Utility maximisation	Economics	Simplicity for simulation modeling and predicting interactions between people and resources. Parameters simple to measure	Assumes individuals are rational and have perfect information. Lack of social context
Knowledge-deficit model	Social psychology	Simple linear relationship between three variables	Does not include other well understood predictors of behaviour
Theory of planned behaviour	Social psychology	Incorporates additional social constructs that are likely to influence behaviour. High predictive validity.	Downplays the role of rationale weighting up of costs and benefits. Parameters can be difficult to measure.

Assuming individuals are economically rational is the basis of numerous studies investigating conservation of natural resources (Edwards-Jones, 2006; Edwards et al., 2011; Keane et al., 2012). Comparing the net profit of different livelihood options is a rel-

atively simple approach to apply when developing mechanistic models, and in chapter 6 I have shown this approach can be useful for identifying the impact of policy levers on household decision-making. Although rational choice theory is appealing because of its simplicity, the assumptions of this approach are rarely met (Van Den Bergh et al., 2000). Approaches that are able to consider the social context of decision making are more likely to reflect the reality of the human decision making process. I have explored two social psychology models (chapters 3 and 4) and suggest these can be useful alternatives to utility maximisation.

The knowledge-deficit model assumes a simple linear progression from knowledge to attitudes to behaviour. This model is often implicitly applied when exploring the influence of attitudes on behaviour in conservation (Infield and Namara, 2001; Waylen et al., 2009) and when assessing how environmental education can influence behaviour e.g. Vaughan et al. (2003), Trewhella et al. (2005), van der Ploeg et al. (2011) and Howe et al. (2011). However, there are few examples where a relationship between knowledge, attitudes and behaviour has been demonstrated (Heberlein, 2012). Although the knowledge-deficit model is appealing because of its apparent logic, my research has demonstrated that attitudes alone may not be a useful predictor of behaviour. Using this model (chapter 3) I was unable to link attitudes to behaviour and in chapter 4, I apply the theory of planned behaviour and show that attitudes have little impact on decisions to change behaviour. As a result, I suggest studies aiming to explore predictors of behaviour need to broaden the focus beyond attitudes. The theory of planned behaviour is one approach that includes attitudes plus additional predictors of behaviour and I have shown how factors such as self-belief (perceived behavioural control) may impact decision-making (chapter 4). I have illustrated how people with high belief in their cultivation abilities are more likely to establish plantations.

The theory of planned behaviour has repeatedly been found to have high predictive validity (Armitage and Conner, 1999; Ajzen et al., 2011) and offers a more complex representation of potential predictors of behaviour. Socio-demographic characteristics are likely to influence behaviour (Chukwuone, 2009) and are not explicitly included in the model. However, these factors are likely to influence social constructs, such as attitudes, and are therefore implicitly included. The theory of planned behaviour does not

explicitly include economic rationale in the decision-making process. Although I have highlighted the limitations of assuming economically rational behaviour, economic constraints are likely to influence how people make decisions. It could be argued that the theory of planned behaviour accounts for an individuals' economic situation within the social construct perceived behavioural control. A persons' belief about their ability to access the resources needed to carry out a behaviour will depend upon their economic circumstances and this constraint is downplayed in the theory of planned behaviour. Nonetheless, the theory of planned behaviour provided a useful tool for studying human behaviour as it enables distinct social constructs to be identified and their relative influence on behaviour examined. Understanding which social constructs are the most likely to influence behaviour can inform policy and enable the development of targeted conservation interventions. Using the theory of planned behaviour, Zubair and Garforth (2006) explore barriers to the adoption of tree planting schemes on farms in Pakistan. The authors found the lack of adoption was a result of negative local social norms, as there was little endorsement of tree planting activities from village elders (Zubair and Garforth, 2006). In this case, conservation interventions aiming to encourage tree planting may have greater impact if efforts are focused on generating support from prominent local community members. This example illustrates how social psychology approaches can be used to improve interventions aiming to change behaviour. The success of conservation interventions is likely to be influenced by its social context (Waylen et al., 2010) and my research shows the theory of planned behaviour can be valuable for helping to disentangle the influence of social factors on behaviour. I suggest using this model could help design and implement more effective conservation interventions by targeting the specific factors motivating and constraining behaviour in a particular context.

7.3 Difficulties in measuring behaviour

To understand how effective conservation interventions are at changing human behaviour, an estimate or at least a proxy for behaviour must be measured. Often studies are unable to show a relationship between the hypothesised predictors of behaviour and the behaviour of interest e.g. Infield and Namara (2001), Waylen et al. (2009) and chapter 3. The difficulty in linking attitudes and other social constructs to behaviour may in part be due to complexities in measuring behaviour. By directly observing whether indi-

viduals had initiated cultivation of a new species I was able to quantify actual behaviour (chapter 4) and is one the strengths of this research.

Measuring behaviour may be particularly difficult if the behaviour of interest is sensitive, such as illegal hunting (St John et al., 2010b). When behaviours are carried out illegally, direct questioning may not provide accurate estimates of activity levels, as respondents may fear reprisals and hide their illegal activity (Gavin and Solomon, 2010). This bias can be minimised by innovative methods, such as the Randomised Response Technique, which provides a level of anonymity through random allocation (using a dice or coin) of the question-answer process (St John et al., 2010b). This method has been shown to reduce response bias and improve estimates of rule-breaking, however it does rely on large sample sizes to identify trends and is not a suitable approach when there are few respondents (Lensvelt-Mulders et al., 2005). Nonetheless, the Randomised Response Technique is an approach that can be used elicit and improve estimates of illegal behaviour (Gavin and Solomon, 2010; St John et al., 2010b). Although this approach is useful for understanding levels of rule breaking, it does not help clarify the relationship between attitudes (plus other predictors) and behaviour. However, with more accurate estimates of behaviour we are more likely to discern the predictors of behaviour. My research in chapter 6 may have benefited from using RRT, as the harvesting I investigated was illegal. It is possible that people hid their harvesting activities and so I may have under-estimated the total number of people actively harvesting. A key limitation of RRT is that this method does not link individuals to a specific behaviour, but measures behaviour at the population level. This would not be appropriate for my study, as I needed to determine predictors of individuals that were illegally harvesting. Nonetheless, the testing and development of novel approaches such as RRT is an exciting area of current research and can potentially enable future studies of illegal harvesting to reduce response bias in estimates of sensitive behaviours (Gavin and Solomon, 2010).

7.4 Influencing behaviour through conservation interventions

Conservation interventions can potentially change behaviour at different scales, from influencing institutional activities (chapter 2), to households (chapter 6) and individual decision-making (chapter 4). International agreements and policies play an increasingly

prominent role in strategies to combat biodiversity loss. However, policies can only have a conservation impact if they influence institutions and encourage implementation, or impact households and individuals. I have illustrated how botanic gardens are implementing the Global Strategy for Plant Conservation (GSPC) and highlighted differences in the influence of this policy across the global north and global south regions. Policies that are global in scope may need to consider differences in how institutions interpret policy in order to successfully influence their activities. Successful policy implementation relies on two factors: capacity and will (McLaughlin, 1987). There appears to be strong support for the GSPC amongst the botanic garden community (Wyse Jackson and Kennedy, 2009; Blackmore et al., 2011), yet, a lack of capacity may be restricting successful GSPC implementation. My research identified a lack of funding as an important barrier to implementation (chapter 2). For conservation policies to effectively influence institutional activities, it is clear financial resources are needed for building capacity amongst institutions that are responsible for implementing a policy.

My research examining the socio-economics of cultivation and harvesting (chapter 6) has demonstrated how a bioeconomic approach can be useful to explore which policies impact household level decision-making. Considering the interactions between a coupled human and natural system allowed me to observe feedbacks when simulating different policy scenarios. By changing the incentives associated with certain behaviours, conservation interventions may be able to discourage behaviours that conflict with conservation aims (Milner-Gulland, 2012). I have shown how some policies, introduced to deter people from wild harvesting, may have very little impact on household-level decision-making. I suggest caution is needed when assuming households will readily switch livelihoods as there may be barriers restricting households' ability to adopt new practices such as cultivation (e.g. land ownership, chapter 5). Furthermore, households may resist in reducing harvesting effort because of factors such as job satisfaction and tradition (Pollnac et al., 2001). This highlights one of the limitations of assuming decision-making is based on economically rational choices. Development of the bioeconomic model (chapter 6) to include additional determinates of decision-making may provide greater insight into how households respond to different interventions. This would be useful to guide future policy-making when attempting influence household-level decision-making.

To change behaviour conservation interventions need to be locally relevant. When there are barriers restricting behaviour change, promotion of conservation is unlikely to succeed. In chapter 5 I illustrate how land ownership is a barrier to developing cultivation of a new species. Local and international conservation organisations have promoted cultivation in this region as an alternative to wild harvesting, yet with little secure land tenure it is unlikely that cultivation will be adopted, even when there is a positive social context (i.e. positive attitudes towards cultivation). Conservation interventions may have unforeseen consequences that negates any positive impact on the species, habitat or ecosystem of interest. For example in chapter 6, I illustrate how cultivation, proposed as strategy to reduce pressure on a wild harvested population, can increase harvesting intensity. The social context of conservation is important for the success of interventions, and local socio-economic and cultural factors need to be explicitly considered when designing interventions (Waylen et al., 2010). For example, social norms dictating management practices of *Pandanus* species in Madagascar were broken down after establishment of a national park (Jones et al., 2008). Harvesters were more likely to cut the plants apical meristem (thus killing the plant) within the protected area. Recognising how social norms impact behaviour, such as harvesting, can help conservationists avoid breaking down local institutions that govern natural resource management (Jones et al., 2008). Incorporating both biological and social scientists when developing conservation interventions is likely to improve effectiveness (Margles et al., 2009). The influence of conservation interventions on human behaviour can be challenging to predict, and drawing upon different disciplines in conservation practice will provide a more nuanced understanding of the potential implications of interventions.

7.5 Implications of this research for botanic garden activities

Botanic Gardens Conservation International (BGCI) provides the secretariat for the Global Strategy for Plant Conservation and has been closely involved in shaping the GSPC since its inception and working to support its implementation. The Secretary General of BGCI led the development of the GSPC and spearheaded the engagement with Convention on Biological Diversity (CBD) secretariat. This resulted in the adoption of the GSPC at the 2002 Conference of the Parties of the CBD, thus becoming incorporated as a cross-cutting theme within the CBD (Wyse Jackson 2002). Although

BGCI publications generally report the success of the GSPC (BGCI 2012) there is little evidence to suggest any additional resources for plant conservation have been generated since the GSPC was ratified (Paton and Nic Lughadha 2011), although the establishment of a full-time global GSPC Officer seconded from the CBD Secretariat to BGCI facilitated dedicated human resources to promote implementation. One of the limitations of the GSPC is the lack of measurable targets, no baseline data and no indicators to assess progress (Bridgewater 2011). The Plant Conservation Report (CBD 2009), published before the 2010 target deadline, as part of a review of the GSPC, provides an anecdotal overview of projects contributing to each of the targets, illustrating some successes. There has been little effort in developing approaches to monitor progress, although the need for target indicators has been acknowledged (Chase et al. 2011). A potential problem in developing indicators for the GSPC targets is that the majority of targets are broad and possibly, over-aspirational. Because the GSPC encompasses a wide range of plant conservation challenges, most botanic gardens could fit their existing activities into one or more of the target descriptions. One could argue that the GSPC provides justification for the activities already carried out by botanic gardens. Potentially the GSPC has not stimulated additional plant conservation initiatives. However, my research in chapter 2 suggests that many botanic gardens have been influenced by the GSPC and this policy does provide a useful framework for plant conservation initiatives.

Ensuring institutions know a policy exists is a logical first step to facilitating implementation. Although most botanic gardens were aware of the GSPC (indicating widespread dissemination), I show that not all botanic gardens were influenced by this policy. By providing guidelines and suggestions about how to implement the policy, the GSPC may have greater influence on botanic gardens. I suggest guidelines for implementation could highlight how institutions can contribute to meeting the policy targets. My research highlights the need for a communication mechanism between policy-makers and the institutions implementing the GSPC. The recently developed 'GSPC Toolkit', an online resource to support GSPC implementation (Secretariat of the Convention on Biological Diversity, 2011b), could provide a forum for dialogue between implementing institutions. This forum could also provide a feedback mechanism where implementing institutions are able to share their experiences with policy-makers. However, dedicated funding would be needed to maintain such a resource to support policy implementation.

My research in chapter 2 identifies the GSPC targets relating to sustainable use of plants in need of greater implementation and it is argued that botanic gardens could contribute more to these targets (Simiyu, S, 2010). Institutions other than botanic gardens are likely to be addressing GSPC targets associated with sustainable use of plant resources. However, the need to redefine the social role of botanic gardens has recently been acknowledged (Dodd and Jones, 2010) and novel projects addressing plant conservation and human well-being could be initiated (Botanic Gardens Conservation International, 2012). Although not all botanic gardens will want to develop programmes addressing sustainable use of plants, I suggest greater emphasis is needed within botanic gardens to address the increasing need for sustainable plant use, enabling botanic gardens to contribute more fully to the GSPC targets currently neglected. Recently a network of Latin American botanic gardens has indicated economic plant species will be the focus of future conservation work (Faggi et al., 2012). My research in chapter 4 indicates botanic gardens can use their skills in education and horticulture to change behaviour and encourage cultivation of over-harvested species. If more botanic gardens were enthusiastic about tackling sustainable use of plants, it would be useful to compile examples of projects already initiated from botanic gardens across the globe (e.g. Belize Botanic Garden and xate cultivation). Evaluating which projects are effective and comparing the outcomes of different interventions could be uploaded to the GSPC toolkit and may motivate additional botanic gardens to include sustainable use projects in their conservation activities.

7.6 Encouraging cultivation as a conservation strategy

There is little evidence to support the proposal of cultivation as a conservation strategy for over-harvested species. I have shown that people require technical knowledge about how to grow a new species to successfully encourage adoption of cultivation (chapter 4). I have also demonstrated how botanic garden training can effectively influence technical knowledge and increase peoples' self-belief in their abilities to cultivate a new species. As botanic gardens highlight education and training as priority activities (chapter 2), these institutions could help to address sustainable use of plants through training people to cultivate over-harvested species. However, I have suggested caution is needed when

assuming cultivation will encourage people to stop wild harvesting and that this could reduce pressure on wild populations (chapter 6). There is only one example (bulb cultivation in Turkey) where cultivation has effectively reduced wild harvesting pressure and increased local livelihoods (Entwistle et al., 2002). I have highlighted how access to seeds can be a barrier to uptake of cultivation (chapter 4) and how wild harvesting of plant material to establish plantations can increase harvesting pressure (chapter 6).

Given the long history of horticultural expertise within botanic gardens (Rae, 2011), botanic gardens could provide plant material to help people set up plantations. In response to global targets such as the Millennium Development Goals, some botanic gardens have been using their horticultural skills to simultaneously address plant conservation and human well-being (Blackmore et al., 2011). For example, the newly established Tooro Botanic Garden in Uganda has been working with local communities to develop a demonstration garden of medicinal herbs and spices. This project teaches horticultural skills and encourages home gardening of valuable species. In addition, local healers meet frequently at the botanic garden to discuss health topics, document local knowledge and highlight medicinal plants that could be cultivated (Botanic Gardens Conservation International, 2010). As highlighted by Donaldson (2009), botanic gardens could extract greater conservation value from their living collections and use their expertise more effectively to address both plant conservation and human-well-being. Teaching and encouraging cultivation could be an innovative approach for botanic gardens to apply their horticultural skills and address plant conservation and human well-being (Maunder, 2008). Perhaps, under specific circumstances (such as secure land tenure and high plant production rates) cultivation may be an appropriate conservation strategy, and botanic gardens could provide the training needed to encourage uptake. However, further research will be needed to ascertain under which specific conditions cultivation can reduce pressure on the wild population and how plantations impact local biodiversity levels (Trauernicht and Ticktin, 2005).

7.7 Critique of research approach adopted in this thesis

From chapters 2 to 5 I have adopted an information theoretic approach to explore my data. This approach compares the relative support for a candidate set of competing mod-

els with each model representing a plausible hypothesis (Johnson and Omland, 2004). The competing models are ranked according to a criterion assessing relative support; in my thesis I have used the Akaike Information Criterion (AIC). The AIC is one of many alternative criterion available for ranking the models and there is little consensus indicating a single best criterion for ranking (Guthery et al., 2005). Other approaches include the Bayesian Information Criterion, Takeuchi's Information Criterion and Network Information Criterion. I have chosen to use AIC because of the relative simplicity compared to other criterion approaches and the accessibility of literature providing guidance in implementing this approach (Anderson and Burnham, 2002). This approach has gained increasing use amongst ecological scientists in recent years (Johnson and Omland, 2004). However AIC has received criticism suggesting this approach can be inappropriately applied (Guthery et al., 2005). One concern is AIC may encourage thoughtless construction of a candidate set of models and data dredging (Mundry, 2010). Generating valid inference from the candidate set of models relies upon the plausibility of each model (hypothesis) tested (Arnold, 2010). Some authors suggest the AIC approach assumes the candidate set includes the 'true' model (Mundry, 2010). However Anderson and Burnham (2002) argue AIC provides a means to rank the candidate set, it does not ensure that the models tested are accurate representations of the system of interest. This highlights the importance of careful thought and drawing upon a priori knowledge when developing the candidate set of models.

There are some examples where authors have constructed a candidate set of models that include all possible combinations of the explanatory variables include in the analysis (e.g. Fleishman et al. (2002). While this may be useful in exploratory data analysis it could lead to data dredging and potentially spurious findings (Anderson and Burnham, 2002). The number of models should not exceed the sample size used to test the models. In my thesis I develop small candidate sets and did not test all possible combinations and interactions of the explanatory variables included in the candidate set. A frequent criticism of the AIC approach is the presentation of models in journals with little informative data (Guthery et al., 2005). To allow transparency whilst using the AIC approach I have included a table for each candidate set of models outlining the parameters included, the AIC value, the delta AIC and the weights of the models. This is to allow the reader an opportunity to examine the relative support for each model for the analyses I

have carried out. I have highlighted limitations of the AIC approach and indicated how I attempted to overcome these problems e.g. developing a small candidate set of models and presenting tables in my thesis showing important information when choosing the best-supported model. The conclusions I have suggested in each chapter could be limited if the candidate sets of models were poorly developed at the outset (Mundry, 2010). Despite this limitation, developing a candidate set of models explicitly is thought to be a more robust approach compared to alternatives such as stepwise deletion or addition (Whittingham et al., 2006).

Linear regressions are a useful and simple method for analysing data, however there are four main assumptions that must be met when using this approach. First, the error term of a variable should be normally distributed, as skewed distributions can distort the relationships between response and explanatory variables. Secondly, the response variable measures must be independent from each other. Third, the response and explanatory variables are assumed to have a linear relationship. Finally, the error variance of the variables must be constant, that is, the residuals (the difference between the observed and the fitted values) should have constant variability when plotted (Crawley 2007). The response variables I tested were all either binomial or ordinal and so the assumption of normal distribution would not be met. As this assumption was not valid, I applied alternative approaches using generalised linear models (chapters 3,4 and 5) plus extensions including proportional odds models (chapters 2 and 4) and binomial mixed effects models (chapters 2 and 3).

Generalised linear models are useful when the variable errors are non-normal and one is able to specify a specific error structure such as binomial or Poisson. A Poisson generalised linear model is based on the assumption that the variance of the error distribution is determined by the mean, whereas in binomial generalised linear models the variance is fixed at one (Crawley, 2007). However these assumptions are frequently not met, resulting in ‘overdispersion’ (Breslow, 1995). This can be assessed by comparing residual deviance with the degrees of freedom. Overdispersion is suggested when the residual deviance is larger than the degrees of freedom indicating considerable uncertainty in the variation remains and is not accounted for by the model. Overdispersion suggests an underestimation of the standard errors associated with the coefficient estimates (Hinde

and Demétrio, 1998). If there is evidence of overdispersion a ‘quasi-binomial’ or ‘quasi-possion’ error structure can be specified and may be more appropriate (Crawley, 2007). In all of my analyses the degrees of freedom were larger than the residual deviance and so overdispersion is unlikely to be a problem when specifying the models. However, there are formal tests available to assess the level of overdispersion in data (Dean, 1992) and in future studies it may be useful to carry out this additional analysis.

Social science data are frequently collected through questionnaires where responses are measured as agreements or disagreements to statements. This provides ordered factor variables such as in chapter 4 where I use a three level factor as a response variable. Calculating means of an ordinal variable assumes the intervals between factor levels are equal (Knapp, 1993). In table 4.2 I have presented means of an ordinal variable yet it is unlikely this assumption was met, because the data are measured as positive, neutral or negative and the scoring does not determine the distance between the levels. In addition the mean values presented were rescaled between 0 and 10 whereas the modelled data were rescaled between 0 and 40. For consistency the results should all be presented on a common range. On reflection, it would be better to present the median values, which is included in appendix C.

In chapter 4 there are multiple statements measuring a single construct (e.g. four statements measuring attitude) and it was important to determine how the scores should be combined. Ajzen (2003) suggests statements should be multiplied whereas Francis et al. (2004) suggest addition is more appropriate. Multiplication is used when the statements are measuring different components of a single construct and originally I followed Ajzen (2003). In response to a reviewer’s comments I later recombined the scores using simple addition as my statements were all measuring the same component of the social construct. This recombination had little effect on the modelled results, mostly like because the original Likert scale had only three levels (positive, neutral and negative). As I used a coarse measure, it is possible that I did not detect differences that do exist between the two groups tested (trained and untrained farmers). My conclusions suggesting that the training programme did not impact attitudes and subjective norms may therefore not be accurate. For future research it would be useful to create a more sensitive study with more statements measuring the components of a construct and a

more detailed Likert scale. This would make it easier to detect differences between peoples' attitudes, subjective norms and perceived behavioural control.

In all of the analysis approaches described above, collinearity between explanatory variables can potentially cause incorrect estimation of parameter coefficients (Crawley 2007). If predictor variables are correlated it can be difficult to disentangle independent effects of each variable. For each of my chapters I tested for collinearity by plotting combinations of the explanatory variables and found little evidence to suggest collinear variables. However, multicollinearity can be difficult to detect (Freckleton, 2011). Investigating multicollinearity more formally could have been carried out using variation inflation factors, a test that measures the relationship between multiple variables (Stevens, 2002). The approach I used throughout my thesis was based on Burnham and Anderson (2002) whereby I developed a candidate set of models with model selection based on AIC. This is in contrast to a stepwise deletion or addition approach, which has received strong criticism (Whittingham et al., 2006). The AIC approach is generally robust to collinear variables and collinearity does not affect model selection (Freckleton, 2011). Although collinearity can bias individual coefficient estimates towards zero (Smith et al., 2009), which may have led me to underestimate the importance of some predictor variables in my analysis. This suggests my conclusions in chapters 2-5 are likely to remain valid but that some important effects found in my results could be potentially stronger than I have reported.

Over recent years the AIC approach has become increasingly applied in ecological analysis (Lukacs et al., 2007; Symonds and Moussalli, 2011). However there are alternative approaches that I could have employed in my thesis. Structural equation modelling is a useful framework for evaluating the relationships between multiple variables and is particularly powerful when considering variables that cannot be observed directly, known as latent variables (Pugesek et al., 2003). This approach would have been useful in my thesis when assessing constructs such as attitudes, which cannot be measured directly. Potentially, structural equation modeling could be applied in chapter 4 where I used the theory of planned behaviour to investigate the predictors of xate cultivation.

7.8 Limitations and future research

The bioeconomic model presented in chapter 6 has several limitations. However I argue that the model has value in exploring the relative impact of conservation interventions aiming to reduce harvesting pressure of over-exploited species. The biological model used in chapter 6 is quite simplistic as I assume logistic density dependent population growth and do not take into account distinct life stages of the plant population. Differences in mortality rates for the life stages are likely to influence population dynamics, especially if specific stages are targeted for harvesting (Mooney and McGraw, 2006; Milner et al., 2007). Recent research on *Chamaedorea* harvesting suggests female plants are less capable of regenerating and reproducing after defoliation compared to males (Lopez-Toledo et al., 2012). Repeated harvesting increases plant mortality rates and our model does not currently capture this. A useful extension of this model would be to capture this effect.

In the bioeconomic model I assume that individuals are economically rational, choosing the option with the greatest profit. The alternative models of human behaviour explored in chapters 3, 4 and 6 and sections above highlight that this is a simplification of human decision making. However while acknowledging that all models have limitations, researchers seeking to understand the world about them need to select the most appropriate model for their subject matter. In the case of xaté harvesters in Guatemala, there are no cultural traditions associated with harvesting. Therefore I argue that assuming decisions concerning xaté harvesting are, to a best approximation, economically rational. For cases where a species may have cultural value or be exploited for local use rather than income, decisions may be expected to deviate more markedly from economic rationality.

Incorporating heterogeneity in individual characteristics would provide greater insight into how peoples characteristics impact decision-making (Keane et al., 2012). Also, individuals' decisions are made in isolation of the other people, and our model ignores how social networks and the behaviour of others influence decision-making. This would be useful area for future research and has so far received little attention in natural resource management (Milner-Gulland et al., 2006).

Education activities aiming to inform people about the environment and conservation can take many different forms including posters and newsletters (van der Ploeg et al., 2011), interactive theatre (Penn, 2008), guided tours and walks (Ballantyne et al., 2001). My research investigating the influence of environmental education and training is limited in the type of education that was evaluated (informal education in chapter 3 and technical training in chapter 4). It would be a useful next step to undertake a comparative study investigating the relative impact of different strategies to identify which approaches have the greatest impact on participants. Greater insight about the influence of different programmes would help to design and tailor education activities to meet the specific aims of the education programme. To quantify the impact of environmental education, participants need to be interviewed before and after a programme, or alternatively a control group (i.e. people not participating in environmental education) can be used for comparison, given similar socio-demographic characteristics (Ferraro and Pattanayak, 2006). It would be beneficial if evaluation were built into the design of an education programme from the outset, to determine the effectiveness and success of education programmes.

It would be useful if human behavioural research in conservation science were more informed by theoretical behavioural frameworks. This would allow the assumptions of each model to be considered and advance the understanding of the process and mechanisms underlying behaviour. My research shows that measures of attitudes are unlikely to provide sufficient information to predict behaviour, and I suggest conservation scientists need to broaden their focus to include other social constructs when conducting research on human behaviour. Future research could apply the theory of planned behaviour to examine how conservation interventions influence incentives of individuals by assessing changes in social constructs and how this impacts decision-making. For example, payments for ecosystem services are becoming increasingly applied as an approach to change peoples behaviour (Wunder et al., 2008), yet, there is little understanding of what determines participation in such schemes. A social psychology perspective could facilitate a deeper understanding of the motivations and constraints of people to participate. Future research could focus on identifying key factors (such as positive attitudes towards a payments for ecosystem service scheme or endorsement from prominent community members) that are likely to impact decision-making and therefore the success of the conservation intervention.

7.9 Conclusion

By exploring different behavioural frameworks I have shown conservation research can benefit from applying approaches from different disciplines. Developing a greater understanding of how conservation interventions influence behaviour at multiple scales is needed to improve the formulation and implementation of conservation policies. Botanic gardens have provided a valuable case study to assess how conservation interventions (such as the GSPC) have influenced their activities and also how botanic gardens can influence individuals (through education and training). I have demonstrated that these institutions can play an important role in plant conservation. As botanic gardens across the world are redefining their social role, I suggest conservation interventions initiated by botanic gardens display greater emphasis on combining their educational and horticultural skills, working with local communities to address plant conservation challenges. This would enable botanic gardens to contribute more fully to conservation policies such as the Global Strategy for Plant Conservation and firmly place them at the centre of developing plant conservation strategies and improving human well-being.

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Appendix A

Global Strategy for Plant Conservation Survey

The Global Strategy for Plant Conservation (GSPC) has stimulated botanic gardens around the world to play a leading role in plant conservation.

In 2010, new plant conservation targets for the period 2011-2020 will be agreed. At this time we are keen to celebrate the achievements made so far and raise awareness of the vital work of botanic gardens in implementing the GSPC.

The aim of this global survey is therefore to find out more about the activities of botanic gardens that contribute to the GSPC. The results of the survey will be presented at the 4th Global Botanic Gardens Congress in June 2010.

Thank you for taking the time to complete the questionnaire, your response is vital to this study! It will take approximately 15 minutes to complete. The bar at the bottom of the page will show how far through the survey you are.

If you would prefer to complete a paper copy of the survey please contact Sophie Williams. Please feel free to ask for more information and assistance.

E-mail: s.williams@kew.org (Email Me)

Skype: [sophiewilliams115](#)

Postal address : School of Environment and Natural Resources, Bangor University, Thoday Building, Deiniol

Road, Gwynedd, LL57 4RU, Wales

Personal website: [Sophie's website](#)

For more information on the GSPC, please visit: www.bgci.org/worldwide/gspc/

Introduction

1. Responses from individual botanic gardens will not be reported and you are not required to provide any personal details. However, if you would be happy to discuss your botanic garden and the GSPC further please provide a contact name and e-mail and/or phone number

Background Information

2. Name of Botanic Garden

3. In which country is your botanic garden?

4. What is the total area of your botanic garden? (please specify units)

5. What year was your botanic garden established?

6. How many members of staff does your botanic garden employ?

Full time

Part time

7. How many volunteers does your botanic garden have?

8. What is the status of your botanic garden?

Public/State

Private

University

Other (please specify)

9. What is the annual budget of your botanic garden? (US \$)

Less than \$50,000
\$50,001 - \$100,000
\$100,001 - \$250,000
\$250,001 - \$750,000
\$750,001 - \$1.5 Million
More than \$1.5 Million

10. What is the primary funding source of your botanic garden?

State
Self-generated
Private
Other (please specify)

11. Is your botanic garden aware of the Global Strategy for Plant Conservation?

Yes
No
Don't Know

12. Please indicate how influential the Global Strategy for Plant Conservation has been on the activities of your botanic garden:

Very influential
Fairly influential
Not at all influential

13. Please tick the GSPC targets your botanic garden is currently contributing towards:

14. Please provide examples of projects at your botanic garden contributing to the different targets:

15. Please rank the five targets that your botanic garden sees as priority activities (1= highest priority)

16. For the targets that your botanic garden does NOT contribute towards, please indicate why:

17. If you have ticked other, please comment on the factors you feel limit your ability to contribute to the GSPC:

18. Is your botanic garden aware of the BGCI Plant Search database?

Yes
No
Don't know

Thank you for taking the time to complete this survey. The results will be presented at the 4th Global Botanic Garden Congress in June 2010.

If you would like more information about the survey or the results please feel free to contact Sophie Williams.

Thank you again!

20. Please use this space if you have any additional comments or suggestions:

Table A.1: Summary of botanic garden sample

Variable	Category	% (n = 255)
BGCI Member	Yes	72
	No	28
GSPC Influence	Very	54
	Fair	27
	Not	19
Region	Africa	10
	Asia	14
	Europe	37
	North America	23
	Oceania	8
	South America	8
Budget category (US\$) ppp corrected	<\$50,000	29
	\$50,000-\$100,000	18
	\$100,000-\$250,000	25
	\$250,000-\$750,000	27
	\$750,000-\$1.5 million	18
	>\$1.5 million	134

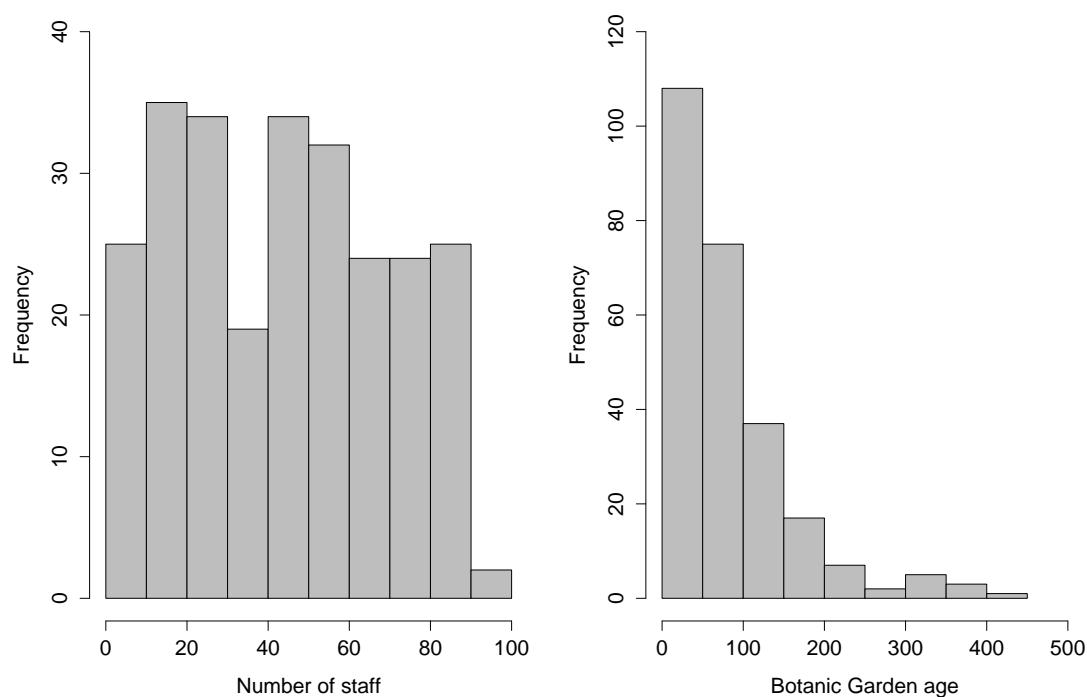


Figure A.1: Histograms showing the number of full time staff employed at the sampled botanic gardens and the age of sampled botanic gardens. Included as variables to assess what predicts GSPC influence.

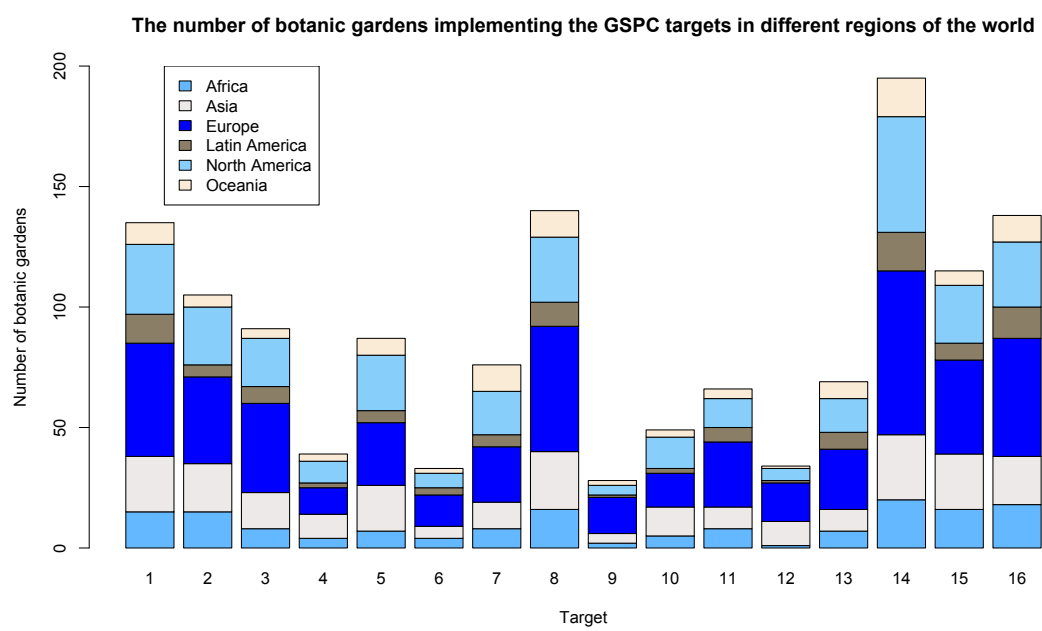


Figure A.2: Implementation of the GSPC by botanic gardens in different regions of the world

Appendix B

Botanic Garden Impact on Visitors Survey

Questionnaire

Arriving

Leaving

If leaving:

How long have you spent in the Garden? _____

Did you have contact with any staff, volunteers or guides whilst in the Garden?

☐ **Yes** ☐ **No**

Conservation knowledge

Can you name one botanic garden, other than this one? _____

Biodiversity is:

- ☐ A washing powder
- ☐ The variety of life
- ☐ A type of genetic engineering
- ☐ A family of plants
- ☐ A place in South America
- ☐ Don't know

Can you name one of the world's biodiversity hotspots? _____

Can you name an internationally threatened plant species? _____

Can you name a threatened UK plant species? _____

The IUCN Red List is a list of:

- ☐ Protected habitats in the UK
- ☐ Top earners in the UK
- ☐ Threatened species
- ☐ Plant species in the UK
- ☐ Don't know

2010 is the international year of: _____

Can you name one of the main human causes of plant extinction? _____

New Ecological Paradigm:

	Strongly agree	Mildly agree	Unsure	Mildly disagree	Strongly disagree
We are approaching the limit of the number of people the earth can support					
Humans have the right to modify the natural environment to suit their needs					
When humans interfere with nature it often produces disastrous consequences					
Human ingenuity will insure that we do NOT make the earth unliveable					
Humans are severely abusing the environment					
The earth has plenty of natural resources if we just learn how to develop them					
Plants and animals have as much right as humans to exist					
The balance of nature is strong enough to cope with the impacts of modern industrial nations					
Despite our special abilities humans are still subject to the laws of nature					
The so-called “ecological crisis” facing humankind has been greatly exaggerated					
The earth is like a spaceship with very limited room and resources					
Humans were meant to rule over the rest of nature					
The balance of nature is very delicate and easily upset					
Humans will eventually learn enough about how nature works to be able to control it					
If things continue on their present course, we will soon experience a major ecological catastrophe					

Prioritisation of conservation

We have £100, donated by Bangor University, to give to charity and would like our survey participants to help us decide where this money should go.

Here is the £100 in £10 tokens. How would you like this to be allocated between the following charities?

WaterAid – Water and sanitation for all

WaterAid is an international non-governmental organisation. Our mission is to transform lives by improving access to safe water, hygiene and sanitation in the world's poorest communities.

Cancer Research – Together we will beat cancer.

Cancer Research UK is the world's leading charity dedicated to beating cancer through research.

WWF – For a living planet.

WWF addresses global threats to people and nature such as climate change, the peril to endangered species and habitats, and the unsustainable consumption of the world's natural resources

Plantlife International – Our Plant, Our Planet, Our Future

Plantlife is a charity working to protect Britain's wild flowers and plants, fungi and lichens in the habitats in which they are found.

This botanic garden

Birmingham

Eden Project

Ness Botanic Garden

Kew

Cambridge

Edinburgh

Background Information

Age:

18-25 ☐ 26-35 ☐ 36-45 ☐ 46-55 ☐ 56-65 ☐ 65+ ☐

Female ☐ Male ☐

Education: What is your highest education qualification?

GCSE or equivalent	
HND/GNVQ or equivalent	
A / AS Levels	
First Degree (e.g. BA, BSc)	
Higher degree (e.g. MA, MSc, PhD)	
Other (please specify)	

Are you a member of any conservation organisation? Yes ☐ No ☐

Please specify: _____

Summary of responses to the New Ecological Paradigm items (%). Percentages are for all five botanic gardens (n = 1054).

Item	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
We are approaching the limit of the number of people the earth can support	44.02	37.19	9.30	7.69	1.80
Humans have the right to modify the natural environment to suit their needs	6.36	33.30	9.87	28.46	22.01
When humans interfere with nature it often produces disastrous consequences	53.32	30.83	6.55	6.07	3.23
Human ingenuity will insure that we do NOT make the earth unliveable	11.01	29.51	25.43	22.01	12.05
Humans are severely abusing the environment	58.25	32.35	3.51	3.89	1.99
The earth has plenty of natural resources if we just learn how to develop them	43.64	31.12	8.35	11.10	5.79
Plants and animals have as much right as humans to exist	80.55	13.00	2.18	2.75	1.52
The balance of nature is strong enough to cope with the impacts of modern industrial nations	2.94	11.67	15.56	35.29	34.54
Despite our special abilities humans are still subject to the laws of nature	69.26	24.57	3.70	1.61	0.85
The so-called 'ecological crisis' facing humankind has been greatly exaggerated	3.04	17.08	16.79	25.52	37.57
The earth is like a spaceship with very limited room and resources	39.18	34.54	12.24	10.34	3.70
Humans were meant to rule over the rest of nature	4.27	9.11	8.16	22.01	56.45
The balance of nature is very delicate and easily upset	54.17	31.69	5.79	6.36	1.99
Humans will eventually learn enough about how nature works to be able to control it	8.16	26.66	23.81	24.19	17.17
If things continue on their present course, we will soon experience a major ecological catastrophe	42.31	33.78	15.37	6.36	2.18

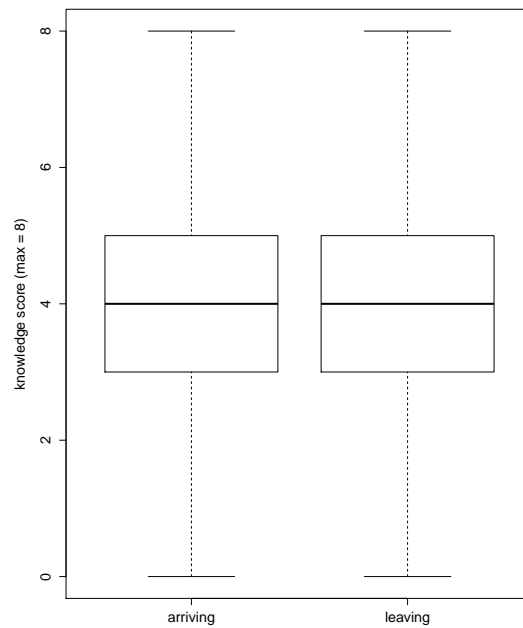


Figure B.1: Knowledge scores of visitors arriving and leaving a botanic garden.

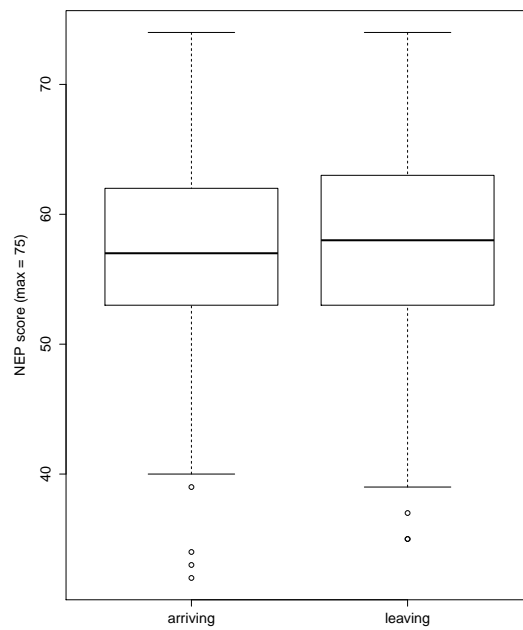


Figure B.2: Environmental attitude scores of visitors arriving and leaving a botanic garden.

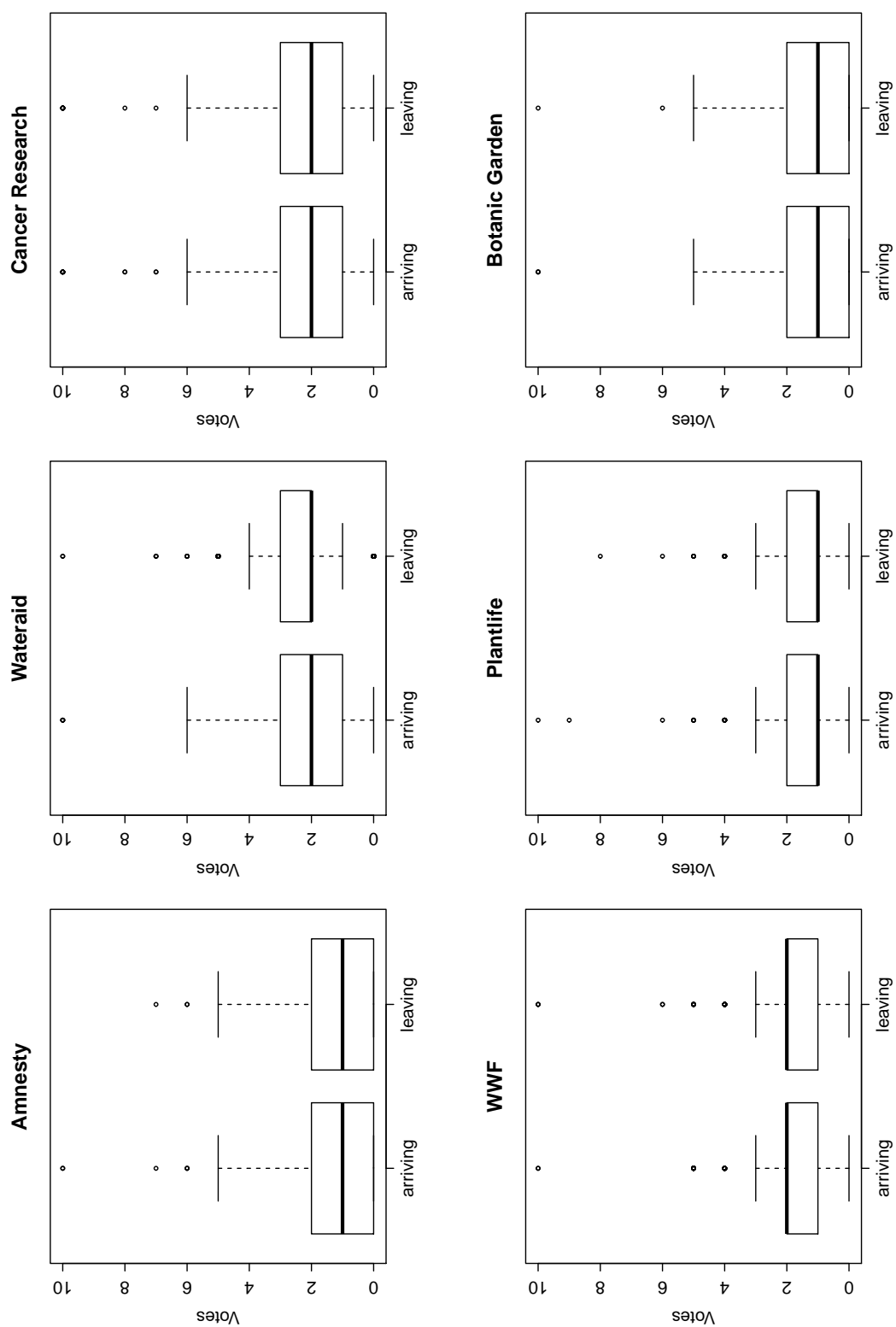


Figure B.3: Summary of the votes for the six charities when arriving and leaving the botanic garden

Appendix C

Sample of data to illustrate calculation of attitude, social norm and perceived behaviour control scores

Table C.1: A sample of the raw scores for attitude, social norm and perceived behavioural control statements

Person ID	attitude 1	attitude 2	attitude 3	attitude 4	SN 1	SN 2	PBC 1	PBC 2
1	3	1	1	3	3	1	1	3
2	1	1	1	3	1	1	1	1
3	3	1	1	3	1	1	1	3
4	3	1	3	3	2	2	1	3

Table C.2: A sample of the summed scores for attitude, social norm and perceived behavioural control. Scores were then rescaled to a common range between 0 and 40.

Person ID	Attitude	SN	PBC
1	8	4	4
2	6	2	2
3	8	2	4
4	10	4	4

Table C.3: A sample of the median values for each of the attitude, social norm and perceived behavioural control statements. Values are rescaled to a common range between 0 and 40.

Trained median	Untrained median
10.0	10.0
10.0	8.3
6.67	6.6
10.0	10.0
20.0	16.6
20.0	20.0
10.0	3.3
20.0	6.6

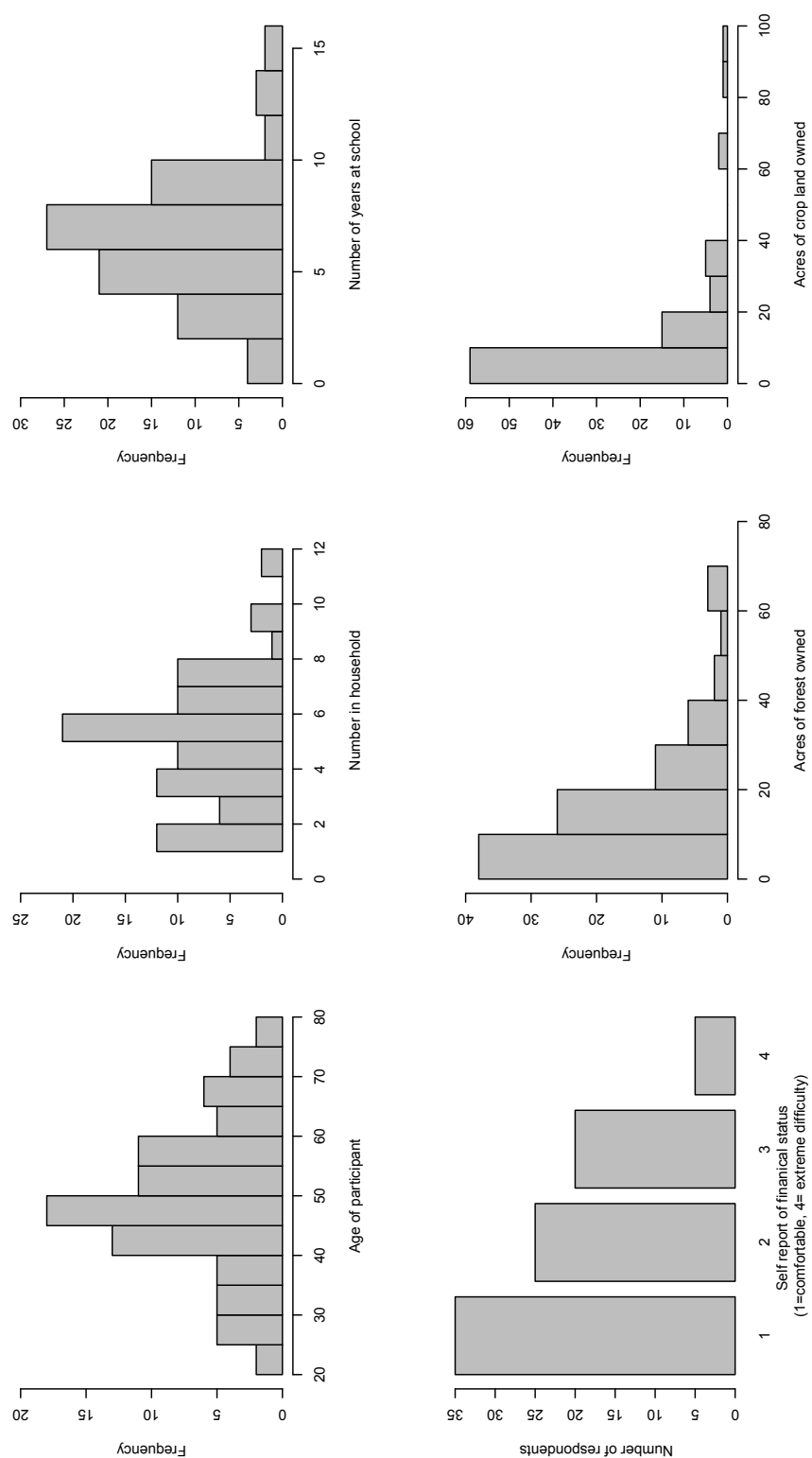


Figure C.1: Summary of the predictors variables measured to assess characteristics of xaté cultivators

Appendix D

Characteristics of Xaté Harvesters Survey

Thank you for agreeing to talk with me and if you don't want to answer any of my questions, that's ok just tell me.
This study is for the doctorate practice of the student Sophie Williams from the University of Wales, Europe.
We are doing this survey to learn about the cultivation and harvesting of xaté.
Here is the contact information for Sophie, if you have any questions about this study.
You do not need to tell us your name and nobody will be able to identify any of the communities involved in the research.
It is voluntary to participate in this study, and if you are happy to participate then I will start to ask you some questions.

Date Village Interviewer Gender

1	How many people live in your household?	1	<input type="text"/>
2	How long have you lived in this village?	2	<input type="text"/>
3	What are the three main income activities for your household?	3	<input type="text"/>
4	Make a list of the main three sources of income? 2a <input type="text"/> 2b <input type="text"/> 2c <input type="text"/>		
5	Does anyone in your household own land?	5	Si <input type="checkbox"/> No <input type="checkbox"/>
	5.1 If yes, how much is land and how much to pay?	5.1	<input type="text"/>
6	Does anyone in your household borrow land from your family?	6	Si <input type="checkbox"/> No <input type="checkbox"/>
	6.1 If yes, how much is land and how much to pay?	6.1	<input type="text"/>
7	Does anyone in your household rent land?	7	Si <input type="checkbox"/> No <input type="checkbox"/>
	7.1 If yes, how much is land and how much rent?	7.1	<input type="text"/>
8	Is it possible to buy land at the moment?	8	Si <input type="checkbox"/> No <input type="checkbox"/>
9	Is the land that is available good for cultivating xaté? 9.a <input type="text"/> Very good <input type="text"/> Good <input type="text"/> Bad <input type="text"/>	9 c	<input type="text"/>
10	How much is land at the moment? be specific in units	10	<input type="text"/>
11	Is it possible to borrow money if you wanted to buy land?	11	Si <input type="checkbox"/> No <input type="checkbox"/>
12	Where can you borrow money from?	12	<input type="text"/>
13	Do you have a loan at the moment?	13	<input type="text"/>
14	What is the maximum they would lend you?		<input type="text"/>
15	How much interest would you have to pay?	15	<input type="text"/>
16	Do you know anyone that harvests over the border?		
	Yes -> 18.1		
	No -> 19		
	16 a <input type="text"/>	16 b	<input type="text"/>
16.1	How many people do you know that harvest across the border?	16.1	<input type="text"/>
16.2	What happens if people get caught harvesting across the border?	16.2	<input type="text"/>
16.3	Is there a fine for harvesting across the border?	16.3	<input type="text"/>
16.4	How many people do you know that got caught in the last 12 months?	16.4	<input type="text"/>
17	Do people in your household cultivate xaté?		
	Si -> 18		
	No -> 17.1		
	17.a <input type="text"/>	17 b	<input type="text"/>
17.1	Do you want to start cultivation?	17.1	Si <input type="checkbox"/> No <input type="checkbox"/>
17.2	Would you decide to cultivate if the price of cultivated leaf increased?	17.2	<input type="text"/>
17.3	How much would cultivated leaf price have to be for you to start to cultivating?		<input type="text"/>
18	Do people in your household wild harvest xaté?		
	Si -> WH questions		
	No -> Finish		
	20 c <input type="text"/>	20 b	<input type="text"/>

WH

1	How many people in your household wild harvest xaté?	1	<input type="text"/>
2	Do people from your household go out on trips every month?	2	<input type="text"/>
3	How many trips do people from your household make in a month?	3	<input type="text"/>
4	How long does it take to get to a good harvest place?	4	<input type="text"/>
5	How do you get to the place to harvest?	5a	<div>Moto <input type="text"/></div>
		5b	<div>Pie <input type="text"/></div>
			<div>Otros <input type="text"/></div>
6	How long is a normal trip?	6	<input type="text"/>
7	How many trips do people in your household normally make in a month?	7	<input type="text"/>
8	How do you transport your xaté out of the forest? Ask frequency	8a	<div>Horse <input type="text"/></div>
		8b	<div>Pie <input type="text"/></div>
		8c	<div>Otros <input type="text"/></div>
9	How many leaves in a grisa? Measure grisa if available	9	<input type="text"/>
10	How many grisas do you harvest per day on average?	10	<input type="text"/>
11	How many grisas do you normally gather on a good trip? and on a bad trip?	11	<input type="text"/>
		11.2	<input type="text"/>
12	What is the price per grisa at the moment?	12	<input type="text"/>
13	Does the price change?		<div>Si <input type="text"/></div> <div>No <input type="text"/></div>
14a	When is the highest?	14	<input type="text"/>
14b	When is the lowest?	14	<input type="text"/>
15	Is it legal to harvest in the Peten?	15	<div>Si <input type="text"/></div> <div>No <input type="text"/></div>
16	How worried are you about getting caught? on a scale of 1-5 (1 =not at all, 5 = very	16	<div>1 <input type="text"/></div> <div>2 <input type="text"/></div> <div>3 <input type="text"/></div> <div>4 <input type="text"/></div> <div>5 <input type="text"/></div>
17	If too many people get caught would you stop? How many is too many people?		
18	If you had a good job would you still go and wild harvest, even if you lost the job?		
19	What work opportunities would encourage you to stop harvesting?		

CU

1	When did you start xate farming?	1	<input type="text"/>
2	What kind of cultivation is it?	2a	<input type="text"/>
		2b	<input type="text"/>
		2c	<input type="text"/>
3	Do you grow xate for leaf or seed?	3a	<input type="text"/>
		3b	<input type="text"/>
4	Where did you get your xate seed?	4	<input type="text"/>
		4a	<input type="text"/>
		4b	<input type="text"/>
		4c	<input type="text"/>
		4d	<input type="text"/>
5	What did you have to buy to set up your xaté cultivation? Write costs	5a	<input type="text"/>
		5b	<input type="text"/>
		5c	<input type="text"/>
		5d	<input type="text"/>
6	What is the total area of your xaté?	6	<input type="text"/>
7	How many plants per? (mansana, ha or acre)	7	<input type="text"/>
8	Have you harvested xaté from your plantation?	8	<input type="text"/>
9	What is the total area of your xaté?	9	<input type="text"/>
10	How many plants per? (mansana, ha or acre)	10	<input type="text"/>
11	Have you harvested your xaté?	11	<input type="text"/>
12	How long did you have to wait to harvest after planting?	12	<input type="text"/>
13	How many leaves do you harvest each month?	13	<input type="text"/>
	13.1 What price did you get for this?	13.1	<input type="text"/>
14	How many leaves do you harvest per plant each year?	14	<input type="text"/>
15	How long do the plants live for?	15	<input type="text"/>
16	Do you grow other crops on the same land at the same time?	16	<input type="text"/>
	16.1 If yes, which crops?	16.1	<input type="text"/>
17	What did you use this land for before you started xate farming?	17	<input type="text"/>
	17.1 If you didn't grow xate on your land what would you grow instead?	17.1	<input type="text"/>
18	Generally, how many hours a day do you work on your xaté?	18	<input type="text"/>
19	How much does it cost for all the inputs into xaté farming per year? (e.g. fertilisers, pesticides etc)	19	<input type="text"/>
20	Do you have a xate nursery?	20	<input type="text"/>
	20.1 If yes, how much did it cost you to set up?	20.1	<input type="text"/>
21	Do you have an irrigation system for your xate?	21	<input type="text"/>
	21.1 If yes, how much did it cost you to set up?	21.1	<input type="text"/>
22	Have you had any of your xaté stolen?	22	<input type="text"/>
	22.1 If yes, how much was stolen and when?	22.1	<input type="text"/>
23	How many times have you had xaté stolen?		<input type="text"/>
24	How worried are you that your xaté will be stolen? on a scale of 1-5 (1 =not at all, 5 = very)	24	<input type="text"/>
25	Do you have security for the xaté?	25	<input type="text"/>
	25.1 If yes, how much does this cost? time if self and family or \$ if employ someone else	25.1	<input type="text"/>
26	If the price of cultivated leaf decreased would you stop cultivating? (open ended)		<input type="text"/>