Global Ecology and Conservation 3 (2015) 645–653

Contents lists available at ScienceDirect

Global Ecology and Conservation

journal homepage: www.elsevier.com/locate/gecco

Original research article

Seed harvesting of a threatened African tree dispersed by rodents: Is enrichment planting a solution?

Carrie E. Seltzer[a,*], Colin T. Kremer[b,1], Henry J. Ndangalasi[c], Norbert J. Cordeiro[d,e]

[a] University of Illinois at Chicago, Biological Sciences, MC 066, 845 W Taylor St, Chicago, IL 60607, USA

[b] W.K. Kellogg Biological Station, Michigan State University, 3700 E Gull Lake Dr, Hickory Corners, MI, 49060, USA

[c] University of Dar es Salaam, Botany, PO Box 35060, Dar es Salaam, Tanzania

[d] Roosevelt University, Biology, WB 814, 430 S. Michigan Avenue, Chicago, IL 60605, USA

[e] The Field Museum, 1400 South Lake Shore Drive, Chicago, IL 60605, USA

A R T I C L E I N F O

Article history:
Received 20 November 2014
Received in revised form 21 February 2015
Accepted 21 February 2015
Available online 2 March 2015

Keywords:
Recruitment
East Usambara Mountains
Eastern Arc Mountains
Cricetomys
Germination
Seed fate

A B S T R A C T

Non-timber forest products (NTFPs) provide income to local communities with less ecological harm than timber extraction. Yet overharvesting can still influence the regeneration and sustainability of these resources. Developing sustainable harvesting practices for emerging NTFPs depends on the biology of the NTFP species, the ecological context in which management occurs, and its cost in terms of effort and resources. Allanblackia stuhlmannii (Clusiaceae) is a canopy tree species whose seeds are a source of vegetable oil and an important food for rodents. In an experiment within the Amani Nature Reserve (Tanzania), we studied how enrichment planting of A. stuhlmannii seeds affected germination and establishment rates under varying local levels of seed abundance and rodent activity. Overall, germination and establishment rates were high (4.8% and 2.2%, respectively, after 11 months), while local ecological conditions had a short lived (1–2 weeks) and unexpectedly small influence on the persistence of planted seeds. Given these rates, we estimate a cost of approximately US$0.14 per seedling. Enrichment planting of seeds, across a range of local ecological conditions, appears to be a viable and cost effective management strategy for increasing A. stuhlmannii recruitment in harvested areas.

1. Introduction

Non-timber forest products (NTFPs) such as fruits, seeds, sap, or leaves offer income sources that can be obtained without deforesting parcels of forest. For example, Brazil nuts (*Bertholletia excelsa*), hearts of palm (*Euterpe edulis*), and açaí berries (*Euterpe oleracea*) are commonly collected directly from forests. Although NTFP harvest is less damaging than timber extraction or clearing forests for agriculture or pasture, it is not free of environmental consequences (Peters, 1994; Ticktin, 2004; Ticktin and Shackleton, 2011). Harvesting affects regeneration and demography; for example, gathering frankincense resin can reduce seed production (Rijkers et al., 2006) and collection of whole plants can alter the size structure of herb

* Correspondence to: National Geographic Society, 1145 17th St NW, Washington, DC 20036, USA.
E-mail addresses: carrieseltzer@gmail.com (C.E. Seltzer), colin.kremer@yale.edu (C.T. Kremer), hjndangalasi@udsm.ac.tz (H.J. Ndangalasi), ncordeiro@roosevelt.edu, ncordeiro@fieldmuseum.org (N.J. Cordeiro).
1 Present Address: Yale University, Department of Ecology & Evolutionary Biology, P. O. Box 208106, New Haven, CT 06520, USA.

http://dx.doi.org/10.1016/j.gecco.2015.02.011

populations (Law and Salick, 2005). Sustainable harvest levels vary and depend on species' life history traits (Zuidema et al., 2007). Some tree populations may be able to withstand harvests of up to 92%–93% of a seed crop (Zuidema and Boot, 2002; Emanuel et al., 2005), while such extreme harvest levels may seriously hinder the recruitment of other NTFP species.

Harvesting can also alter interactions between NTFP species and their consumers and mutualists, with unexpected and important consequences. For example, intensive açaí berry harvest reduces the diversity of seed-dispersing, frugivorous birds (Moegenburg and Levey, 2002). Many desirable NTFP's are oil-rich seeds and the preferred food sources of scatter-hoarding rodents. Well-documented examples include agoutis (*Dasyprocta leporina*) and acouchies (*Myoprocta acouchy*) in Central and South America consuming Brazil nuts (e.g. Jorge and Peres, 2005, Tuck Haugaasen et al., 2011) and *Carapa* spp. (e.g. Jansen et al., 2004). African giant pouched rats (*Cricetomys* spp.) act similarly to agoutis in seed predation and dispersal (Guedje et al., 2003; Nyiramana et al., 2011) but less is known about their effects on NTFP dispersal and regeneration. These conditional mutualists act as seed predators, but also disperse seeds (Theimer, 2004) and increase germination rates by scarifying seeds (Miller, 1995). Their net effect on NTFP demography depends on the abundance of food resources (which can be depleted by harvesting) and the intensity of competition for these resources.

Management strategies for NTFPs focus on maintaining natural recruitment by limiting harvests spatially and/or temporally, or augmenting recruitment by planting additional seeds or seedlings (enrichment planting) (Peters, 1994). Harvest restrictions promote natural dispersal and recruitment processes, but are difficult to enforce in remote or urgently threatened areas (Duchelle et al., 2012). Enrichment planting, the focus of this paper, can also boost recruitment (Makana and Thomas, 2004), but requires time and resources. To date, enrichment planting in tropical forests has primarily been studied in the context of reforestation, rather than sustainable NTFP harvest (Ådjers et al., 1995; Schulze, 2008; d'Oliveira and Ribas, 2011; Cole et al., 2011). However, traditional strategies of enrichment planting are known from the Amazon estuary where residents have long planted and managed açaí berries (*E. oleracea*) and other desirable NTFP species (Anderson et al., 1995). Experimentally, enrichment planting of Brazil nut (*B. excelsa*) seedlings has been successful, depending on light levels (Kainer et al., 1998; Peña-Claros et al., 2002). In practice, managers interested in enrichment planting must decide between using seeds and seedlings. Seedlings often have higher success, but require additional time, investment, infrastructure, and care. Seeds are more likely to suffer from predation or poor germination under natural conditions, but are easier to transport, store, and plant, and in some cases, may be less expensive (Schulze, 2008; Cole et al., 2011). Ecological context is also important in designing strategies. For example, the ability of scatterhoarding rodents to locate cached (or planted) seeds, and eat or re-cache them (Jansen et al., 2004), could negate the benefits of seed planting, depending on local resource levels. Ultimately, selecting appropriate management approaches requires understanding both the practical and biological factors influencing the survival, germination, and establishment of target species.

In the present study, we are interested in the management and sustainability of seed harvest of an endemic, threatened tree species in Africa. Nine species of trees from the genus *Allanblackia* (Clusiaceae) are found in moist forests across tropical Africa. They bear large fruits with lipid-rich seeds traditionally pressed for cooking oil. Recently, a coalition of organizations, called the Novella Africa Initiative, has begun working in Tanzania, Nigeria, and Ghana to develop a sustainable supply chain for three species, *A. stuhlmannii, A. floribunda*, and *A. parviflora*, as a component of mixed agroforestry (Jamnadass et al., 2010). *Allanblackia* cultivation and harvest, as well as commercial uses for its oil, are active research areas. However, several biological factors currently prevent farms from providing sufficient *Allanblackia* seeds, and wild populations cannot meet the expected demand (Pye-Smith, 2009). Much of the present supply comes from wild populations, including locally managed reserves that permit seed collection. Harvest is also occurring in protected areas where seed collection is prohibited, such as the Amani Nature Reserve in the East Usambara Mountains of Tanzania (NJC & HJN unpub. data).

Given the developing market for *Allanblackia* seeds, and the already extensive harvesting pressure in and outside of protected areas, evaluating strategies for ensuring sustainable *Allanblackia* seed harvests is important and timely. We conducted an 11-month study, tracking the fate of *A. stuhlmannii* seeds experimentally planted in environments spanning a range of seed density and predator activity. By assessing persistence, germination, and establishment rates through time and across environments, we determined the effectiveness and cost of enrichment planting as a management option, as well as the extent to which its success varies with ecological context. Finally, this study extends an NTFP management strategy to an emerging system in Africa, adding to the broader, growing literature on the conservation and management of NTFP species.

2. Methods

Study system. The Amani Nature Reserve (ANR) (S 5° 6′, E 38° 38′) protects 8380 ha of lowland and submontane rainforest in the East Usambara Mountains (EUM) in northeastern Tanzania (Tanga region), part of the Eastern Arc Mountains. About 75% of EUM forest has been cleared for tea plantations, non-native timber plantations, and small-scale multicrop farming (Burgess et al., 2007). The EUM receive 1700–2300 mm of rain throughout the year but the heaviest rains are in the short (October–November) and the long (late March–May) rainy seasons (Hamilton and Bensted-Smith, 1989).

A. stuhlmannii Engl. (Clusiaceae) is a rainforest canopy tree endemic to the Eastern Arc Mountains of Tanzania. *A. stuhlmannii* is diecious, with approximately one-third of the mature trees in the forest being reproductive females (Mathew et al., 2009). It is one of the most common canopy tree species in ANR. Each female tree typically produces 3–160 fruits per year, varying considerably among years and individual trees (NJC & HJN unpub. data). Fruits mature over one year into large