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Efficiency of conservation areas to protect orchid species in Benin, West Africa

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ABSTRACT

The effectiveness of protected areas to guarantee future conservation of several plant species remains questionable. This study was carried out in the Biosphere Reserve of Pendjari (BRP) and surrounding unprotected areas to assess the efficiency of the reserve to conserve orchids. A total of 90 plots (52 in protected areas; 38 in unprotected areas) were sampled. The recorded data include: orchid species, number of individuals per species, the height and diameter at breast height of host trees. Diversity indices were used to assess the orchid diversity in the protected and unprotected areas. Preferred habitat conditions of orchid species were investigated using Constrained Correspondence Analysis. An independent *t*-test and two-way analysis of variance were performed to assess an existing combined effect of vegetation type and the conservation status on the density of orchid species. The Importance Value Index (IVI) was used to measure how dominant an orchid species is in a given zone according to the conservation status of the zone. Only three epiphytic orchids (*Calyptrochilum christyanum*, *Cyrtorchis arcuata* and *Plectrelminthus caudatus*) were recorded and all in gallery forest of unprotected areas. Indeed, 67% and 58% of the orchid species were only recorded in unprotected areas and in gallery forest, respectively. There was no significant difference between the density of all recorded orchids in protected and unprotected areas. The conservation status of the studied zone had a significant effect on the densities of *Nervilia kotschyi* and *Eulophia guineensis* ($p < 0.0001$). The highest IVI of *N. kostchyi* was observed in the protected area and of *E. guineensis* was in the unprotected area.

This first effort to compile a reference list of the orchid species of the BRP showed that some orchid species were well represented within the protected area, but all of the epiphytic orchids were recorded from unprotected areas. A representative gap can be assumed to exist for most epiphytic orchids only recorded in the gallery forests of unprotected areas. Our results highlighted the need to redefine protective management strategies for orchid species in the BRP.

1. Introduction

The role of protected areas in the prevention of extinction of species has been much debated (Bruner et al., 2001). Several studies focused on the effectiveness of the protected areas to ensure the representativeness and persistence of biodiversity components (Defries et al., 2005; Wittemyer et al., 2008; Houéhanou et al., 2011, 2012, 2013). Some of the studies (Djossa et al., 2008; Gouwakinnou et al., 2009; Schumann et al., 2010; Fandohan et al., 2011) have emphasized the positive effect of protected areas to conserve some valuable species. However, a review of conservation goals for different protected areas (Myers et al., 2000; Diniz and Brito, 2015; Françoso et al., 2015) indicated a clear difference between expectations of conservation and the effectiveness in species conservation. In addition, a gap of some priority areas for orchid protection still needs to be filled by the existing protected areas network (Wan et al., 2014). Furthermore, the number of species threatened with extinction far exceeds the projections of scientists (Myers et al., 2000). This is the case of orchid species (CITES, 2017).

Orchids are distributed throughout the world from tropical to high alpine areas (Delforge, 2001). The Orchid family is with the Asteraceae the two largest families (Doyle and Luckow, 2003).

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From the demographic explosion, correspondingly strong land modification was observed in West Africa (Wittig et al., 2007; Wittemyer et al., 2008). Habitat alteration, including total loss, modification, and fragmentation was by far the main threat to most orchids in the tropics (Dressier, 1981). As a result, significant modification of light intensity, humidity, and other microclimatic factors affecting the survival of the epiphytic orchids, were observed. Many orchid species in West Africa are now considered to be at risk of extinction as a result of selective logging of valuable timber species and clear-felling for agricultural development (IUCN/SSC Orchid Specialist Group, 1996; Pillon et al., 2007; Pant, 2013). Wild orchids have been overharvested at large scale to supply the medicinal, edible, and horticultural trades (Kasulo et al., 2009; Pant, 2013; Ghorbani et al., 2014; Liu et al., 2014; Vermeulen et al., 2014; Hinsley et al., 2015). Reliable statistics on the extent of the trade in orchids in West Africa are scarce. However, several representatives of the orchid family are under threat of extinction due to indiscriminate collection (Cribb et al., 2005; Dunkan et al., 2005). In West Africa, extraction of wild orchids for trade affects mostly those few orchid taxa that either produce very showy flowers or provide certain edible products (IUCN/SSC Orchid Specialist Group, 1996). As a result of these multiple threats, orchids feature prominently in the Red Data Book prepared by International Union for Conservation of Nature (IUCN) (Pant, 2013). The entire family is now included in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 2017). However, in West Africa, large populations of orchids are still assumed to be present in their natural habitats in protected areas. It is therefore paramount to assess how effective the protected areas are in conserving the orchids in West Africa.

The Biosphere Reserve of Pendjari (BRP) is part of a well-managed protected area network in West Africa. It conserves 28% of the total flora of Benin Republic (Assédé et al., 2012). Previous studies have highlighted the importance of this reserve in plant conservation (Gouwakinnou et al., 2009; Fandohan et al., 2011; Houéhanou et al., 2011, 2013). Although the BRP is assumed to be the best way to conserve biodiversity of this area, its effectiveness in future conservation of several plant species is not always guaranteed (Houéhanou et al., 2013). Substantial representative gaps remain in its coverage of some plant taxa. Terrestrial orchids are known to colonize both savanna and forest areas (Delforge, 2001), while epiphytic orchids need appropriate host plants on which to grow.

In the Sudanian zone of Benin Republic, the two major networks of protected areas are focused on large mammal conservation. The targeted zones to create the conservation areas are then savanna ecosystems (the main habitat of those animals), covering up to 80% of the total protected areas. Based on the ecology of orchids, one might expect a gap of representation in the network of the protected areas in the study area. In Benin Republic, very few scientific studies have focused on orchid species (Akoègninou et al., 2006).

The purpose of this paper is to assess the suitability of existing conservation areas to conserve orchid taxa in West Africa. This study therefore compares protected and unprotected areas to test the assumption that the protected areas will have a higher conservation status of the orchid taxa than the unprotected areas. Specifically, we addressed two research questions: (1) What are the habitat requirements of orchid species occurring within the area? (2) How are orchid populations affected by the conservation status of the land, i.e. in protected versus unprotected habitats?

2. Materials and methods

2.1. Study area

This research was conducted in the Biosphere Reserve of Pendjari (BRP), located in the Sudanian zone of Benin Republic (West Africa) and in its surrounding areas (Fig. 1). The BRP covers about 4666.4 km^2. It is composed of the National Park of Pendjari or core zone (2660.4 km^2) representing the protected area in this study, and the hunting zones (Pendjari: 1750 km^2 and Konkombri: 251 km^2). In the protected area, anthropogenic activities are strictly prohibited. The surrounding areas representing unprotected areas in this study are dominated by farmlands, fallows (disturbed savannas), and gallery forests. The vegetation types in the unprotected areas were all subjected to selective cutting of valuable tree species for timber and poles, livestock grazing and harvesting of non-timber forest products. Gallery forest occurs along the Pendjari river both inside and outside the reserve. The dominant vegetation type in the protected area is savanna (wooded grassland), intermingled with patches of woodland and grassland. The climate is tropical with a five-month dry period (November–March). The mean annual rainfall is 1000 mm with 60% rain between July and September (Delvingt et al., 1989). Temperature varies between 21 °C during the night, and up to 40 °C during the day (CENAGREF, 2016). Ferruginous, indurate and swampy tropical soils occur in many areas of the protected and unprotected areas. The BRP is surrounded by 20 villages with subsistence agriculture as the main activity followed by livestock breeding and natural resources harvesting. Logging and clearing of land for agriculture remain the main sources of income for the local population. Cultivated crops include rice, yams, maize, sorghum, millet, and cotton; the latter being a cash crop and requires intense use of pesticides (Delvingt et al., 1989).

2.2. Data collection

Data were collected between December 2014 and August 2015, i.e. covering the two main seasons of the region: dry and rainy seasons. The vegetation map of the reserve (König, 2005) was used to identify the three main vegetation types (savannas, woodlands and gallery forests). Both protected and unprotected areas were included in the study. In each vegetation type, points were randomly selected to serve as the starting point of a transect. In total, 65 transects of at least 3 km long in each vegetation type were surveyed for the presence of orchid species.

Three-person teams were used to intensively survey the trees and the vegetation on the ground for the presence of epiphytic and terrestrial orchids. One team member monitored the compass bearing of the transect, and the other two members scanned the vegetation for orchids. The presence of orchid species was confirmed by two team members. This method was adapted from Bergstrom and Carter (2008) and Yulia et al. (2011).

Sample plots (Fig. 1) were selected along the transects, based on the presence of orchid species. Rectangular plots (10 m × 50 m) were sampled in gallery forests (due to the linear shape of the gallery forests) and Square plots (30 m × 30 m) in savannas, woodlands and fallows. At least 25 plots were sampled per vegetation type, and 90 plots in total (Table 1; with 52 plots in protected areas and 38 in unprotected areas).

The species and number of individuals of all orchid species (terrestrial and epiphytic) and the identity of host trees of epiphytic orchids were recorded within each plot. The dominant plant species of tree and shrub layers were recorded. Simultaneously, field data on environmental variables were collected. These included the vegetation type, vegetation cover, soil texture, and the presence of rocks or stones. Signs of human disturbance, including agriculture, grazing, tree cutting and pruning, were also collected within the plots of unprotected areas.

Herbarium specimens of all recorded orchid species were prepared and confirmed with the National flora (Akoègninou et al., 2006) and at the National Herbarium of Benin Republic.

2.3. Data analyses

2.3.1. Orchid diversity and habitat requirements

Diversity indices were used to assess the orchid diversity in the two zones (protected and unprotected areas). The taxonomic diversity considers the number of species, genera, and families. The Shannon-