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Abayomi (2000), Agindotan et al. (2003), (Kelebeni, 1983), (Usman and Smith, 1992), (Chege, 1998;

1987a,b; Tijani, 1993,1995), (Kumasi et al., 2001)
References should be listed at the end of the paper in alphabetical order. Articles in preparation or articles submitted for publication, unpublished observations, personal communications, etc. should not be included in the reference list but should only be mentioned in the article text (e.g., A. Kingori, University of Nairobi, Kenya, personal communication). Journal names are abbreviated according to Chemical Abstracts. Authors are fully responsible for the accuracy of the references.

Examples:

Chikere CB, Omoni VT and Chikere BO (2008). Distribution of potential nosocomial pathogens in a hospital environment. *Afr. J. Biotechnol.* 7: 3535-3539.

Moran GJ, Amii RN, Abrahamian FM, Talan DA (2005). Methicillinresistant *Staphylococcus aureus* in community-acquired skin infections. *Emerg. Infect. Dis.* 11: 928-930.

Pitout JDD, Church DL, Gregson DB, Chow BL, McCracken M, Mulvey M, Laupland KB (2007). Molecular epidemiology of CTXM-producing *Escherichia coli* in the Calgary Health Region: emergence of CTX-M-15-producing isolates. *Antimicrob. Agents Chemother.* 51: 1281-1286.

Pelczar JR, Harley JP, Klein DA (1993). *Microbiology: Concepts and Applications.* McGraw-Hill Inc., New York, pp. 591-603.

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Full Length Research Paper

Conservation and historical biogeography: How did the mountain chicken frog get to the Caribbean?

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***Leptodactylus fallax*, commonly known as the mountain chicken frog, is a large terrestrial frog currently found on two islands in the Caribbean. Habitat destruction, overhunting and disease outbreaks have contributed to declining population numbers. In order to identify appropriate conservation strategies, the historic geographic distribution of this frog must first be determined. Because no archeological evidence exists, this was accomplished by reviewing historical documents and inspecting museum collections. Inaccuracies in location and species names were identified in documents as well as in the mislabeling of museum specimens. Two means for natural immigration (dispersal and vicariance) and the artificial introduction by humans were considered. The authors concluded that the Amerindians transported *L. fallax* to eight islands throughout the Lesser Antilles as potential food resources as they colonized this area. The implication that 75% of the historical distribution is currently unoccupied by this species is considered in light of future reintroduction projects.**

Key words: *Leptodactylus fallax*, Amerindians, dispersal, vicariance.

INTRODUCTION

Wildlife biologists, zoo and aquarium personnel, and conservationists are often asked to “save a species” sometimes in a specific location. But should they? Important considerations need to be addressed before answering this question. Is the location part of the historic geographic range? How and when did the species arrive? Is it an endemic or an exotic?

Historical biogeography is the study of the geographic distribution of an organism and how that distribution occurred (Crisci et al., 2003). Understanding the past and present range of a species is necessary to appropriately identify and implement viable conservation strategies. One

species that could benefit from this process is *Leptodactylus fallax*, commonly known as the mountain chicken frog (Figure 1). It is a large terrestrial frog (SNV 121 to 167.2 mm) (Heyer, 1979) with a unique form of reproduction called obligatory oophagy (Gibson and Buley, 2004): a female lays eggs in a foam nest in which tadpole development occurs while the female produces infertile eggs as a source of nutrient for the young.

Currently this species is found on the islands of the Commonwealth of Dominica and Montserrat, but historically may have been found throughout the Lesser Antilles, the southeastern arm of the archipelago of the Caribbean

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Figure 1. The mountain chicken frog (*L. fallax*).

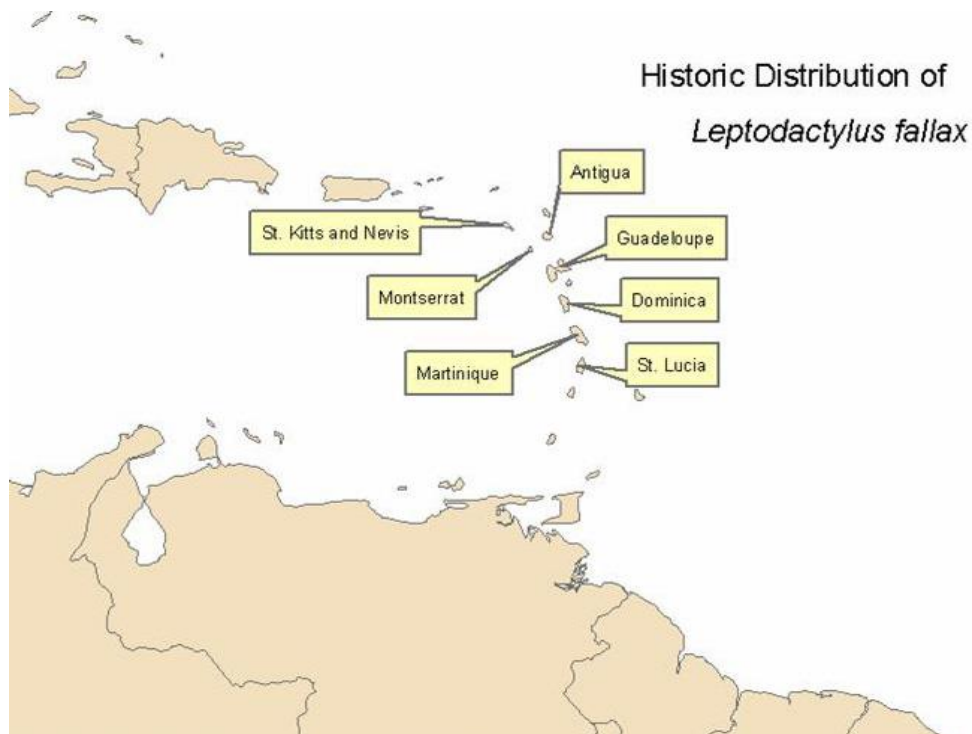


Figure 2. Historic distribution of *Leptodactylus fallax*.

Islands (Figure 2). Conservation organizations have expressed interest in reintroducing this species to several islands in order to re-establish its former range and

create ancillary populations as a “safety net” to catastrophic events: the population inhabiting the island of Montserrat is threatened by volcanic activity and populations found on

this and the island of the Commonwealth of Dominica are being decimated by the pathogenic chytrid fungus, *Batrachochytrium dendrobatidis*. However, it must be determined which islands actually composed the historical range of *L. fallax* before reintroduction should be considered.

A number of factors contribute to the puzzle of reconstructing the historical distribution of *L. fallax*. First, there appears to be no archaeological evidence, such as skeletal remains. As a result, we are forced to rely entirely on the historical literature and preserved specimens. Second, there have been inconsistencies in the taxonomic nomenclature that has been assigned to this species (see "Museum Specimen Search"). Third, preserved specimens have been mislabeled or lost, as will be documented below. And finally, several important historical references describing the geographic distribution of the frog are in French and mistranslations have been done.

METHODOLOGY

Literature search

A comprehensive literature search was conducted for the keywords "*Leptodactylus*" and "*L. fallax*". All relevant literature was obtained and pertinent references found in this literature were also gathered. Often these consisted of field notes from early explorers and many of these accounts were in French. The original French sources were then translated and compared with earlier translations to identify if any inaccuracies existed which are relevant to the geographic distribution of this frog species. The information in these sources was used to piece together the historical biogeography of *L. fallax*.

Museum specimen search

An index to herpetology collections in the United States can be found on the Internet (California Academy of Sciences, 2014). This source lists eight institutions holding specimens of *L. fallax* (Table 1). The web page for each institution was reviewed for information regarding number of individual specimens, location and date collected. In two cases, data were not available on-line and institutional personnel were able to supply collection records. One institution, the University of Kansas, listed ten specimens from the "Republica Dominicana" however there are no historical accounts of this species ever occurring in the Dominican Republic. Consequently, field notes were obtained, the collection was visited, and the specimens examined.

Biogeographical reconstruction

Attempting to reconstruct the historical distribution of *L. fallax* requires consideration of how this species first occurred on islands in the Caribbean. Our own training and field experiences and a review of relevant literature on island immigration enabled us to determine possible means for the arrival of the frog on the islands. Groome (1970) appropriately describes the challenge: "In general, Amphibia are absent on oceanic islands, for their eggs and tadpoles require fresh water and their skins are totally allergic to salt." Similarly, Meyer (1953) identifies the improbability of a natural immigration of the frogs to the islands: "Amphibians as a group are

delicate creatures, extremely susceptible to salt water, to desiccation, and to the heat of the sun, and since they do not possess wings, it is difficult to imagine how they could cross sea barriers."

There are two possible modes of natural immigration: vicariance and dispersal. Vicariance is the process by which one population is divided into two by the formation of a barrier, such as the rising of a mountain range or the flooding of a plain. Dispersal is the process by which members of a population cross a pre-existing barrier, sequentially becoming an isolated population. The arrival of *L. fallax* on islands in the Caribbean was further assessed by investigating known incidents of rafting and studies of ocean currents. In addition, more unusual modes of dispersal were noted in the historical literature.

RESULTS

The historical distribution of *L. fallax* by island in a north to south distribution

This reconstruction is based on accounts from the historical literature, inventories of museum collections, and in some cases a review of the specimens included in the collections.

Jamaica

The Jamaica Journal tells the story of a woman bringing a pair of *L. fallax* to this island and the successful breeding at two different sites (Proctor, 1973). This journal does not have a scientific focus and normally contains essays and poems, so it is likely that this was a fictional account. Additionally, a West Indies herpetologist confirmed no past or present reports of this species in Jamaica (Personal communication – Jay King). It is unlikely that *L. fallax* occurred on this island.

Dominican Republic

Lescure (1979) states that there is a translation error in the word Dominica in the book "*Amphibiens vivants du monde* (World living amphibians)". It states that *L. fallax* was a species found in the Dominican Republic, instead of on the island of the Commonwealth of Dominica. With the exception of a listing of *L. fallax* specimens at the University of Kansas from the Dominican Republic, no other accounts can be found. It was determined that these specimens were actually *L. albilabris* (Personal observation – Jay King). It is unlikely that *L. fallax* occurred on this island.

Puerto Rico

Attempts were made in 1929 and 1932 to introduce *L. fallax* to this island, but both failed. Barbour (1937) states, "The imported population which was taken while calling at night from Dominica, may be males only, according to Major Chapman Grants." Other than the brief unsuccessful attempts to introduce this species, it is unlikely that this

Table 1. Institutions with collections of preserved specimens of *L. fallax*.

Institution	Collection site	Year	No. of specimens
Carnegie Museum of Natural History ^a	Dominica	1969	1
	Dominica	1879	5
Museum of Comparative Zoology Harvard University ^b	St. Kitts / Nevis	1879	2
		?	5
	Dominica	1961	14
		1963	4
	1966	1	
Museum of Natural History University of Kansas ^c	Montserrat	1962	12
		1995	1
	Republica Dominicana*	1963	10
Museum of Vertebrate Zoology University of California ^d	Dominica	1881?	1
Museum of Zoology University of Michigan ^e	Dominica	1930?	1
National Museum of Natural History Smithsonian Institution ^f	Dominica	1929	5
		1930	1
		1964	1
		1964	1
		1965	11
		1966	46
		1967	10
	Montserrat	1980	4
		1996	2
		1980	2
		?	1
Natural History Museum of Los Angeles County ^g	Dominica	1963	1
Peabody Museum of Natural History Yale University ^h	Dominica	1890	1
Texas Cooperative Wildlife Collection Texas A&M University ⁱ	Dominica	1991	1
		1997	1

*These specimens were identified as *Leptodactylus albilarbirs*; ^a<http://www.carnegiemnh.org/>;

^b<http://www.mcz.harvard.edu/>; ^c<http://www.nhm.ku.edu/>; ^d<http://mvz.berkeley.edu/>; ^e<http://www.ummz.lsa.umich.edu/>;

^f<http://www.mnh.si.edu/>; ^g<http://www.nhm.org/>; ^h<http://yale.edu/>; ⁱ<http://wfscnet.tamu.edu/tcwc/tcwc.htm>.

species occurred on this island.

St. Kitts/Christopher

The Harvard Museum of Comparative Zoology contains four specimens collected from St. Kitts in 1879 and 1881 (Harvard, 2008). This represents a confirmed occurrence on this island.

Nevis

The four specimens in the Harvard Museum of Comparative Zoology listed above have “St. Kitts/Nevis” at the top of the record pages, but the identification of the collection location is “St. Kitts”. Since St. Kitts and Nevis are in such close proximity to one another, it is possible that specimens from these two islands were grouped together. *L. fallax* may or may not have occurred on this island.

Antigua

“*Cystiganthus*” was a term historically used to denote a genus of frogs. It is no longer used and frogs that previously were identified with this genus have now been reclassified into 17 other genera in 12 families. For example, Lescure (1979) states, “Dunn (1934) mentions the existence of *L. fallax* in Antigua based on a specimen of the British Museum classified as *Cystiganthus fuscus* by Gunther (1858).” Such name changes have only added to the confusion of the historical distribution of many species. However, Lescure believes the specimen described above may have been from the neighboring island of Montserrat because, “Antigua, originally a coral island, does not seem to offer the biotope conditions in favor of the *L. fallax*,” but he offers no additional substantiation of his claim. It is probable that *L. fallax* occurred on Antigua.

Montserrat

L. fallax is currently found on this island (Kaiser, 1994). Amerindian artifacts from Montserrat housed at the National Museum of the American Indian include pottery and stone carvings that depict images of frogs.

Guadeloupe

Historical references are highly contradictory. Lescure (1979) records that Father Du Tertre in 1667 wrote that “None of these frogs can be found on the Guadeloupe,” but Barbour (1912) describes this island as “a living environment of the *L. fallax*.” *L. fallax* may or may not have occurred on this island.

Commonwealth of Dominica (Dominica)

L. fallax is currently found on this island (Kaiser, 1994). It was first incorrectly identified in 1841 by Dumeril and Bibron as *Cystignathus ocellatus* (Lescure, 1979).

Martinique

In 1776, the naturalist Moreau de Jonnes was the last to report the presence of *L. fallax* on Martinique (Barrau, 1978; Lescure, 1983). A specimen was sent to the Paris Museum but is currently missing from the collection. Barrau (1978) believes the origin of this specimen cannot be confirmed because Moreau de Jonnes also traveled to other islands of the Lesser Antilles including Dominica. Failed attempts to introduce the frog occurred in 1965 and 1966 when a “lot” of frogs from Dominica were reintroduced to Martinique by M. Baly (Lescure, 1983). *L. fallax* did occur on this island but no longer exists.

St. Lucia

Barbour (1912) mentions that *L. pentadactylus* was recorded from this island, but provides no support for this statement. *L. pentadactylus* and *L. fallax* can, however, be easily confused by morphology. Lescure (1979) makes two confusing statements. First, he says, “No *Leptodactylus* specimens from St. Lucia are found in any natural history collections,” but then he states, “In the Catalogue of the Museum of Paris, written between 1839 and 1862, someone mentioned the skin of *C. ocellatus* among specimens of reptiles and amphibians sent from St. Lucia by Mur Bonnacour, on January 26, 1850 and on January 1851” (As stated earlier, *C. ocellatus* was inappropriately applied to *L. fallax* in the Commonwealth of Dominica). This specimen no longer exists in the Museum of Paris and, therefore, cannot be examined. Regardless of species, Lescure (1979) questions whether this specimen may have been collected in Dominica and then sent from St. Lucia to Paris. It is probable that *L. fallax* occurred on this island.

Trinidad

Lescure (1979) states, “*L. pentadactylus* can be found in Trinidad. *L. fallax* cannot be found there. The specimen labeled MCZ 8663 which had been identified as *L. fallax* is in fact a *L. pentadactylus*.” There was no other occurrence in the literature pertaining to the historical distribution of either species on Trinidad. Another large frog, *L. bolivianus*, does occur on Trinidad and could be easily mistaken for either of these species. It is unlikely that *L. fallax* occurred on this island.

Museum specimen search

As can be seen in Table 1 all known specimens of *L. fallax* in museum collections were originally obtained in the Commonwealth of Dominica, Montserrat, or St. Kitts/Nevis. An interesting exception is the collection at the University of Kansas.

This institution listed ten specimens of *L. fallax* as having been collected in the “Republica Dominicana.” Field notes from the collection were obtained which state, “Republica Dominicana: El Seibo: 2.3 mi SE Miches.” It was confirmed that this is a location in the Dominican Republic. The collection was visited and specimens examined. All ten frogs in the collection were determined to be *L. albilarbris*. It appears that this error was due to historical name changes.

In 1923, a frog from the Dominican Republic was named *L. dominicensis* (Heyer, 1979). In that same year, a different species from the Commonwealth of Dominica was assigned the same name. It was not until 1926 that this duplication was discovered. In accordance with the principle of priority, the frog from the Commonwealth of

Dominica was renamed *L. fallax* (Heyer, 1979). Later, in 1978, *L. dominicensis* was renamed *L. albilarbris*. Apparently, the confusion in the naming and renaming of the species resulted in the incorrect labeling of these ten specimens.

Historical biogeography

In order for vicariance to have occurred there must have been some former land connection between Central or South America and the islands in the Caribbean. The plate tectonic model (Duellman, 1999) proposes that a series of islands were formed in the area of present day Central America but then drifted eastward to form the Greater Antilles. However, the islands on which *L. fallax* likely occurred are part of the Lesser Antilles. These islands were formed by volcanism during the Tertiary Period (1.8 – 65 mya) (Malhotra and Thorpe, 1999). Consequently, there is no evidence to support the past existence of any land bridges connecting the Caribbean islands to either Central or South America thus eliminating the possibility of dispersal due to vicariance.

An alternative explanation is dispersal. Dispersal can occur through various means. Animals may disperse under their own power (e.g., walking, swimming or flying) or be carried. Barbour (1937) speaking of species dispersal in general states, "There has been undoubtedly some dispersal by flotsam and jetsam and some dispersal by winds and some transport by migrating birds and a good many types have been carried by man, both primitive and civilized".

In the literature, the term "floatation" has been applied to active swimming and to the use of rafts (Myers, 1953). This type of dispersal may occur when an individual is randomly "washed" into the water by a storm or when an individual enters the water on its own. Schoener and Schoener (1983) tested the propensity for voluntary dispersal by a lizard, *Anolis sagrei*. In this study, individual lizards were placed on rock outcroppings 1.5 to 3 m from shore. Their behavior was observed and 37% of all trials resulted in individuals leaping into the ocean and swimming or floating to shore. Schoener and Schoener (1983) suggest that, "Results support the hypothesis that lizards will leave islands on their own volition if those islands are inhospitable enough." They also propose that nearly all short-distance dispersals occurred during and immediately after hurricanes when lizards are most likely to be washed into the water (Schoener and Schoener, 1984).

Many evolutionary strategies have developed to aid in floatation. Some pacific species of the lizard family *Gekkonidae* have tubercular or granular scales that form spaces and retain pockets of air that may act as a natural "life jacket" (Schoener and Schoener, 1984). Some lizards have decreased surface tension around the central regions of the body which affects buoyancy thus

keeping their head and upper body above the water level. Yet, other species may gulp air to help them float. Schoener and Schoener (1984) tested the ability of *A. sagrei* to float in saltwater over a 24 h period. All individuals completed a one hour test period. The rate of success of floating decreased linearly with increasing time, with 30% being able to complete 24 h of floating. Therefore, a lizard jumping into the sea could conceivably reach an island, if currents were pulling in the right direction (Schoener and Schoener, 1983).

Although floating in seawater may be a possible option for the dispersal of lizards, this would not be a viable means of dispersal for frogs. In the case of frogs, floatation would necessitate the use of rafts.

During heavy rains animals often seek refuge in vegetation. As rivers rise and vegetation is torn away from the banks of rivers, rafts are created that may contain and then sweep animals downstream (Figure 3). King (1962) observed "rafts" floating pass a given point in the Rio Tortugero in Costa Rica. The amount of material ranged from 0.15 to 305 m² of vegetation per minute. King (1962) states, "If the whole year is considered similar to the seven weeks of observation, and if the total number of rivers entering the Caribbean from Central and South America is considered, the square feet of rafting material entering the Caribbean each year must be impressive."

Many rafts were torn apart by waves and eddies as they entered the mouth of a river. However, if the surf was low or if there was an off shore wind to blow a raft through the surf, rafts would float out to sea. Once in the open ocean, water hyacinth rafts would last two to three days and hyacinth/grass rafts would last an additional several days.

Heatwole and Levin (1972) provide data on the frequency of finding individual organisms on rafts. Of 59 pieces of flotsam (floating debris) picked up at sea, 25% contained live terrestrial animals, 21% had two species, 6% had three or more, and one contained 12 species. In 22% of flotsam a number of conspecific individuals occurred on the same drift item. Termites, ants, lizards, snakes, toads, mammals and a crocodile have been found on flotsam.

Henderson and Powell (1999) propose that all species that successfully colonized the islands of the Caribbean originated in "coastal habitats, forest edges, and other open situations making them more tolerant of high ambient temperatures and sun-drenched habitats than, for example, forest-dwelling species." Such an increased tolerance would facilitate the ability to survive a prolonged over-the-water journey. For example, some species of Puerto Rican anoles appear to have a high tolerance to saltwater, with a body impermeable to water (Schoener and Schoener, 1984). In addition, if rafting occurred during heavy rains, the possibility of desiccation and predation by birds may be greatly reduced.

Although no comprehensive study addressing the rate



Figure 3. Water hyacinth raft, Costa Rica.

of success of rafting from one island to another was found, there are accounts of successful rafting. In 1828, a boa constrictor, drifted to St. Vincent on the trunk of a cedar tree (Guilding, 1828). Apparently it rafted 250 miles from the Orinoco River. In another case, an alligator was carried on a tree trunk from South America to Barbados in 1886 (Fielden, 1889).

Another report lends credibility to the possibility of natural dispersion via rafting (Censky et al., 1998). In 1995, at least 15 green iguanas (*Iguana iguana*), males and females, were observed arriving on Anguilla after floating ashore on a mat of logs and uprooted trees. Iguanas were also found on Scrub Island (off Anguilla) and Barbuda. This occurred after Hurricanes Luis and Marilyn crossed the eastern Caribbean. This species had previously never been identified on any of these islands and is believed to have originated on Guadeloupe.

Myers (1953) describes another means of dispersal: "Except by the hand of man, two methods are available, flotation and wind-dispersal. Wind dispersal is available only to smaller animals which may be borne aloft by the wind or blown by the storm winds of high velocity, often in pieces of vegetation." Despite the fact that it seems improbable that frogs would be dispersed by winds, there have been reports of such events throughout history. McAfee (1917) wrote, "The idea of organic matter and particularly of living things raining down from the sky, on first thought, is hard to entertain. There have been recorded in all periods of historic time, however, showers of one kind or another of animals and plants or their products: showers of hay, of grain, or manna, of blood, of fishes, of frogs, and even of rats."

Two spectacular accounts involving flying or raining frogs can be found in the historical literature (McAfee, 1917): "During the storm that raged with considerable fury in Birmingham (England) on Wednesday morning, June 30 (1892), a shower of frogs fell in the suburb of Moseley. They were found scattered about several gardens. Almost white in color, they had evidently been absorbed in a small waterspout that was driven over Birmingham

by the tempest." And: "In Paeonia and Dardania [Greece] (200 AD), it has, they say, before now rained frogs, and so great has been the number of these frogs that the houses and the roads have been full with them; and shutting up their houses endured the pest; but when they did no good, but found that all their vessels were filled with them, and the frogs were found to be boiled up and roasted with everything they ate, and when besides all this they could not make use of any water, nor put their feet on the ground for the heaps of frogs that were everywhere, and were annoyed also by the smell of those that died, they fled the country."

One last possible means for the dispersal of frogs in the Caribbean is artificial dispersal (or transport) by humans. Pre-Columbian Amerindians traveled maritime routes throughout the Caribbean. Amerindians from the Orinoco region of South America reached the Lesser Antilles as early as 2000 BC and continued their expansion into the Greater Antilles (Steadman et al., 1984). At the time of Columbus' arrival the Taino, Hatabey and Carib cultures were established throughout the Caribbean. As observed in the carvings and pottery of Amerindians, frogs were of symbolic value to the cultures of the Amerindians (Rouse, 1992).

Honeychurch (2002) investigated the role of the frog in traditional Carib culture. "The Carib, like their other Amerindian ancestors who lived on the islands before them, divided the year into two. One half of the year was male. The other half of the year was female. The male was dry. The female was wet. The man was represented by the bat. The woman by the frog, the dry season was the time of the Bat Man. The wet season was the time of the Frog Woman. June 21, is the time of the Frog Woman. The wet season is beginning and frogs come out when it rains. They produce many eggs and the Frog Woman represents fertility.....Under the spirit of the Frog Woman it is the task of the female to plant the crops."

Images of frogs commonly occur in Pre-Columbian art. Lesure (2000) assessed clay figures and effigies from the Mazatán area of Mesoamerica dated between 1400 and 1000 BC. He compared the kinds of reptiles and amphibians represented in art to the frequencies of the same animals occurring in faunal remains. "Toads" were found in 72% of effigies but were completely absent from faunal remains.

Images of frogs were carved into rocks in the form of petroglyphs, depictions are found on pottery, and in jewelry (Figures 4 and 5). Images of the Frog Woman, the Tainos refer to her as Atabey or Attabeira, can be found throughout the Caribbean, Central America, and South America. The Kalinago people and other Caribs crafted her in stone, bone, shell and clay as half frog and half woman (Figure 6). "Her hands and feet are webbed like a frog. She faces us with her anus and legs wide apart like the limbs of a frog. Her navel is prominent at the centre of every image made of her. Her vagina is exposed. She is ready for sex (Honeychurch, 2002)".

A variety of frogs provided an essential food source for



Figure 4. Toad effigy vessel – earthenware – Veracruz culture – 1st century.



Figure 6. Stone carving depicting the Frog Woman.



Figure 5. Frog pendant – cast gold – Costa Rica – 11th to 16th century.

the people who brought them to the Caribbean. Paintings and carvings found in South America show frogs being sold in markets (Figure 7). It is known that frogs were consumed by the Aztec, Inca and Maya. The Maya ate a frog called the *uo* (*Leptodactylus* spp.), which was a source of fat, and the Aztec, not only ate adult frogs, but the tadpoles (Coe, 1994). They are considered a delicacy and *L. fallax* was the national dish of Dominica.



Figure 7. Ceramic vase. Pre-Columbian. Woman holding frog.

Historical literature depicts a strategy used by early maritime travelers of transporting a variety of animals to islands to establish ready food supplies. Portuguese sailors released rabbits, pigs, sheep and monkeys (*Macaca fascicularis*) on the island of Mauritius around 1528 (Sussman and Tattersall, 1981). Endemic West Indian animals, such as the agouti and feral pig, were carried by aboriginal peoples from South America to the islands of the Caribbean (Olson, 1982; Steadman et al., 1984). On many islands iguana (*Iguana iguana*) (Grant, 1937) and red-footed tortoise (*Geochelone carbonaria*) (MacLean, 1982) are considered as viable food sources and were likely transported to the Caribbean by the Amerindians.

Consequently, and as others have suggested (Barbour, 1912; Barrau, 1978; Kaiser and Henderson, 1994), it is highly feasible that the Amerindians introduced *L. fallax*'s ancestor as a food supply to various islands in the Caribbean.

Barbour (1912), believing *L. pentadactylus* and *L. fallax* to be the same species (*L. fallax* was not classified as a separate species until 1923) wrote, "This species, with an enormous distribution over the South American mainland, has been recorded from but three West Indian islands, - Dominica, St. Kitts and St. Lucia. This distribution strongly suggests an artificial introduction as an article of food. It may, however, have been extirpated upon other islands where it once occurred for this very reason". It is then confusing why Barbour in the same text would write, "An argument against their artificial introduction, we may cite Father Labat, who, in his accurate and engrossing narrative entitle 'Nouveau voyage aux iles d'Amerique,' [in French] informs us that, 'In Martinique and on a few other islands one finds the most beautiful frogs in the world, they are called toads because their appearance resembles those found in Europe, that is their skin is grey with yellow and black spots or stripes; they don't stay in water, but in the woods where they crow very loud, especially at night. Their flesh is white, tender and delicate. Only the head is discarded.'" This description does accurately describe *L. fallax*, and there does not appear to be any portion of Father Labat's statement that would argue against introduction.

Kaiser and Henderson (1994) 'speculate' that Amerindian settlers introduced this frog and support their speculation by citing Barrau (1978). In this original French text, Barrau describes a situation of over-hunting and the effects of the introduction of domesticated animals (pets, pigs, bovines) to Martinique, "The following species became extinct or endangered: agouti *Daysprocta*, the giant frog *Leptodactylus*, the iguane *Iguana* - (which was so popular that the island was named after it "Luanacaera") le lamantin *Trichechus* which was found along the coasts, the large "pilor" rat". There is no other mention of frogs or Amerindians. It is possible that this and other mistranslations of original text have led to confusion regarding the location of particular species on

various islands.

DISCUSSION

Reconstructing the historical geographic distribution of *L. fallax* is problematic. In some cases, earlier conclusions have been based on inaccurate translations. In others, speculations were made without substantive evidence. However, historical accounts and museum collections support the reconstruction of the historical distribution of *L. fallax* to include the Commonwealth of Dominica, Montserrat, St. Kitts, Martinique, and possibly St. Lucia, Antigua, Guadeloupe and Nevis. Due to recent attempts to introduce the species, it may have briefly occurred on Puerto Rico. It is unlikely that it ever occurred on the Dominican Republic, Jamaica, or Trinidad. Vicariance as a mode of introduction for any Lesser Antillean species is not supported by paleogeographic data. Dispersal via rafting is supported for some species, but it is highly unlikely in the case of *L. fallax* for several reasons. First, King et al. (2005) showed through antimicrobial peptides that *L. fallax* and *L. pentadactylus* share a common ancestor. Because of the range of *L. pentadactylus*, and theoretically that of the ancestor, rafts would have had to originate from northern or north-eastern South America to reach the Caribbean. By observing the combined movements of southern and northern equatorial currents, trade winds and buoy trajectories (Molinari et al., 1981), it is noted that the ocean currents in this region move in a north-westerly direction. Rafts originating from South America, under normal weather conditions, would not reach the Lesser Antilles.

Second, it is possible that non-normal weather conditions (hurricanes) could carry a raft to the Lesser Antilles. But the current distribution of *L. fallax* is on the west coast and central portions of Montserrat and the Commonwealth of Dominica. Hurricanes would deliver rafts to the east coast.

Third, successful rafting would necessitate an ocean voyage of hundreds of miles and a time frame of between two and four weeks (Censky, 1998). Due to the permeability of amphibian skin, it is not probable that a frog could withstand such a trip.

And lastly, although some historical references attest to the possibility of "flying" as a dispersal mechanism of frogs, the probability of such a natural phenomenon makes this an unlikely scenario.

Introduction of the ancestor of *L. fallax* by Pre-Columbian Amerindians as they colonized these islands appear to be the most likely mechanism. Frogs were considered a food staple and this type of strategy has been employed by these and other peoples during island colonizing events. As reported in Barbour, 1912, Father Labat said, "Their flesh is white, tender and delicate". Recent discussions have occurred on whether or not *L. fallax* should be reintroduced to islands on which it may

have previously been found. Two terms need to be appropriately defined: introduction and naturalization. Introduction is “the deliberate or accidental release of a species into a country in which it is not known to have occurred within historic times (Lever 2003)”. Naturalization is, “the establishment in the wild of self-maintaining and self-perpetuating populations of an introduced exotic species unsupported by, and independent of humans (Lever 2003)”. The ancestor of *L. fallax* can clearly be classified as an “introduced exotic” but at some point, once it became established, it would have become a “naturalized” species.

It must be remembered that ecosystems are not static and change with time. As biologists and conservationists, we must decide at what point in time we desire to preserve a biotic community. For example, suppose a prairie had been a forest before bison migrated and destroyed the trees. Do we maintain the land as a prairie or do we try to return it to the previous state of a forest? The same can be asked about the islands of the Lesser Antilles: Do we return the islands to a state before *L. fallax* was introduced or after introduction but before local extinction?

A real world situation occurred on the Hawaiian island of Nihoa (Lockwood and Latchinsky, 2008). In this case, the government hired pest managers to eliminate the gray bird grasshopper (*Schistocerca nitens*) from the island. The insect was first observed in 1977. But how did it arrive on Nihoa? Did it “stowaway” on some type of vessel or was it carried by wind from another location? Accidentally introduced by humans or a natural occurring pioneer event? Should this make a difference? And why was this species being considered for eradication? Why not other exotic species? Yes, it was destroying local vegetation, but the endangered Nihoa miller bird (*Acrocephalus familiaris*) was recovering due to the grasshopper as a food source. Are the plant species more “valuable” than the miller bird or the grasshopper? So why choose a time frame in the history of Nihoa before the arrival of the grasshopper? These are all questions that must be answered. In the end, no action was taken- not because a decision was made to save the grasshopper, but because no method of extermination could be found that would not harm other species.

Based on historical biogeography, the ancestor of *L. fallax* should be considered an introduced, exotic species on each of the islands on which it is and was found. Since it is not an endemic species, a strict point of view would dictate that it should not be reintroduced to any of the islands. But the islands of the Lesser Antilles are volcanic in origin and, therefore, no species is native. Such islands are colonized by immigrating pioneering species whether naturally dispersed or, as in this case, artificially introduced. If this line of reasoning is followed, then can any species, in an island ecosystem, ever be considered a native?

More importantly, is the present frog the same as the ancestral frog? *L. fallax* currently is not found on any mainland masses. Therefore, it has either become extinct

from the mainland or it may represent a speciation event that occurred after the original frogs were transported to the islands. Easteal (1981) concluded, “The colonization of a new area by a species may be a major event in the evolution of that species and can result in the formation of a new species. This can occur if the colonizing event itself causes isolation between different populations, which then diverge genetically as the result of micro-evolutionary processes or if the colonizing event itself, in cases where it involves few individuals, brings about a radical genetic change in the founding population”.

Regardless, whether it is an ancestral or new species, this frog is found nowhere else in the world except on these few islands and, therefore, should be considered a recent endemic to the Lesser Antilles. Its survival may be dependent on its reintroduction to the islands of St. Kitts/Nevis, Antigua, Guadeloupe, Martinique, St. Lucia and the careful management of the frogs on all the islands. All attempts should be made to establish it to its historical home range.

This research demonstrates that without a thorough review of historical documents and museum collections, the historical distribution of a species may be impossible to ascertain. Consideration of the present and past geographical distribution of a species, the means by which a species first occurred, and current threats to its continued existence must all be assessed in order to delineate appropriate and viable conservation strategies.

Conflict of interests

The authors have not declared any conflict of interests.

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Full Length Research Paper

Composition and stand structure of a regenerating tropical rainforest ecosystem in South-western Nigeria

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The dynamics of forest regeneration in a tropical rainforest ecosystem in South-western Nigeria as exemplified by International Institute of Tropical Agriculture Forest Reserve, Ibadan, Nigeria was assessed. Twenty-four sample plots of 25 × 25 m each were used to assess all plants ≥ 5 cm diameter at breast height (dbh) (1.3 m) in each plot for density, height, dbh and frequency. Detrended Correspondence Analysis (DCA), similarity and diversity statistics were used to analyze the data. A total of 1,328 trees (885.33 trees/ha) from 57 species and 28 families were encountered. Dominant families include *Moraceae*, *Sterculiaceae*, *Papilionaceae*, and *Sapindaceae*. *Lecaniodiscus cupanioides*, had the highest density (94.67 trees/ha) with Relative Importance Value (RIV) of 20.81% while *Euadenia trifoliolata*, *Malacantha alnifolia*, *Solanum enriathum* and *Zanthoxylum zanthoxyloides*, had the least RIV of 0.640, 1.24, 0.79 and 0.64%, respectively. Species such as *Lecaniodiscus cupanioides*, *Newbouldia laevis*, *Spondia mombim*, *Sterculia tracagantha*, *Antiaris toxicaria*, *Milicia excelsa*, *Funtumia elastica* and *Albizia zygia* were identified as universal species. Simpsons' diversity indices ranged from 0.375 to 0.924 for all the plots. The equitability index ranged from 0.793 to 0.985 for all the plots, while the basal area ranged from 0.052 to 27.809 m²/plot. The cumulative stem diameter class of 10 to 44 cm accounted for 72.57% of the total number of stems in the forest estate. High Eigen value (73.3%), length of ordination space coverage (-3 to 6) and the location of all the plots in the first quadrant indicated that the environment was stable; indicating minimal variation in floristic composition between plots and high heterogeneity of the site and species respectively. Conclusively, this study demonstrated that natural regeneration could be an effective strategy for restoration of tropical tree species, diversity, canopy height, tree stem density and size distributions.

Key words: Ordination, density, species, diameter-class, relative importance value.

INTRODUCTION

Vast areas of primary rain forest today are being lost through exploitation, large scale forest fires, urbanization

and conversion to agriculture. As a result, degraded vegetation type and secondary forests are replacing

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patches of species-rich lowland rain forest. Species richness may recover rapidly during secondary forest regeneration; however the species composition of secondary forests remains very different from that of mature forest for many decades (Finegan, 1996; Wijdeven and Kuzee, 2000). Although difficult to be defined, secondary forests are estimated in a worldwide basis to cover between 530 million ha to 600 million ha (FAO, 1996). Emrich et al. (2000) suggested that tropical secondary forests are now being recognized for their value in the conservation of biological diversity and high regenerative potential (Chazdon, 1998). Investigations into floristic composition and structure of forests are essential for providing information on species richness of the plants and the changes that they undergo that can potentially be useful for management purpose and assist in understanding the forest and ecosystems functions as a whole (Ssegawa and Nkuutu, 2006; Addo-Fordjour et al., 2009; Pappoe et al., 2010).

An improved understanding of secondary forests is sought, both for timber management (Patrick et al., 2004) and biodiversity conservation is vital for the sustenance of the ecosystem (Guariguata et al., 1997; Foster et al., 1999). In most tropical countries, secondary forests comprised larger areas than primary forest for decades (Gómez-Pompa and Va'zquez-Ya'nes, 1974). However, fundamental aspects of tropical forest regeneration following agriculture remain poorly understood (Foster et al., 1999; Patrick et al., 2004), because most studies of tropical secondary forests have been confined to the first few decades of vegetation recovery. Studies of later successional phases are needed to address issues central to the recovery of plant diversity and composition in tropical secondary forest, as clear patterns may only emerge over extended periods of time (Brown and Lugo, 1990; Laurance and Bierregaard, 1997; Martin et al., 2004). In particular, protected areas of primary forests in the tropics act as effective sources of native plant species for the recolonization of abandoned lands. Hence the objectives of this study includes; 1) Characterizing the floristic structure and composition of the main tree species; 2) characterizing the regeneration dynamics and prioritize woody species for conservation and 3) study of relationship between environmental factors, the structure and floristic composition of the forest reserve.

MATERIALS AND METHODS

Study area

The study area is located on the one thousand hectares land in the International Institute of Tropical Agriculture (I.I.T.A) campus at Idi-Ose, Northern part of Ibadan, Nigeria. It is located on longitude 7°30'N and latitude 3° 55'E at 243 m above sea level. The rolling topography is dominated by slopes of between 3-10% (Moormann et al., 1975). The area is underlain by metamorphic rocks of pre-cambrian basement complex, consisting largely of banded gneiss alternating with strata of quartzites and quartz schists (Aiboni,

2001). The soils are predominately Ferric Luvisols (Moormann et al., 1975). The site falls within the humid tropical lowland region with two distinct seasons: the longer wet season and shorter dry season. Wet season last for eight months from March to October while dry season last for four months from November to February. The rainfall pattern has bimodal peak with an annual total ranges between 1,300-1,500 mm most of which falls between May and September. The average daily temperature ranges between 21-23°C while the maximum is between 28 and 34°C. Mean relative humidity is in the range of 64-84% (Hall and Okali, 1979, Osunsina, 2004).

Floristic data measurement

Data collection for this study are purely based on vegetation survey comprising of tree characteristics which includes; total number of species, total number of stems (stem density), Diameter at breast height (dbh) of each tree and total tree height from Twenty four (25 X 25 m) permanent sample plots. In each sampling plot, all trees \geq 5cm in diameter at breast height (DBH) were measured with the aid of diameter caliper and total height (HT) using Haga altimeter according to methods described by Dike et al. (1992), Ojo (1996) and Isikhuemen (2005). Within each plot, all live woody vegetation with (stems \geq 5 cm DBH) and plant species that cannot be identified on the field were collected, pressed, and identified at Forestry Research Institute of Nigeria herbarium. The ecological status of the tree species was determined by calculating the Relative Importance Value (RIV) for each species which was obtained by summation of the relative percentage values of frequency, density and dominance (Oyun et al., 2009). The Law of Frequency or valence analysis (Raunkaier, 1934) was used to assess the rarity or commonness of the woody species (Hewit and Kellman, 2002; Pirie et al., 2000). In this classification the percentage frequency of the species was classed as A, B, C, D and E; where A represents rare (0 to 20%), B is low frequency (20 to 40%), C is intermediate frequency (40 to 60%), D is moderately high frequency (60 to 80%) and E is high frequency or common (80 to 100%). With this classification, the expected distribution of the species is $A > B > C \geq D < E$. The diversity of trees (individuals \geq 10 cm dbh or \geq 5 cm dbh) was determined for each plot using Simpson's diversity and similarity indices (Vasanthraj and Chandrashekar, 2006) Basal area and densities were determined on per hectare basis (Mishra et al., 2005; Addo-Fordjour et al., 2009). The basal areas of the trees in each plot were summed up and converted to basal area per hectare. The densities of trees were calculated on per hectare basis for each plot and used to calculate mean number of individuals/ha for the entire stand. The diversity indices of the communities were calculated following Kent and Coker (1992). Detrended correspondence ordination analysis was used to analyzed the floristic data.

Stand structure was determined by diameter classes (Adam and Ek, 1974). Tree data were grouped into 5 cm diameter classes for example class boundaries of 5-10, 10-15 e.t.c. These will give the frequency of trees in each diameter class (Oladoye, 2012)

RESULT

Floristic composition and structure of tree species

A total of 1,328 trees representing 57 species from 28 families were encountered during the study (DBH > 5 cm). *Moraceae* had the highest number of species (7), *Sterculiaceae*, *Papilionaceae* and *Sapindeae* had 4 species each, while *Tiliaceae*, *Solanaceae*, *Rutaceae*, *Oiaceae*

and *Myrsitaceae* had 1 species each (Table 1). Among the identified tree species, *Antiaris toxicaria*, and *Spondia mombin* had the highest frequency of 79% each, while *Funtumia elastica*, *Sterculia tracagantha*, *Lecaniodiscu cupanioides* had frequency of 75% each. The least frequency (4.1%) was found in *Azelia africana*, *Celtis midberii*, *Euadenia trifoliolata*, *Glyphea brevis*, *Kigelia africana*, *Malacantha alnifolia*, *Phyllanthus discoides*, *Rithiea capparoides*, *Solanum erianthum*, *Theobroma cacao* and *Zanthoxylum zanthoxyloides* (Table 1). The stocking density of dominant tree species/ha in the study area ranged from 0.67 trees/ha to 95 trees/ha. *L. cupanioides* had the highest RD of 10.07, followed by *A. toxicaria* (8.43), *S. tracagantha*(7.91), and *N. aervis* (7.83). In addition, *E. trifoliolata*, *G. brevis*, *K. africana*, *M. alnifolia*, *R. capparoides*, *S. erianthum*, *Theobroma cacao* and *Z. zanthoxyloides* had the lowest RD of 0.08 and relative importance value (RIV) of 0.64, 1.24, 0.78, 0.64, 0.64, 0.64, 0.71 respectively (Table 1). Highest RIV (20.8%) and density of 94.67 tree/ha was found in *L. cupanioides* followed by *A. toxicaria* (19.12; 74.66 trees/ha) (Table 1). The distribution of the 57 species into Raunkaier's frequency classes showed that 32 (56%) of the species encountered were rare (Table 2). A few species were however of the low and intermediate frequency classes. This distribution does not follow the expected $A > B > C \geq D < E$ frequency distribution proposed by Raunkaier (1934) in that frequency class E was not represented.

Similarity and diversity and of tree species

In the dendrogram similarity levels ranged between 5 to 57% (Figure 1). Some plots were floristically identical (plots 37 and 60). Based on two dimensional scaling, cluster analyses of the 24 plots sampled revealed 6 groups of plot assemblages. Members in each assemblage suggested a closer ecological similarity. The groupings revealed the similarity in species composition between plots.

Table 3 shows density/plot which ranged from 3-97. Plot 89 had the highest (97) followed by plot 37 (91) and the least was found in plots 6 (3). Dominance was generally low in most of the plots with average of 0.051. However, dominance was high in plot 69 (0.62) and plot 6 (0.55) which contains mainly *G. sepium* and *A. zygia*. Species distribution was even (Evenness = 0.49) and average diversity index (Simpson) for all the plots was 0.95. Simpsons diversity indices revealed high diversity values in plot 57 (0.92) and the least was found in plot 69 (0.37) with *B. micrantha*, dominated. Plot 37 dominated by *A. toxicaria*, plot 30 with *B. angolensis* (0.92). Plot 41 was dominated by *L. cupanioides* (14) and *A. cordifolia* (11) (Table 3).

Basal area on plot basis ranged from 0.051 to 27.81 m². Plot 30 had the highest basal area of 27.809 and density of 62, from 20 species. The lowest basal area was found

in plots 6 and 69 (0.05 and 0.21 m²) respectively (Table 3).

Stand ordination for tree species

The stand ordination (Figure 2) shows a continuous gradient of plots along axis 1 and a discontinuous gradient along axis 2. Axis 1 and axis 2 represents 73.3% of the variance accounted for by the first four-ordination axes. This indicate high heterogeneity of the study site, with exception of plot 69 which is a degraded plot, and plots 68 and 57 that are outliers because most the species presents in other plots are not common to them. Four groups were identified from the ordination diagram based on the similarities in their floristic composition and closeness of the plot to each other. Group 1 include plots 26, 70 and 86; these are located adjacent to each other at the extreme right side of the horizontal axis with percentage floristic composition ranging from (60-80)% and have 12 species in common, which include; *Celtis midberii*, *Manilkara obovata*, *Ceiba pentandra*, and *S. tracagantha*.

The second group include plots 84, 97, 76, 30, 60, 95, 64, 28.17, 41, with 11 species common to them, which include; *Celtis zenkeri*, *Albizia zygia*, *Bosquia angolensis*, *A. toxicaria* and *F. elastica*. The third group include plots 14, 8, 37, 90, 6, 49, 89, they have 9 species in common, having; *Monodora tenuifolia*, *Trichilia monadelphica*, *L. cuscupanioides*, and *A. toxicaria*. The fourth group has only plot 69, which is dominated by *Bridelia micrantha* and *Chromolaena odorata* as a result of invasion. The first (horizontal) axis shows the gradient of all the plots on the positive side of the axis, the vertical axis show plot 69 on the top left corner. Superimposition of the species ordination diagram on the plot ordination diagram gives an insight into species with optimum abundance in each plot. It can therefore be inferred that *Bridelia micrantha* was abundant in plot 69 as reflected in the table, while species such as *Alchornea cordifolia*, *M. obovata*, *A. africana*, *M. thonningii*, *H. floribunda*, *S. smombin*, *C. pentandra*, *L. cupanioides*, and *Baphianitida*, were abundant in plots 84, 48, 97, 76, 30, 60, 95, 64, 41, 28.17. *Celtismidberii* was abundant in plot 26, while *Rothmania longiflora*, *Manilkara obovata*, *Azelia africana*, were abundant in plots 86 and 70.

All the plots are located in the first quadrant and very close to the centre. This suggests that the species presents in these plots are closely related and can be said to thrive under the same ecological condition probably because of some common characteristics such as family composition and growth requirements.

Tree species ordination

Species ordination by DCA of tree species ≥ 5 cm diameter at DBH in the 24-plots within the study area

Table 1. Density (D), frequency (F), relative density (RD), relative frequency (RF) and relative importance value (RIV) of tree species in the study area.

Plant spp	Family	Code	Density /Ha	%F	RF	RD/Ha	RIV/ha	Rdo/ha
<i>Azelia Africana</i>	Caesalpiniaceae	AFAF	4.67	4.17	0.283	0.52	1.08	0.83
<i>Albizia ferruginea</i>	Mimosaceae	ALFE	4	20.83	1.41	0.44	3.27	0.92
<i>Albizia glaberrima</i>	Mimosaceae	ALGL	2.67	16.67	1.13	0.299	2.56	0.14
<i>Albizia zygia</i>	Mimosaceae	ALZY	32	62.5	4.24	3.59	12.07	4.76
<i>Alchornea cordifolia</i>	Euphorbiaceae	ALCO	35.33	29.17	1.97	3.97	7.92	2.49
<i>Anthocleista djalonensis</i>	Loganiaceae	ANDJ	2	12.5	0.85	0.22	1.92	0.26
<i>Antiaris toxicaria</i>	Moraceae	ANTO	74.67	79.17	5.37	8.38	19.12	8.62
<i>Baphia nitida</i>	Papilionaceae	BANI	10.67	29.17	1.98	1.2	5.15	0.72
<i>Blighia sapida</i>	Sapindaceae	BLSA	12.67	45.83	3.11	1.42	7.64	1.78
<i>Blighia unijugata</i>	Sapindaceae	BLUN	2.67	12.5	0.85	0.29	1.99	0.18
<i>Bosqueia angolensis</i>	Moraceae	BOAN	23.33	37.5	2.54	2.62	7.7	6.27
<i>Bridelia micrantha</i>	Euphorbiaceae	BRMI	6.67	20.83	1.41	0.75	3.57	0.56
<i>Ceiba pentandra</i>	Bombacaceae	CEPE	11.33	33.33	2.26	1.27	5.79	2.81
<i>Celtis mldbraedii</i>	Ulmaceae	CEMI	3.33	4.17	0.28	0.37	0.94	0.28
<i>Celtis zenkeri</i>	Ulmaceae	CEZE	40	58.33	3.95	4.49	12.4	4.08
<i>Chrysophyllum albidum</i>	Sapotaceae	CHAL	4	8.33	0.56	0.45	1.58	0.3
<i>Cola millenii</i>	Sterculiaceae	COMI	30.67	54.17	3.67	3.44	10.79	2.46
<i>Deinboillia pinnata</i>	Sapindaceae	CONI	2.67	12.5	0.85	0.29	1.99	0.18
<i>Dialum guinensis</i>	Caesalpiniaceae	DEPI	11.33	16.67	1.13	1.27	3.53	1.45
<i>Diospyros monbuttensis</i>	Ebenaceae	DIGU	8.67	12.5	0.85	0.97	2.67	0.64
<i>Dracaena arborea</i>	Dracaenaceae	DIMO	13.33	20.83	1.41	1.5	4.32	0.58
<i>Entdadrophagma angolensis</i>	Meliaceae	DRAR	6.67	16.67	1.13	0.75	3.01	0.51
<i>Enttradopphagma cylindricum</i>	Meliaceae	ENAN	6	16.67	1.13	0.67	2.93	0.62
<i>Euadenia trifoliolata</i>	Capparidaceae	EUTR	0.67	4.17	0.28	0.07	0.64	0.02
<i>Ficus exasperate</i>	Moraceae	FIEX	34	45.83	3.11	3.82	10.03	4.8
<i>Ficus mucuso</i>	Moraceae	FIMU	1.33	8.33	0.56	0.15	1.28	0.32
<i>Funtumia elastic</i>	Apocynaceae	FUEL	53.33	75	5.08	5.99	16.16	6.23
<i>Gliricida sepium</i>	Papilionaceae	GLSE	4.67	8.33	0.56	0.52	1.65	0.24
<i>Glyphaea brevis</i>	Tiliaceae	GLBR	6	4.17	0.28	0.67	1.24	0.24
<i>Holarrehena floribunda</i>	Apocynaceae	HOFL	11.33	20.83	1.41	1.27	4.1	1.81
<i>Kigelia Africana</i>	Bignoniaceae	KIAF	2	4.17	0.28	0.22	0.79	0.22
<i>Lecaniodiscus cupanioides</i>	Sapindaceae	LECU	94.67	75	5.09	10.63	20.8	7.13
<i>Lonchocarpus cyanescens</i>	Papilionaceae	LOCY	6	20.83	1.41	0.67	3.49	0.1
<i>Malacantha alnifolia</i>	Sterculiaceae	MAAL	0.67	4.17	0.28	0.07	0.64	0.19
<i>Mangifera indica</i>	Anacardaceae	MAIN	2.67	8.33	0.56	0.29	1.43	0.019
<i>Manlikara obovata</i>	Sapotaceae	MAOB	8	8.33	0.56	0.89	2.03	0.34
<i>Milicia excels</i>	Moraceae	MIEX	15.33	54.17	3.67	1.72	9.07	0.94
<i>Millettia thonningii</i>	Papilionaceae	MITH	19.33	25	1.69	2.17	5.56	3.26
<i>Monodora tenuifolia</i>	Anacardiaceae	MOTE	8.67	37.5	2.54	0.97	6.06	3.69
<i>Morinda lucida</i>	Rubiaceae	MOLU	1.33	8.33	0.56	0.15	1.28	0.5
<i>Morus mesozygia</i>	Moraceae	MOME	10.67	16.67	1.13	1.19	3.46	0.11
<i>Myrianthus arborea</i>	Moraceae	MYAR	6	12.5	0.85	0.67	2.37	1.29
<i>Newbouldia laevis</i>	Boraginaceae	NELA	69.33	75	5.08	7.78	17.95	1.21
<i>Ola subscorpioidea</i>	Olacaceae	OLSU	2	12.5	0.85	0.22	1.92	4.76
<i>Phyllanthus discoides</i>	Euphorbiaceae	PYDI	1.33	4.17	0.283	0.14	0.71	0.09
<i>Pycnanthus angolensis</i>	Myristicaceae	PYAN	3.33	16.67	1.13	0.37	2.63	0.19
<i>Rithiea capparides</i>	Capparidaceae	RICA	0.67	4.17	0.28	0.07	0.64	0.1
<i>Rothmannia longiflora</i>	Rubiaceae	ROLO	8.67	25	1.69	0.97	4.36	1.04
<i>Solanum erianthum</i>	Solanaceae	SOER	0.67	4.17	0.28	0.07	0.64	0.023

Table 1. Contd.

Plant spp	Family	CODE	Density /Ha	%F	RF	RD/Ha	RIV/ha	Rdo/ha
<i>Spondias mombin</i>	Anacardiaceae	SPMO	50	79.17	5.37	5.61	16.35	7
<i>Sterculia tragacantha</i>	Sterculiaceae	STTR	70	75	5.09	7.85	18.032	6.03
<i>Tabernaemontana pachysiphon</i>	Apocynaceae	TAPA	2.67	8.33	0.56	0.29	1.43	0.43
<i>Theobroma cacao</i>	Sterculiaceae	THCA	0.67	4.17	0.28	0.07	0.64	0.05
<i>Trema orientalis</i>	Ulmaceae	TROR	4.67	16.67	1.13	0.52	2.78	0.37
<i>Trichilia monadelpha</i>	Meliaceae	TRMO	31.33	62.5	4.24	3.518	11.99	4.47
<i>Triplochiton scleroxylon</i>	Sterculiaceae	TRSC	2.67	16.67	1.13	0.29	2.56	0.87
<i>Zanthoxylum zanthoxyloides</i>	Rutaceae	ZAXA	1.33	4.167	0.28	0.149	0.71	0.32
			885.33	1475	100.07	99.4	299.47	99.99

Table 2. Distribution of trees according to Raunkaier's Classification Scheme.

Code	Class	Number of species (%)	Remarks
A	0-20	32 (56%)	Rare
B	20-40	12 (21%)	Low
C	40-60	5(7.4%)	Intermediate Frequency
D	60-80	8(14.0%)	Moderately High Frequency
E	80-100	0	High Frequency (Common)

*Figures in parenthesis are percentages of the number of species present in each class.

represents 73.3% (axis 1:43.16%; axis 2:30.17%) of variance accounted for by the first two-ordination axes (Figure 3). High eigenvalue (73.3%) shows that the species and the site are becoming endemic, which is an indication of a stable environment. About 70% of the species are located in quadrant one, this implies high interaction within the site. The first horizontal axis showed a gradient separation: *Chrysophyllum albidum*, *Morus mesozygia*, *Ficus mucuso*, *Celtis zenkeri*, *Zanthoxylum zanthoxyloides*, *Deibollina pinnata*, *Tabernaemonthana pachysiphon*, *Ficus exasperata* on the negative side of the axis, *Pycnanthu sangolensis* is on the central position and *A. toxicaira*, *Albizia ferruginea*, *Monodora tenuifolia*, *F. elastica*, *Newbouldia laevis*, *Trichilia monadelpha*, *Dialum guinensis*, *Bosquia angolensis*, *Milicia excelsa*, *Triplochiton scleroxylon*, *Ceiba pentandra*, *Lonchocarpus cyanescens*, *Mangifera indica*, *Baphia nitida*, *Holarrehena floribunda*, *Cola millenii*, *Celtis midberii*, *Alchorne acordifolia*, *Milletia thonningii*, *Rothmania longiflora*, *Manilkara obovata*, *Azelia africana*, are at the positive end of the axis. This clearly is an indication that environmental factors exert great influence on the species composition and distribution. *Bridelia micrantha* is located on the extreme end of the axis and outside the 95% ellipse. *Manilkara obovata*, *Azelia africana*,

Holarrehena floribunda, *Celtis midberii*, *M. thonningii* are, away from the origination, though there is a higher degree of association or relationship as indicated by variance within the plant resources of the study area. Some of them still exhibit stronger relationship with each other hence they are packed together in the same corner of the ordination space.

Diameter – class size distribution and stem density

Diameter-class size distribution in the 24 plots studied with the corresponding basal area per ha are shown in the Figure 5. A total of 73% of trees were in the smaller dbh class (10 to 44 cm). The highest value of stem density is found in the 15 to 19 diameter class (175) with basal area of 0.39 m² followed by 20 to 24 class (164) and basal area of 0.64 m² (Figure 5). The least was found in 85 to 89 and 95 to 99 diameter classes (8) each with basal area of 0.467 and 0.594 m² respectively. However, highest basal area was found in diameter class >100 (44) having basal area of 13.07 m², followed by 40 to 44 diameter class (1.35 m²). The smallest basal area was found in 10 to 14 diameter class (0.15 m²) with stem density of 130.

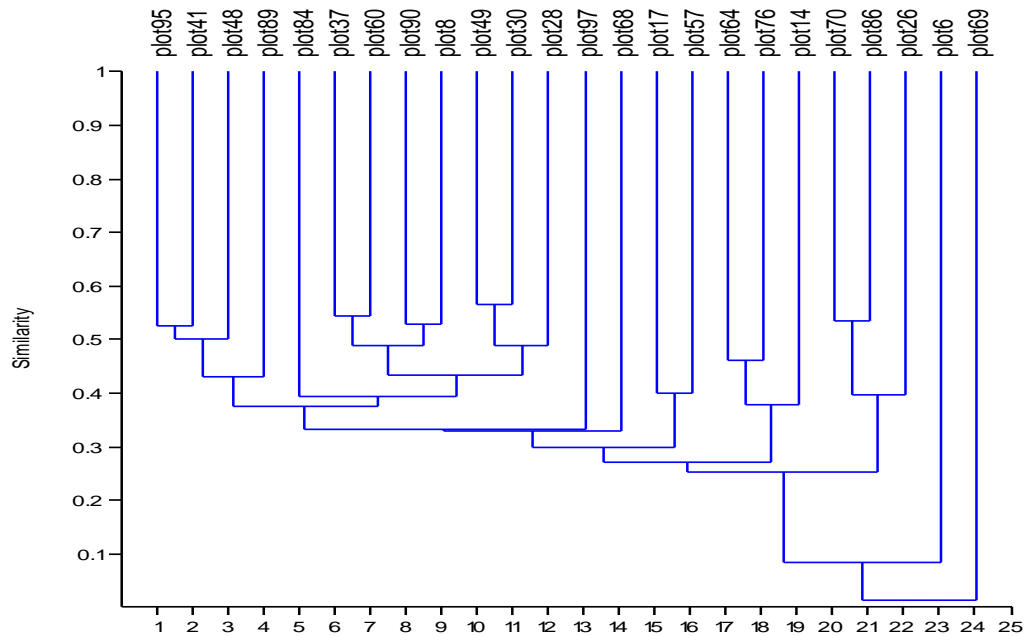


Figure 1. Dendrogram constructed from similarity Jaccard Index matrix based on species composition in the various plots within the forest of International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

Table 3. Tree Species Density, Diversity and Basal Area (m^2) in 24 (25 x 25 m) plots.

Plots	Density/0.0625ha	Number of Species	BA/m ²	Dominance	Simpson	Equitability
Plot86	56	13	16.27	0.11	0.89	0.92
Plot41	70	14	5.61	0.12	0.8788	0.87
Plot49	71	16	11.37	0.10	0.8974	0.88
Plot37	91	22	8.59	0.10	0.9006	0.86
Plot30	62	20	27.81	0.075	0.924	0.92
Plot17	63	13	20.35	0.10	0.8975	0.93
Plot60	60	15	11.19	0.10	0.8961	0.90
Plot28	47	14	6.92	0.12	0.8791	0.88
Plot70	36	10	9.93	0.16	0.841	0.87
Plot69	4	2	0.21	0.62	0.375	0.81
Plot57	75	22	9.06	0.07	0.9244	0.89
Plot95	65	18	16.42	0.09	0.9013	0.87
Plot 6	3	2	0.05	0.55	0.4444	0.92
Plot64	57	10	5.49	0.22	0.783	0.79
Plot76	10	9	1.93	0.12	0.88	0.98
Plot26	67	16	17.83	0.10	0.9	0.89
Plot14	68	15	411.18	0.12	0.89	0.86
Plot 8	55	14	369.65	0.14	0.86	0.84
Plot89	97	17	41.84	0.12	0.88	0.84
Plot48	48	20	242.90	0.08	0.92	0.92
Plot84	54	20	54.60	0.07	0.93	0.93
Plot97	36	16	479.59	0.09	0.91	0.92
Plot68	75	17	531.28	0.09	0.91	0.91
Plot90	66	15	46.96	0.10	0.89	0.89

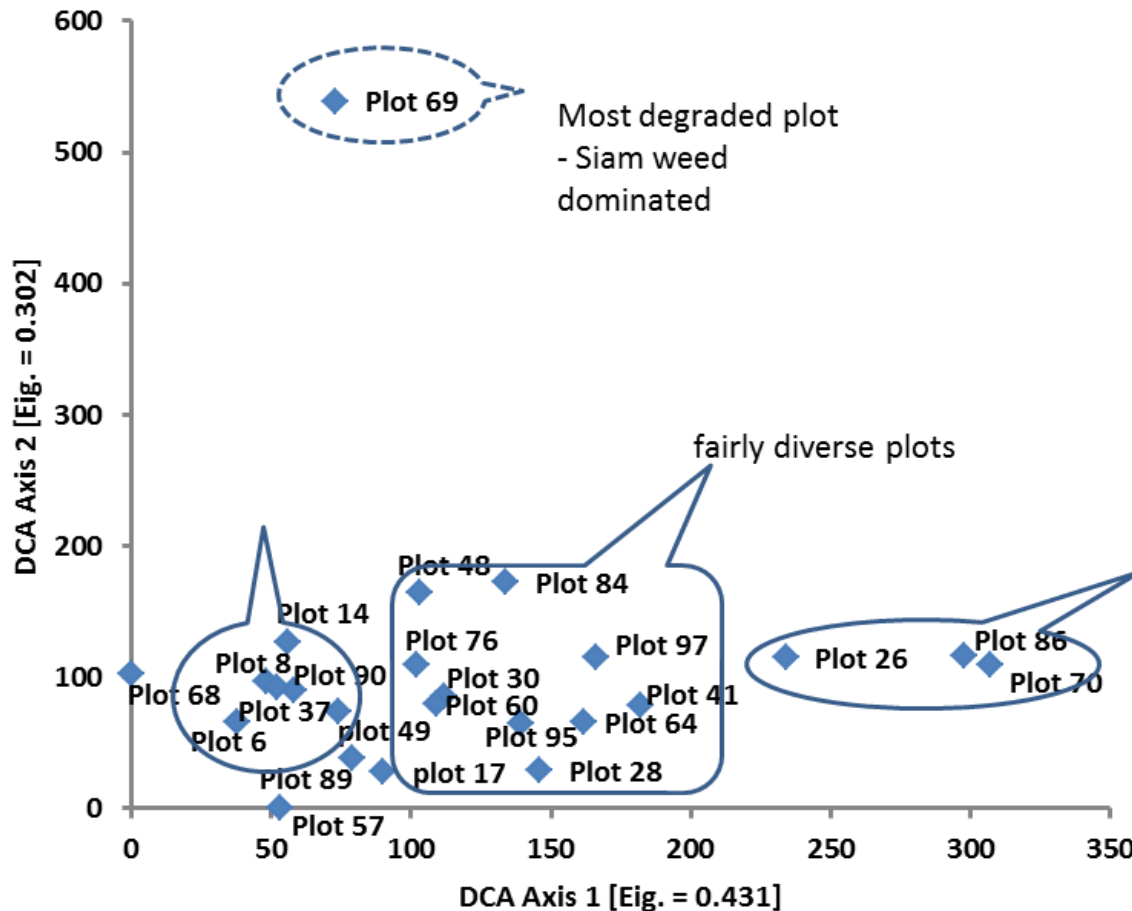


Figure 2. Stand ordination by Detrended Correspondence Analysis (DCA) of stands defining the flora of International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria (IITA), Ibadan Nigeria.

DISCUSSION

The species richness of a forest ecosystem depends on the number of species per unit area; the more species there are per unit area, the higher species richness. A total of 57 species/ha of trees observed in this study were higher than the typical 60 to 70 species/ha that were observed in other studies in West Africa tropical high forest (Lawson, 1985). Vorddzobe et al. (2005) recorded 80 species/ha in a similar secondary regrowth in Ghana, while other researchers have reported lower species richness; 37 species/ha (Anning et al., 2008), 28 species/ha (Addo-Fordjour et al. (2009) in Ghana. The floristic richness of the present study site could be attributed partly to strong contributions coming from different vegetative typologies (Sebashao et al., 2008). High species richness of the IITA study area could also be due to geographical location of the study site and favourable climatic condition and protection over a long period of time (35 years).

The families represented in the present study when compared with the studies of Hall and Okali (1976) on the

same site revealed the presence of families such as Papilionaceae, Euphorbiaceae, Rubiaceae, Moraceae (Table 1). All the prominent species found in the present study have been listed in the previous study of Hall and Okali (1979) and some other authors like Ahn (1961) as constituents of the early stages of secondary forest regrowth. The abundance of LECU, NELA, ANTO, FIEX, FUEL, SPMO, STTR is a distinctive feature of this particular type and are all characteristic of fallow regrowth in the Africa forest vegetation. The dominance of these species in the flora of the IITA forest is considered as the main characteristic of semi-deciduous forests (Vorddzobe et al., 2005, Addo-Fordjour et al., 2009). The presence of some species such as LECU, NELA, SPMO, STTR, TRMO, FUEL, MIEX, COMI, ANTO, ALZY, CEZE, in nearly all the plots and their high density in the entire study site may indicate their wider range of ecological adaptation (Senbeta et al., 2005; Addo-Fordjour et al., 2008).

The density of (885.33 stems/ha) of woody species ≥ 5 cm recorded at the present study is comparable to those reported from lowland tropical forest 716 to 1440

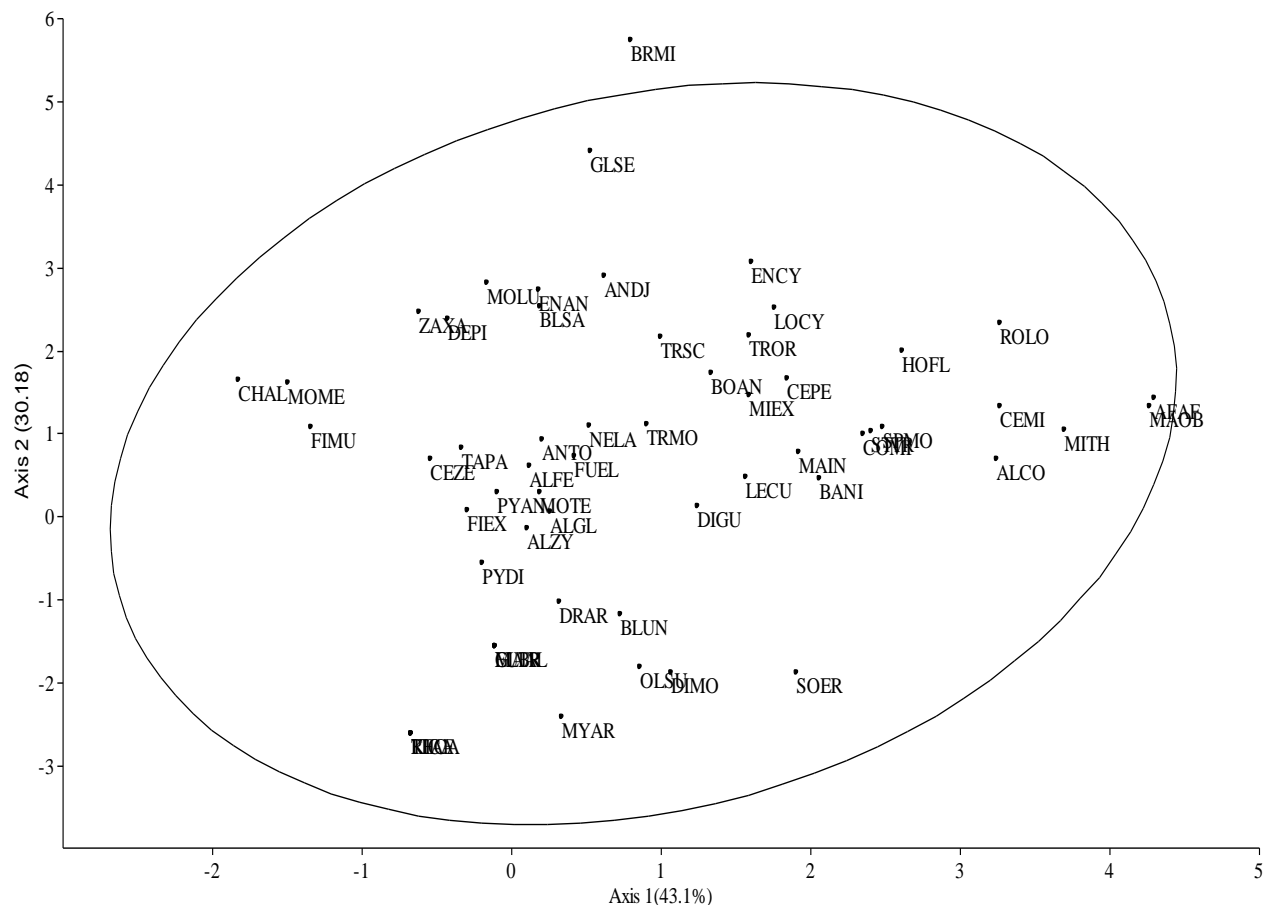


Figure 3. Species ordination by Detrended Correspondence Analysis (DCA) of the Tree Species >5cm at Breast Height at 24 plots within IITA Showing 95% ellipses.

stems/ha in India (Upadhaya et al., 2004), the value was higher than (863/ha) reported by Addo-Fordjour et al., 2009 in Ghana.

Overall, the RIV of the species were generally low, ranging from 0.64 to 20.80%. Only 19 species have RIV value above 5% and this included *A. toxicaria* (19.12%), *L. cupanioides* (20.82%), *S. mombin* (16.35%), *S. tracagantha* (18.03%), *F. elastica* (16.16%), *Newbouldia laevis* (17.95%). The relative frequency contributed to RIV more than other components. EUTR, MAAL, RICA, SOER, THCA, ZAXA had the least RIV value of 0.64% each and were encountered only once. Low ecological status of most of the species in this study, as evidenced by the low RIV of most tree species may be attributed to lack of dominance by any one of the species, which suggests positive interactions among the tree species (Oladoye, 2012). In other words; resource spaces are shared to minimize negative species interactions and plant can obtain resources with relative ease (Tsingalia, 1990; Pappoe et al., 2010). The low RIVs may also imply that most of the species in this forest are rare (Pascal and Pellissier, 1996; Oyun et al., 2009) as reflected in the

distribution of trees according to Raunkaier's classification scheme (Table 3). It should be noted that the summary of the parameters into one has the effect of increasing the difference between the same species among area of similar species composition (Oyun et al., 2009).

The rarity of species may be attributed to the occurrence of abundant sporadic species with low frequency in the stands (Table 2). The high percentage of rare species (65%) observed in this study confirms the generally acclaimed notion that most of the species in an ecological community are rare, rather than common (Magurran and Henderser, 2003). This is comparable with result from Oyun et al. (2009) and Pappoe et al. (2010). The species similarity (Simpsons) between the plots which varied from 0 to 80% for all the plots implies the higher the similarities indices between the plots, the more related they are in species floristic composition. In terms of tree species diversity, Simpson's diversity index of 0.95 was recorded for all the plots, In addition the equitability and Simpsons diversity index of (0.79 to 0.98) and (0.37 to 0.92) respectively for each of the plots

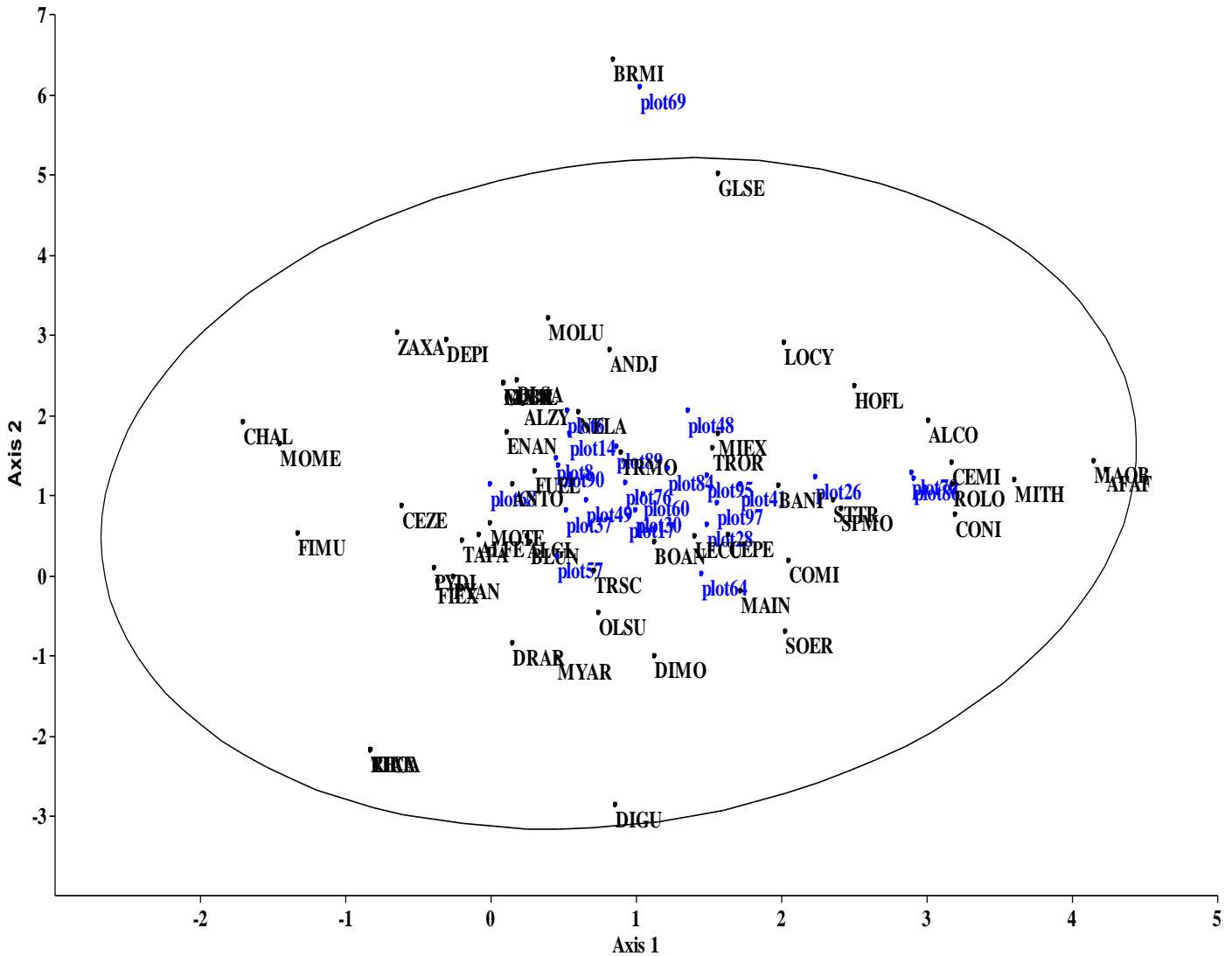


Figure 4. Biplot of Species with plots based on Detrended Correspondence Analysis (DCA) of >5cm at Breast Height at 24 plots within IITA.

implies that between 79.3 to 98.5% of the trees were equitably distributed among the species/plots (Magurran and Henderson, 2003; Pappoe et al., 2010) while between 37.5 for 92.4% of the tree species may be of different species (Pascal and Pellissier, 1996). Plot 57 had the highest diversity (0.92) and the least was found in plot 69 (0.37) with BRMI dominated. Species dominance was generally low with average of 0.051 however, it was high in plot 69 (0.63) and plot 6 (0.56). The higher values of diversity indicate greater stability of community structure (Kohli et al., 1996; Isango, 2007) and this may be attributed to improved soil quality as a result of high organic matter content and high pH. Species distribution was even (evenness = 0.49) with only seven species having frequency of occurrence of between 15 to 19 plots out of 24, this includes ALZY (15),

ANTO (19), LECU (18), NELA (104), STTR (105), SPMO (19), and FUEL (18).

Stand structure parameters allow predictions of forest biomass and can provide spatial information on potential determinant of plant species distributions (Couteron et al., 2005). In this study, stand structure relates to the basal area of trees, density of trees and their distribution into various diameters –size classes and densities of saplings. Total stand density and basal area for all the plots were 885.33 trees/ha and 198.7 m² respectively. This rapid structural convergence with mature forest has been found in other chromo sequences (Denslow and Guzman, 2000; Pena-carlos, 2003). High basal areas are characteristic of mature forest stands and serve as a reflection of high performance of the trees. It may also presuppose the development of an extensive root system

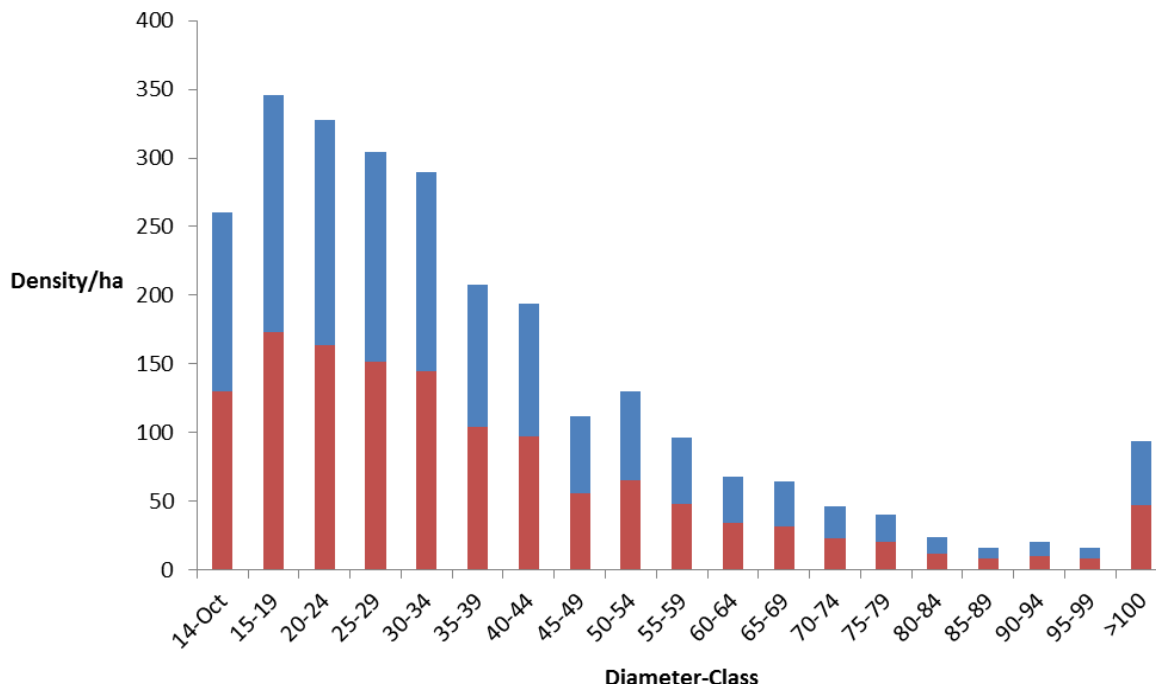


Figure 5. Diameter-Class distribution and the corresponding Density/Ha.

for efficient nutrient absorption for tree growth to take place. The high basal area has an implication for subordinate plants as the big trees suppress the growth of small plants by intercepting much of the solar radiation that might otherwise reach the forest floor. The basal area (m^2/plot) ranged from 0.0515 m^2 to 27.809 m^2 and the volume m^3/plot ranged from 0.06 to 531 m^3 . The highest basal area was found in plot 30 (27.81 m^2) with stem density of 62 tree/ha . The least basal area was found in plots 69 and 6 (0.05 m^2 and 0.12 m^2) with volume and stem density of (0.06 m^3 ; 4 and 0.71 m^3 ; 3) respectively. This low basal area and the corresponding volume may be due to the status of the plots (degraded). Variations in basal area of the trees within the stand were generally low. A few tree species contributed most to the total basal area, these included BOAN (16.2%), ANTO (12.80%), ALZY (6.16%), MIEX (5.79%), FIEX (6.49%), SPMO (6.43%) AND MITH (5.48%). This reflects the dominance phenomenon, whereby few species contribute much to the abundance and total basal area, which is one of the many characteristics of the tropical forest.

BOAN had the highest basal area (42.75 m^2) in the present study; followed by ANTO (33.644 m^2), FIEX (17.05 m^2), SPMO (16.90 m^2), and MIEX (15.24 m^2). These tree species are economical and have the natural inclination to grow very large which is evident in BOAN, MIEX, and ANTO. Hence the need to maintain the IITA forest reserve against exploitation. This implies that the very low contribution of some species to the total basal area may be due to their low numbers and low dbh values. Thus, these species may not be very important in

terms of dominance. For instance, trees in the *Rutaceae* family have been noted not to be important in tropical forest because the family is of great economic importance in warm temperate and sub-tropical climates for its numerous edible fruits. (Mwavu and Witkowski, 2009). However, species of this family become more important in their population and distribution under drier conditions (Lieberman, 1982). Higher number of species in *Moraceae* (6) in this study and their contribution to the total basal area is a reflection of their tendency for natural inclination to grow very large, this is evident in large DBH recorded for ANTO, MIEX, BOAN, FICU. Compared with other tropical forest, IITA Forest Reserve vertically presented a higher structural complexity, for instances, González (1988) classified emergent layer at an average height of 25 m in a dry forest at Liannos, Venezuela against $>31 \text{ m}$ observed in this study.

In terms of size, majority of the trees were of the lower diameter class (10 to 40 cm) (Figure 5). The number of individual categories decreased with increasing size of the trees when compared with the previous study from the same site by Hall and Okali (1979); the numbers of stems in each diameter class distribution has increased greatly. This is an indication that the study area is in the mid-level succession. Larger diameter trees $> 100 \text{ cm}$ accounted for the highest basal area (13.01 m^2). The result of this study confirms the fact that as vegetation matures, total stand density tends to decrease and stand increases in height, basal area and volume. The diameter class distribution in this present study conform to Deiocourts q factors procedure (inverse J-distribution) with

stems frequencies decreasing with diameter increase at diameter at breast height for all the plots. From the foregoing, we can characterize the IITA forest as low-biomass community with small-stemmed trees and this indicate that stands are developing and regeneration from seeds and other vegetative means is present. It suggests that a stable size and age class distribution (Swaine et al., 1987). The shape is characteristic of climax species (Whitmore, 1990) and this distribution also describes a mature stand with many small individuals and few large ones. It is hypothesis that the most abundant species among the IITA forest species are certainly at a stage of equilibrium with climatic and edaphic conditions. The remarkable differences in stand density, basal area and height could be attributed to the intensity of management (absolute protection from human inference).

The length of ordinate axis gradient measured in standard deviation unit (SD) is a reflection of the extent of variability between the plots along the axis. The forest gradient length (0 to 350) indicates a little difference in floristic composition between extreme plots and high heterogeneity of the study site. Species present at one end of the gradient are not likely to be present at the other (Hill, 1979). This is confirmed in this study as three groups are identified from the ordination diagram (Figure 2) based on the similarities in their floristic composition and closeness of the plot to each other. Each of these groups had species that are common to them; group (1) had CEMI, MADIS, CEPE, STTR and HOFL with percentage floristic composition ranging from 60-80%. The second group has eleven (11) species common to them which include CEZE, AZZU, BOAN, ANAF, FUEL, NELA, STTR and percentage similarities ranged from 54-60%. The third group had 9 species in common and these include MUTE, TRMO, LECU, ANTO, ALZY, DLSA, CEZE, FUEL, NELA. The position of plot 69 at the top left corner is an indication of no similarities between plot 69 and other plot. Plot 68 and 57 are outliers and that is they are located at edge of the ordination axis. This implies that most of the environmental factors responsible for the species composition did not affect them.

High Eigen value of 73.3% is an indication of a stable environment showing that the tree species have become naturalize on species ordination. The length of the axes ranged from -3 to 6, the first horizontal axis showed a gradient separating CHAL, MOME, FIMU, CEZE, ZAXA, DEPI, FIEY on the negative side of the axis; PYAM is on the central position ANTO, ALFE, MOTE, FUEL, NELA, TRMO, DIGU, BOAN, MIEX, DEPE, TRSC, CEPE, LOCY, MAIN, BANI, HOFL, COMI, CEMI, ALLO, MITH, ROLO, AFAF, MAOB all at the positive end at the axis. This is clearly an indication that environmental factors exert great influence on the species composition and distribution, BRMI is located on the extreme end of the axis and outside the 95% ellipse.

AFAF, MAOB, ROLO, CEMI, MITH are away from the origination, though there is a higher degree of association

as indicated by variance within the plant resources of the study area. Some of them still exhibit stronger relationship with each other and that explain why they are packed together in the same corner of ordination space. A super imposition of the species ordination diagram on the site ordination diagram gives an insight into the species with optimum abundance in each plot; that is the axis in which the species are located (Figure 4).

All the plots are located in the first quadrant and very close to the center. This suggests that the species presents in these plots are closely related. The low density of some individual species in the study site (IITA) predisposes it to species extraction prior to acquisition and absolute protection. Moreover, the high biological diversity has justified the conservation effort of the International Institute of Tropical Agriculture. The relative species impoverishment in some plots like 69 and 6 in this study is a result of little disturbance in the last few years which led to invasion of the plots with *Chromolaena odorata* and *Combretum* spp. species.

The restoration of high diversity tropical forest following the abandonment of agricultural lands provides a challenge for restoration ecologists. The appropriate restoration strategy depends on the level of degradation, the desired rate of recovery and the desired similarity to species composition of native forest. The results from this study demonstrate that natural regeneration can be an effective strategy for restoration of tropical tree species diversity, canopy height, tree stem density, and size distributions occurred in approximately 40 years. This restoration strategy will be most effective if soils have not been severely degraded, if fires can be suppressed, and if remnant forests (seed sources) are in the landscape. The low cost of natural regeneration makes this strategy a potential option, particularly for restoration of large areas. The characterization of this locally restricted IITA forest successional pattern is decisive in supporting actions taken to rehabilitate degraded lands, and can be a potential tool for sustainable tropical forest management, including the potential to serve as carbon offset mechanism.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Full Length Research Paper

Availability and size class distribution of the most popular Indigenous fruits trees and implications for sustainable harvest around the Ivindo National Park, Gabon

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A study was carried out in “the often” and “the rarely” harvested locations of the Ivindo National Park (Gabon) to determine the availability, height and Diameter at breast height (DBH) size class distributions of *Coula edulis*, *Dacriodes buettneri* and *Irvingia gabonensis*, the three most popular Indigenous fruits (IFs) used by local people for meeting their livelihoods needs around the Ivindo National Park (INP), Gabon. In total 18 sample plots measuring each 20 × 10 m (six), 2 × 2 m (six) and 1 × 1 m (six) were purposely centered around identified mature trees, sapling and seedling individuals following a northeast direction, with three in each harvested location. DBH of mature trees and sapling individuals of the three species were determined and seedling height measured. These tree species were the most abundant in “the often” and “the rarely” accessed locations of the forests and *D. buettneri* was the least abundant in those locations. The poor population structures of seedling, sapling and mature tree species indicate an unhealthy population exposed to disturbances. Since few mature trees have a Fixed Felling Minimum Diameter (FFMD), bigger than DBH size class of (8) (70.0 - 79.9 cm) for *D. buettneri* and DBH size class of (5) (40.0 - 49.9 cm) for each of *C. edulis* and *I. gabonensis* means that the number of mature trees that can be cut off and produce seeds are limited. On-farm tree planting by local people should be encouraged to supply valued fruit trees species and reduce pressure on the protected forests.

Key words: Abundance, size-class distributions, Indigenous Fruits Trees, Sustainable harvest, Ivindo National Park, Gabon.

INTRODUCTION

The importance of forest resources such as indigenous fruit tree species for sustaining the livelihoods of people living nearby national parks is widely acknowledged in many regions of Africa. In the Southern Africa for example,

indigenous fruit trees (IFTs) are important forest resources that contribute to improve the livelihoods of many rural people in the Miombo woodlands areas (Packham, 1993; Maghembe et al., 1994; Mateke et al., 1995; Ngulube et al.,

1995; Maghembe et al., 1998; Leakey, 1999; Muok et al., 2001; Saka et al., 2004; Tiisekwa et al., 2004; Akinnifesi et al., 2004; Kadzere et al., 2004; Mithofer et al., 2006; Akinnifesi et al., 2008) as alternative source of nutrition, cash income and food.

In the Congo Basin for example, the second largest tropical forest after the Amazon Basin, many populations living near natural parks make use of indigenous fruit tree species to fulfil their various sustenance's needs (Brandon and Wells, 1992; Leakey and Tomich, 1999; Cernea and Schmidt-Soltau, 2006; Eyog Matig, 2006; Falconer and Arnold, 1988; Mialoundama, 1993; Belcher and Schreckenberg, 2003; Evans, 1993; Ruiz-Pérez et al., 2000; Belcher and Schreckenberg, 2007). However, due to restriction measures for conservation purposes, local populations have often limited livelihood opportunities to meet their households' needs through forest products gathering from the wild (Ghimire, 1994).

This is also true in the case of Gabon, located in Central Africa, wherein most local people living nearby national parks tend to depend on forest products that are important traditional resources including timber and Non Timber Forest Products (NTFPs) bearing fruits also known as Indigenous Fruit Trees (IFTs). These forest products are one of the important traditional resources and represent major sources of food, income generation and healthcare for many rural people in the country (Walker and Sillans 1961; Bourobou-Bourobou, 1994; Bourobou-Bourobou and Posso, 1995; Pineau, 1995; Viano, 2005; Corblin, 2006; Lescuyer, 2006; Sassen and Wan, 2006).

Despite local people livelihoods' dependence on national park resources, the Gabonese government has established a network of thirteen (13) national parks throughout the country covering nearly 2.9 million (11%) ha of total land area (AFDB, 2011) with some of them representing extensions of the previous biosphere reserves. Protection of natural resources, representing one of the commonly adopted approach by the state to manage its natural resources, has started since colonial period with Lopé reserve establishment in 1946 followed by the Ipassa Makokou Biosphere Reserve in 1979. In that approach, rules and regulations exist under the decree on Customary Rights Law of 2004, Forest Code of 2001, and the National Parks Law of 2007 (Gabonese Republic, 2001, 2004, 2007). However, access and use of resources are strictly prohibited in the core area by the National Park Law of 2007, regulated in the buffer zone and let free of use "open access" in the transition area (Gabonese Republic, 2001, 2004, 2007).

Although subsistence harvesting has low negative ecological impacts on the forests (Hall and Bawa, 1993;

Arnold and Pérez, 2001; Ticktin, 2004; Belcher and Schreckenberg; 2007), however illegal tree cutting and large-scale commercial trade of valued timber issued from preferred slow growing tree species which are also of multiple uses are not without any negative ecological impacts (Hall and Bawa, 1993; Ticktin, 2004). In Gabon, there is a lack of information on the status of NTFPs throughout the country and that available laws and regulations on protected forest of national parks have not fully considered the livelihoods of rural people even though most park areas used to be utilized by them. Thus, restriction measures that local people face may have negative impacts on their livelihood as other countries have experienced (Brandon and Wells, 1992; Ghimire, 1994; Nepal and Weber, 1995; Neumann, 1997; Kaimowitz, 2003; Adhikari et al., 2004). In addition, illegal practices currently observed may continue to threaten local people livelihood if left unchecked.

Although, industrial logging has been recently banned from all national parks, however illegal tree cutting and increasing collection of fruits, nuts and seeds by local people and the lack of valuable information appeared to be sources of concerns, especially the population's structure and supplies of the tree species directed to meet people livelihoods' needs as well as the ecology of the natural forests where these preferred resources are being harvested.

Several of these tree species highly valued for their fruits and nuts by rural people living adjacent to the forests make the trees vulnerable to depletion. *Baillonella toxisperma* (Moabi) is acknowledged as vulnerable in the IUCN Red List of Threatened species as a result of habitat loss (agriculture), selective logging activities and harvesting and trade of fruits and nuts containing oil) (IUCN, 2014; Sassen and Wan, 2006). One of the key concerns of local people and park managers is the increasing scarcity of these preferred multiple uses species from the wild. Thus, there is an urgent need to address such concerns by carrying out quantitative analyses to assess the effects of "illegal" tree cutting, fruits and nuts harvesting on natural populations viability instead of strict biodiversity conservation.

Without such analyses, it is quite impossible to design appropriate conservation and management strategies of the protected forests (Hall and Bawa, 1993; Peters, 1996a, b; Bruna and Ribeiro, 2005), especially in absence of information on species biology and ecological demographic data on growth rate (Condit et al., 1998), and pattern of use and harvest (Bitariho and McNeilage, 2007; Gaoue and Ticktin, 2007). Consequently, it is crucial to estimate the population structure of these preferred tree species as a first step for developing sustainable use and management strategies (Hall and Bawa, 1993;

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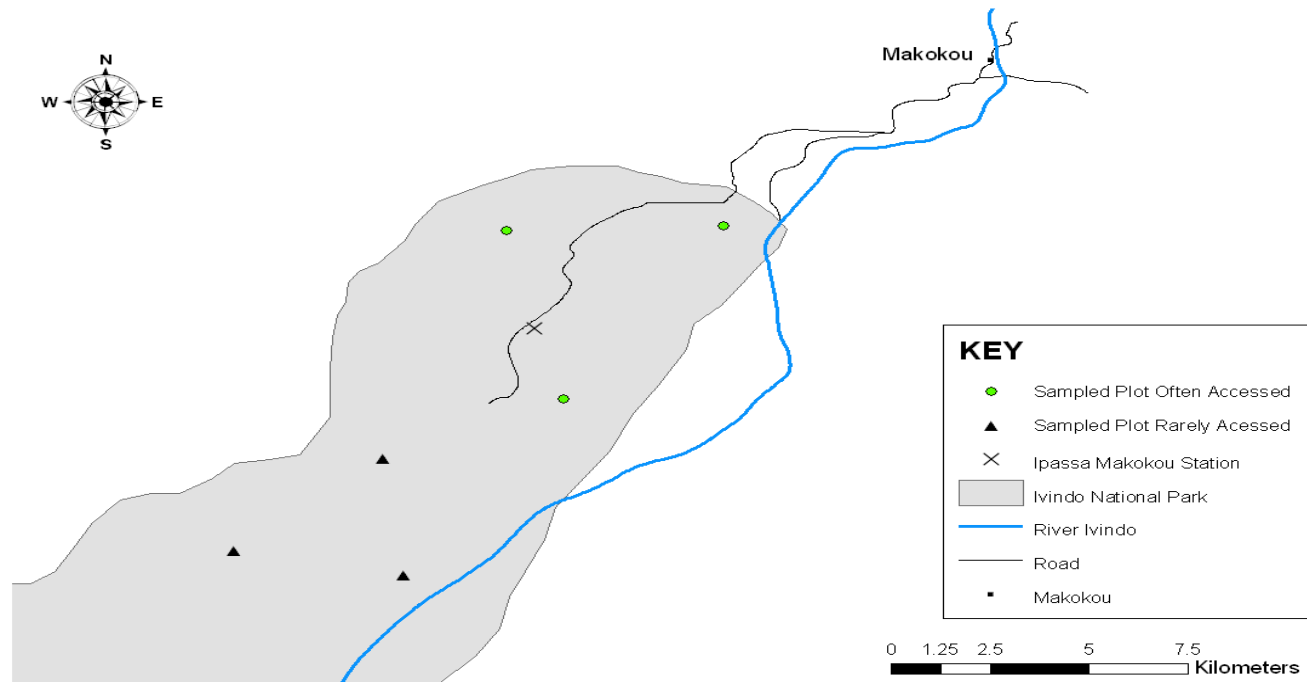


Figure 1. Localization of the study site in and around the Ivindo National Park.

Peters, 1996a,b). In addition, knowledge of the population structure of the target tree species provides useful insight into the availability, survival and habitat characteristics of the species used by local people (Hall and Bawa, 1993; Peters, 1996a,b; Bruna and Ribeiro, 2005) from different locations of forests of the INP that have been exposed to various levels of harvesting.

As a result, this study represents a supportive research that will complement the previous households and market surveys that were already conducted. As overall objective, it is aimed at gathering scientific information on: (i) the possibility of conserving and managing the three fruits tree species used by local people for livelihoods sustenance including *Coula edulis*, *Dacryodes buettneri* and *Iringia gabonensis*, and (ii) monitoring changes in the population structure of the target tree species in their natural forests. Specifically, a reconnaissance survey followed by a forest inventory are carried out to : (i) determine the availability and population structure of the three preferred fruit tree species commonly harvested by local people in and around forests of the INP, and (ii) suggest appropriate implications for their sustainable harvest of these target species.

MATERIALS AND METHODS

Study area

The study was carried out in forested areas in and around the Ivindo National Park (INP) in the province of Ogooué-Ivindo, north-eastern Gabon, about 620 Km from Libreville, main capital city of Gabon. The INP is located in central African region ($0^{\circ} 23' - 0^{\circ} 33' N$, $0^{\circ} 42' - 12^{\circ} 49' E$) (Figure 1). The INP is one of the 13 national parks

that was established in 2002 by a presidential decree. The climate of the region is an equatorial climate hot and humid, characterized by two raining and dry seasons (big and small each) and of a dense and humid vegetation type (Vande Weghe, 2006).

Timber and NTFPs (Indigenous Fruit Trees) are particularly abundant including *Desbordesia glaucescens*, *Dacryodes buettneri*; *Coula edulis*, *Iringia gabonensis*, *Baillonella toxisperma*, *Gambeya lacourtiana* and *Trichoscypha abut*. Most of these forest resources have multiple purposes and used sources of food, timber, cash incomes, medicine and other uses by local people (Okouyi-Okouyi, 2006; Lescuyer, 2006; Sassen and Wan, 2006; Corblin, 2006; Viano, 2005). The INP covering an area of 30,000 ha represents an extension of the previous Natural Integral Reserve of Ipassa of 10,000ha that was established by Man and Biosphere of UNESCO in 1979 for strict protection biodiversity conservation (Vande Weghe, 2006).

The INP covers an area of 30,000 ha and represents an extension of the previous Natural Integral Reserve of Ipassa of 10,000 ha that was established by Man and Biosphere of UNESCO in 1979 (Vande Weghe, 2006). Access and use of forest resources are strictly prohibited in the core area, regulated in buffer zone while let free of use outside of the park by the National Park Law of 2007. Past policies and regulations on forests resources have been initially strengthened the previous views by both Forest Code of 2001 and the Customary Rights Law of 2004. However, policy makers have directed little attention towards setting up rules for accessing and making use of forest resources actually located inside of the newly established national parks, despite the fact that these forest resources used to be utilized by them for meeting various livelihood needs (Okouyi-Okouyi, 2006; Lescuyer, 2006; Sassen and Wan, 2006; Corblin, 2006; Viano, 2005). This poor consideration is source of concerns.

Local people's growing needs of protected resources has led them to illegally accessing and using of the resources, habitat destruction (agriculture), logging operations and uncontrolled trees cutting and trade of fruits and seeds are of the preferred wild species (Lescuyer, 2006; Sassen and Wan, 2006; Viano, 2005). As

a result, resources decline has been observed in the area. Forest species such as *Baillonella toxisperma*, one of most preferred wild species by local people, is already acknowledged as vulnerable and listed in the IUCN Red List of Threatened species driven by human disturbances (IUCN, 2014). Strict protection of forest resources has therefore not fully contributed to safeguard forest resources of the INP since issue of species decline and mismanagement of the resources have been often reported in some parts of the park (Lescuyer, 2006; Sassen and Wan, 2006). Thus, there is a need to seek for new approaches to keep balance between protection and resource utilization by rural people for their livelihoods' needs. This new approach passes through assessing the current status of these valuable traditional resources including nuts and fruits from indigenous trees in terms of availability, size-class distribution and population structure.

Three wild indigenous fruit were selected for this study including *Irvingia gabonensis* (Andock), *Dacriodes buettneri* (Ozigo) and *Coula edulis* (Noisettes). The selection of these wild forest products was based on the consumption and commercial values for local households. The importance of these wild forest products were initially identified during the previous households and market surveys in terms of usages, market values and selling price.

Sampling plot design

Reconnaissance survey and discussions with key informants have contributed to identify "the often" and "the rarely" accessed locations based on harvesting frequencies by local people in locations. "The often" accessed locations, characterized by open access are located close by people's homes and located around the Ivindo National Park (INP) while "the rarely" accessed locations, characterized by prohibited accessed and use of resources are found far away of their homes and inside of the park. Data on availability and population structure of the harvested resources on those sites are very important for management purpose of forest resources of the park.

In total 18 sample plots measuring each 20 × 10 m (six), 2 × 2 m (six) and 1 × 1 m (six) were purposely centered around identified mature trees, sapling and seedling individuals following a northeast direction, with three each in "the often" and "rarely harvested locations. Firstly, mother trees of *I. gabonensis*, *D. buettneri*, and *C. edulis* were identified in "the often" and "the rarely" accessed locations based on local people's knowledge on the area. In total six sample plots measuring each 20 × 10 m (with three in each selected location) were centered following a northeast direction around each mature trees that were identified. All identified adult trees with circumference bigger than 30 cm at breast height were counted and measured using a surveyor's tape at 1.3 m above the forest ground. The circumference at breast height were converted into diameter at breast height (dbh) by dividing ($\text{Pi} = 3.14159 (\pi)$).

Secondly, six sub-plots of 2 × 2 m each were nested within each of the selected location (with three in "the often" and "the rarely" accessed locations). All sapling individuals with circumference smaller than 30 cm at breast height were counted and measured by using a surveyor's tape. Six smaller plots of 1 m × 1 m each were also laid down in "the often" (3) and "the rarely" (3) accessed locations to count the number of seedling individuals (that is trees with height small than 1 m) and measure their height with a pole. For mapping the area, geographical coordinates were taken in the field by using a Garmin Geographical Positioning System (GPS).

Data analysis

Data collected were presented using descriptive statistics such as mean and percentage (%). Frequencies distributions of the dbh and

height class-size distributions of the woody, sapling and seedling Individuals were plotted into graphs. The DBH and height class's limits of woody, sapling and seedling individuals were categorized into ten, five and 11 size classes.

RESULTS

Availability of seedling and sapling individuals by harvesting locations of the park

In all harvested locations of the forests, the number of seedling individuals of *I. gabonensis* (71, 44%) and *C. edulis* (66, 41%) were the most abundant and *D. buettneri* (24, 15%) the least abundant in terms of number and ratio. In "the often" accessed locations, *I. gabonensis* had the highest density of 40 stems of individuals (for a total area of 3 m²) with height less than 1 m, thus accounting for 48% of the stems of the tree species used for fruits and seeds collection. The densities of others trees in "the often" accessed locations were: *C. edulis* 31 (37%) and *D. buettneri* 13 (15%). Tree species densities in "the rarely" accessed were relatively the same except for *Coula edulis* 35 (45%) and this for the same total area (Table 1). Overall, 161 seedling individuals of *I. gabonensis*, *C. edulis* and *D. buettneri* were recorded in the both locations. The majority (84, 52%) was recorded in "the often" accessed and (77, 48%) in "the rarely" accessed locations. In "the often" accessed, means height of seedling individuals range from 22 to 30 cm and from 19 to 24 cm in "the rarely" accessed locations.

The number of sapling individuals of *I. gabonensis* was the most abundant and *C. edulis* the least abundant in all harvested locations of the forests (Table 2). In "the often" accessed locations, only one stem of *C. edulis* was encountered of DBH smaller than 30 cm (for a total area of 12 m²) representing therefore 33% of the tree species used for fruits and seeds collection in all harvested locations the forests. In "the rarely" accessed locations, only two stems of *I. gabonensis* species were recorded (for a total area of 12 m²) accounting for 67% of the tree species and this for the same total area. Means DBH of sapling individuals range from 0 to 28 cm in "the often" accessed and from 0 to 19 cm in "the rarely" accessed locations.

Regarding mature trees, the number of woody individuals of *C. edulis* (5, 36%) and *I. gabonensis* (5, 36%) were the most abundant and *D. buettneri* (4, 28%) the least abundant in all harvested locations of the forests. In "the often" accessed locations, all the three harvested tree species had the same density of species of 2 stems of individuals with DBH greater than 30 cm (for a total area of 600 m²) representing therefore 43% of the tree species used for fruits and seeds' collection in all harvested locations the forests. In "the rarely" accessed, tree species densities were relatively different with the highest recorded for *C. edulis* and *I. gabonensis* (for the same total area) accounting for 3 stems each while *D. buettneri* had only 2 stems around sampled locations.

Table 1. Availability of seedling individuals by harvesting locations.

Locations	Scientific names			Total
	<i>Coula edulis</i>	<i>Dacriodes buettneri</i>	<i>Irvingia gabonensis</i>	
Often accessed	31 (37%)	13 (15%)	40 (48%)	
Mean (Height in cm)	22	30	23	84 (52%)
SE	12	13	9	
Rarely accessed	35 (45%)	11 (14%)	31 (40%)	
Mean (Height in cm)	19	21	24	77 (48%)
SE	10	8	11	
Total	66 (41%)	24 (15%)	71 (44%)	161 (100%)

Percentages of stems of the target tree species around sampled plots are in brackets.

Table 2. Availability of sapling individuals by harvesting locations

Locations	Scientific names			Total
	<i>Coula edulis</i>	<i>Dacriodes buettneri</i>	<i>Irvingia gabonensis</i>	
Often accessed	1 (100%)	0 (0%)	0 (0%)	
Mean (Height in cm)	28	0	0	1 (33%)
SE	0	0	0	
Rarely accessed	0 (0%)	0 (0%)	2 (100%)	
Mean (Height in cm)	0	0	19	2 (67%)
SE	0	0	2	
Total	1 (33%)	0 (0%)	2 (67%)	3 (100%)

Means DBH of mature individuals range from 161 to 212 cm in “the often” accessed and from 136 to 187 cm in “the rarely” accessed locations.

Population structure of seedling, sapling and woody individuals by harvesting locations and implication for sustainable harvest

Figure 1 shows the proportion of seedlings population in each DBH size-class in both “the often” and “the rarely” accessed locations of the forests around the park and this for each of the three target species. For all the target species, there is a lower seedlings’ population in small height size class (1-2) and the absence of individuals in the upper height size classes (8-11) compared to seedlings’ population encountered in the intermediate height size classes ranging from (3-7). The poor proportion of seedling’s individuals in small (1-2) and their absence in upper height size classes (8-11) may be an indication of a poor healthy population.

There is an increasing absence of sapling individuals in almost all DBH size classes of the three target species

(Figure 2). No individual of *D. buettneri* was recorded in both harvesting locations. In rare cases, just one in individual of *C. edulis* was recorded in “the often” accessed location and none in “the rarely” harvested locations. On the contrary, two individual of *I. gabonensis* were recorded in “the rarely” harvested locations and none in “the often” accessed location. These trends are characteristics of a poor health of sapling population of all the three target species.

Figure 3 shows woody population’s structures of each of the three target species in “the often” and “the rarely” accessed locations of the park. Woody population’s structures of each of these species are not so different and there is a marked absence of individuals in some DBH size classes. For *C. edulis* and *I. gabonensis*, no individuals were encountered in the lower (1-4) and upper (8-10) DBH size classes, except in the intermediate DBH size classes (4-8). On the contrary, no individuals of *D. buettneri* were encountered in the intermediate DBH size classes (4-6), except at lower (2-3) and upper (7-9) DBH size classes. All these results are also characteristics of a poor health population of all the matured three tree species in the study.

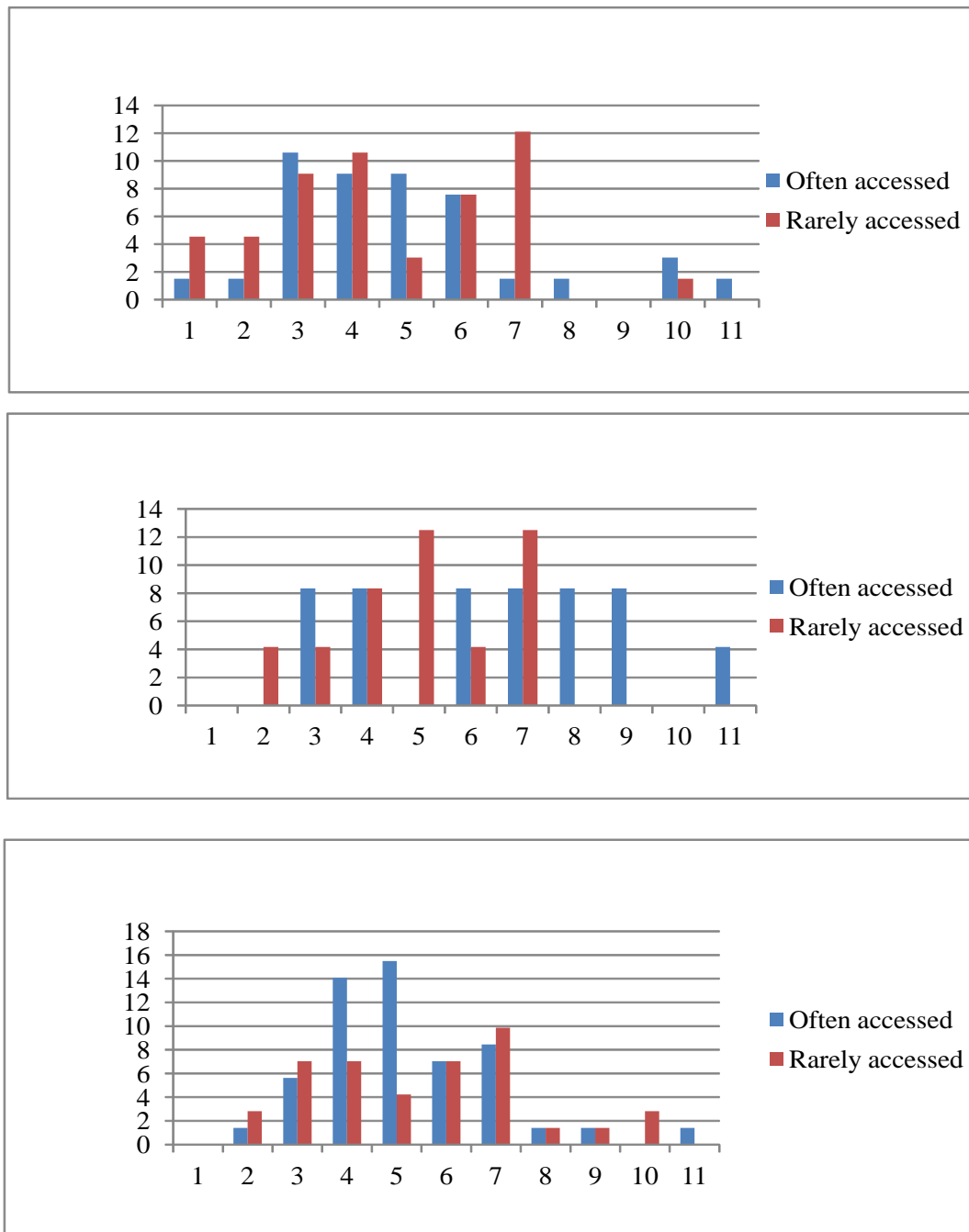


Figure 2. Seedling population structure by harvesting location.

Regarding the optimum DBH of each of the target tree species of 70 cm for *D. buettneri* and 40 cm for each of the *C. edulis* and *I. gabonensis* (See Decree n° 1285 /PR/MEFPE, of the 27 September 1993) that is legally known as Fixed Felling Minimum Diameter (FFMD) by the Forest code, it can be predict that there are few mature trees that have a FFMD, bigger than DBH size class of (8) (70.0 - 79.9 cm) for *D. buettneri*, size class of (5) (40.0 - 49.9 cm) for *C. edulis* and *I. gabonensis*.

DISCUSSION

Availability of seedling, sapling and woody individuals by harvesting locations

Although there were relatively more seedling and woody individuals of *C. edulis* and *I. gabonensis* than *D. buettneri* “the often” harvested locations comparatively to “the rarely” harvested locations, however, the proportion

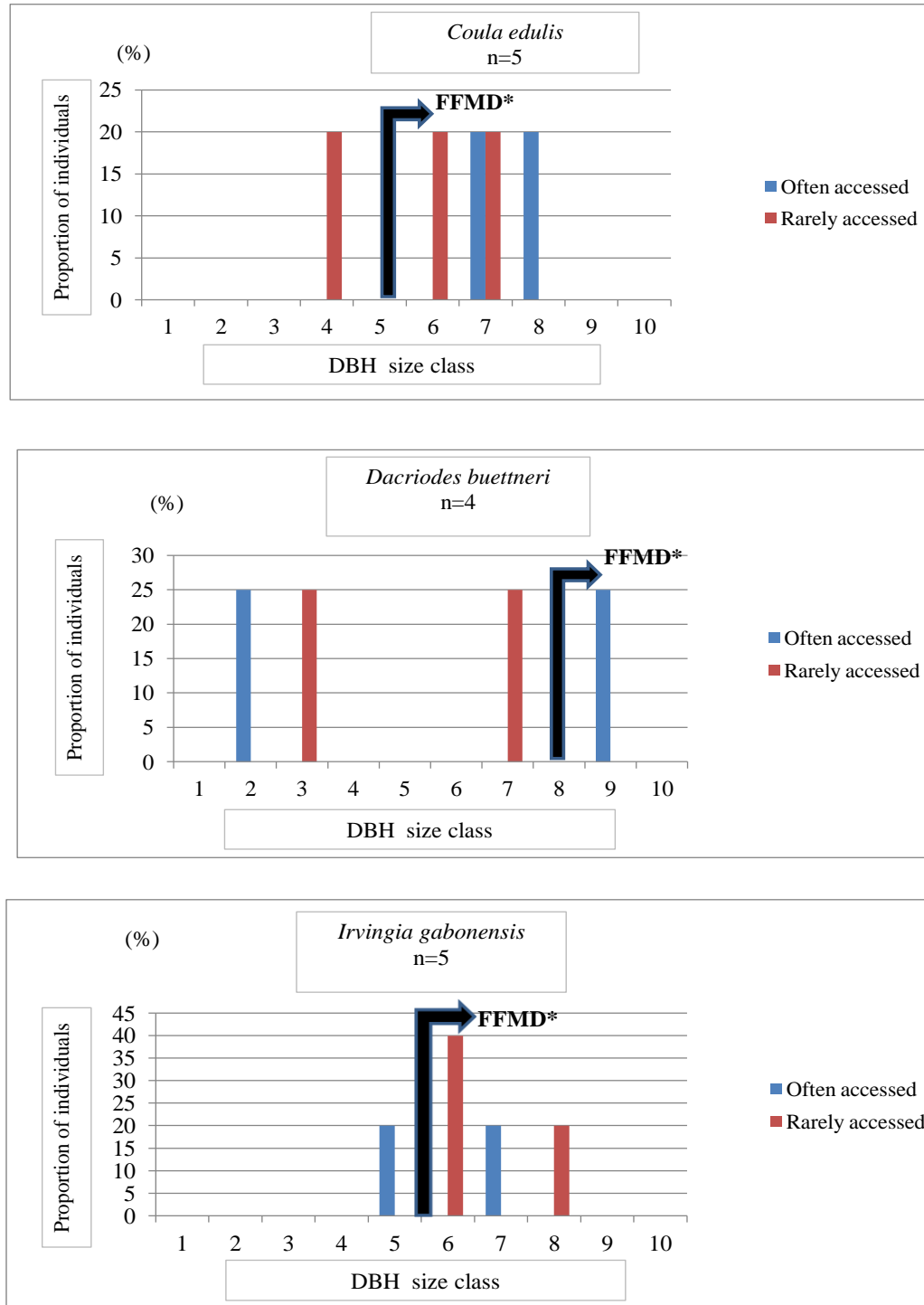


Figure 3. Woody population structure by harvesting location. FFMD*, Fixed Felling Minimum Diameter at breast height acknowledged by the decret n0 1285 /PR/MEFPE , of the 27 september 1993 in Gabon.

of seedling recorded were quite low in both locations (Table 3). This was probably due to past illegal access and uncontrolled tree cutting and other selective timber harvesting activities that have occurred inside and outside of the protected forests. Uncontrolled harvesting

and selective logging often destroys mature and young trees (Whitmore and Sayer, 1992; Chapman and Chapman, 1997; Adekunle and Olagoke, 2010). The impact of timber harvesting may also has a negative impact on forest structure, composition and its regeneration's ability

Table 3. Availability of woody individuals by harvesting locations

Locations	Scientific names			Total
	<i>Coula edulis</i>	<i>Dacriodes buettneri</i>	<i>Irvingia gabonensis</i>	
Often accessed	2 (33%)	2 (33%)	2 (33%)	
Mean (DBH in cm)	212	161	163	6 (43%)
SE	17	149	52	
Rarely accessed	3 (38%)	2 (25%)	3 (38%)	
Mean (DBH in cm)	164	136	187	8 (57%)
SE	57	89	38	
Total	1 (33%)	4 (28%)	5 (36%)	14 (100%)

(He et al., 2010). This negative impact has certainly to do with the fact that logging operations tend to be concentrated around most valuable commercial trees species in the forest as further stressed by (He et al., 2010). Consequently, unsustainable management of timber resources tends to be a common trend in many tropical forests (Putz and Redford, 2010). In the study area, past land uses based on uncontrolled harvesting and selective logging may have influenced the density or availability of sapling and woody individuals since locations “often” and “rarely” accessed were subjected to human pressures in the past. A part of forests of the Ivindo National Park (INP) has been allocated to logging companies before it was gazetted in 2002 and the current location where the park has been established used to be utilized by local people to meet their various livelihoods needs (Corbin, 2006; Viano, 2005; Sassen and Wan, 2006; Lescuyer, 2006). The study carried out by Sapkota and Odén (2009) has stressed out that gap creation after tree felling has a potential to influence not only tree regeneration but also the growth of young seedling individuals. In the case of this study, gap formation after trees have been logged out and its influence on the growth of light demanding species (seedling and sapling individuals) might have caused the current decline of the valued timber species from the wild.

In addition, the differences in stem densities observed could have resulted from the varying levels of disturbances that the area has experienced over the years since few sapling individuals (DBH < 30 cm) of *C. edulis* (one) and *I. gabonensis* (two) were recorded in both harvesting locations. However, no sapling individual of *D. buettneri* (DBH < 30 cm) was recorded in both harvesting locations because probably of intensive tree harvesting (Table 2). Timber and Non-timber species harvesting are not always impacting negatively to the forest stand since the destruction of plants and impacts tend to depend on specie and the parts of the resources used (Peters, 1996a,b; Tickin, 2004). On the contrary, forest resources harvesting may contribute to open excessive canopy gaps that often stimulate growth of seedling species and their survival (Beckage and Clark,

2003). For this study, the issue of forest resource decline may persist in these locations into the future (even though logging operations have been definitely prohibited in all national parks by the Gabonese government) since illegal access and uncontrolled trees cutting inside and outside of national parks are not being successfully addressed yet. Achieving this may call for setting up a proper regulations’ mechanisms in collaboration with people who depend on the resources base (Laird et al., 2010).

Considering that there is no on-farm planting of any of the target species around the study area and throughout of the country where similar cases occurred on one hand and that community forestry initiatives are still at their early stages on the other hand therefore, it is logical to suggest that parks managers and forest department should combined efforts to contain the harvesting of these species around forested areas inside and outside of the park in collaboration with local people knowing that top-down type of resources management often yields issue of resources decline (Ostrom, 2008).

Consequently, participatory involvement of local people in decision-making affecting their lives is crucial for implementing an effective regulatory mechanism over resource access and use (Ostrom, 2008), especially in Gabon where top-down approach based forest management seems to persist. It will be also crucial to grant and securing traditional rights (traditional property rights) over access and use of the resources (Clarke and Jupiter, 2010, Stahl, 2010). In Gabon, past traditional regulatory and institutional arrangements regulating access and use of forest resources have been abolished by the state and the only available legal regulatory and institutional arrangements designed to regulate access and use of forest resources are the ones dictated by the state. Thus, the state has an exclusive property rights over forests and land while local people have just been granted use fruits rights (Gabonese Republic, 2001, 2007). This means that local people are more exposed to rights alienation to some extent. Overcoming issue of property rights over resources access and use passes through a careful and an effective collaboration between legal and traditional regulatory and institutional

arrangements. Failing to achieve such successful synergy between legal and traditional customary resource tenure may more likely yield improper management of the resources and raise conflicts among resource users and state authorities as further highlighted by Clarke and Jupiter (2010).

In the case of this study, going back to such institutional synergy might be a non-negligible solution to address issue of unsustainable management of forest resources. It appears that the implementation of an effective participatory involvement of local communities in forest resources management (FRM) initiatives and trees planting represents a crucial mechanism that will more likely contribute to control and/ or regulate tree cutting and harvesting of fruits and seeds in the area given that the state alone seems to be failing to successfully managing the resources. Achieving the latter would require to implement a proper coordination and monitoring systems as well as training provision to the community followed by the formulation of clear and supportive by-laws by the state (Laird et al., 2010).

Population structure of seedling, sapling and woody individuals by harvesting locations and implication for sustainable harvest

Although population structures of seedling, sapling and woody individuals vary according to harvesting locations however, such trends indicate unhealthy population in each forest location. Past timber logging activities, illegal access and uncontrolled tree cutting could have influenced seed dispersal mechanisms, fruiting, germination and regeneration of each of the species while creating gap formation in stand forest. The absence of taller seedling individuals in the upper height size classes [8-11] compared to seedlings' population in the intermediate height size classes of [3-7] may be an indication of a poor natural regeneration (Figure 1). This means that seed sources were certainly depleted through strong harvesting of mother trees that have negatively impact of seeds and gene's ability to disperse as evidenced by Moran (2010). Overturning such poor trends may call for enrichment by tree planting that could more likely increase the population of the three target species on one hand and reduce pressure on resources base on the other hand around the study area.

The marked absence of sapling individuals in almost all DBH size classes of the three target species is also an indication of unhealthy population in the forests due to the fact that there are not enough sapling individuals in the forest undergrowth (Figure 2). Thus, the target tree species have certainly a poor sprouting ability meaning certainly that the current species population is less likely to increase and grow into more mature stems. There is also a paucity of some mature individuals in the lower [1-4] and upper [8-10] DBH size classes for both *C. edulis* and *I. gabonensis* and at [4-6] for *D. buettneri* suggesting

that the recruitment process of those species may have been affected by a combination of factors including the history of logging operations and human disturbances in the area (Figure 3). Thus, past timber logging activities and illegal access and uncontrolled tree cutting of reproductively mature trees have certainly reduced the population of the target species and affected their seeds production.

Tree production's ability is strongly correlated to tree Fixed Felling Minimum Diameter (FFMD) also known as Minimum Cutting Diameter or Optimum Tree Felling Diameter. Thus, timber species under the minimum cutting diameter are not sufficiently fecund since they are unable to produce enough seed to maintain the regeneration of the forest stand (Gullison et al. 1996). Sustainable management of timber species therefore calls for a strict respect of the legally determined cutting diameter by the state (SNOOK, 1996; Sist et al., 2003; Zimmerman and Kormos, 2012). The results of this study showed that there are few mature trees that have their Minimum Cutting Diameter bigger than DBH size class of (8) [70.0 - 79.9 cm] for *D. buettneri* and DBH size class of (5) [40.0 - 49.9 cm] for each of *C. edulis* and *I. gabonensis*. This means that the small numbers of mature trees that can produce seeds are limited and that they are not mature enough to produce seeds. Completely stopping all use of wood stems and fruits for resources sustainability and livelihood purposes of the local people might not be a viable solution to overcome the issue of resource decline in the area.

On the contrary, one of the feasible solutions might be directed towards implementing a proper regulation mechanism that would both aim at controlling and/ or regulating tree cutting and fruits harvesting in those forests locations given that these valued timber species appeared not to be able to recover from the further impacts related to tree cutting and intensive fruits and nuts harvesting. Thus, regulating tree cutting and fruits harvesting by allowing sustainable harvest calls for developing an appropriate management system for NTFPs (Peters, 1996b; Hall and Bangor, 2004; Vermeulen, 2009). The fact that trees cutting and fruits collection are limited to small size classes has probably to do with the fact that there is already scarcity of the "larger" preferred species in both "the often" and "the rarely" accessed locations of the park since those locations have experienced almost similar levels of harvesting pressures over the years (Figure 4). Past and current harvesting practices and other timber harvesting activities have certainly contributed to the decline of larger trees from the wild. This implies that strict forest protection type policy that is implemented by eco-guards and parks managers has not fully contributed to keep the forest "less disturbed" including inside of the park. Thus, uncontrolled harvesting of trees have certainly driven resources decline through destruction of mature and young trees (Whitmore and Sayer, 1992; Chapman and

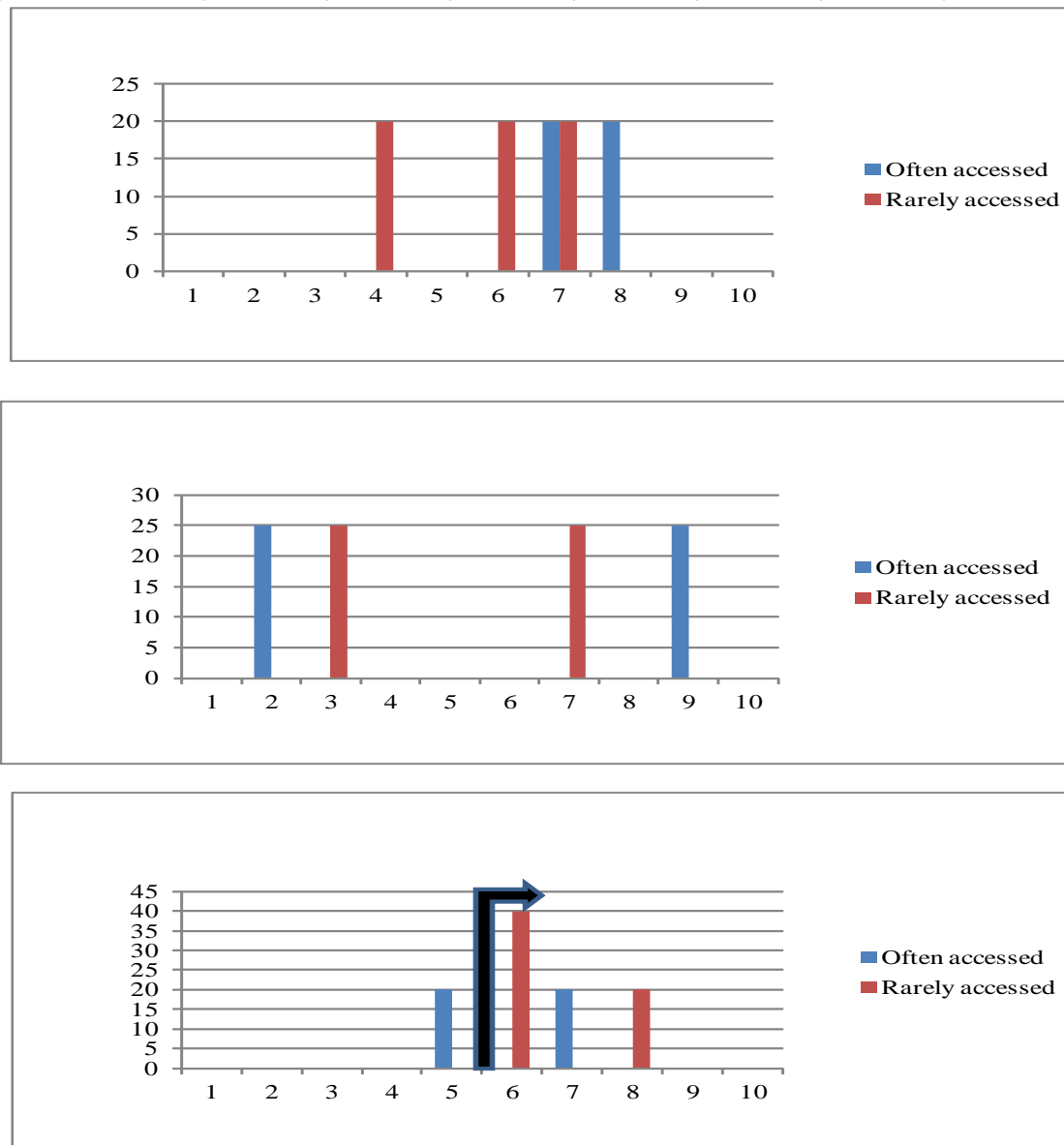


Figure 4. Woody population structure by harvesting location.

Chapman, 1997, Adekunle and Olagoke, 2010). Reversing such issue of forest resources decline is highly needed for both livelihood sustainability of local people and forest stand as a whole.

Conclusion

The study on the "Availability and size class distribution of the most popular Indigenous Fruits Trees and implications for sustainable harvest around of the Ivindo National Park, Gabon" is necessary and significant to the local community. The lower availability of seedling, sapling and woody of *D. buettneri*, *C. edulis* and *I. gabonensis* in "the often" and "the rarely" accessed locations and their

poor population structures are an indication of unhealthy population. Thus, it would be important to focus on the protection and management strategies of the above target tree species to prevent further depletion. Among management strategies include limiting the number of trees cut per season (for forest recovery purpose) or encouraging resources users to turn towards other timber species (less valuable but with similar importance) as an alternative to generate the current stocks of the species. In the meanwhile, it would be also important to carry out monitoring operations on species growth rate for sustainable use's purpose. The current community forestry initiative in the country should also focus on on-farm cultivation of these valued timber species inside and outside

of the protected forests otherwise trees would not be available to local people in the near future, knowing that they are slow growing and take long to mature.

Recommendations

- i. The current national parks policy based on the prohibition of logging operations and livelihoods activities inside of the parks has not been as effective in conserving and managing resources since forests depletion has been observed. Therefore proper controls over tree cutting and fruit harvesting are needed to allow adequate regeneration strategies of target species. Achieving this would require proper planning and takes into account the current financial and human resources.
- ii. There is a need to raise awareness of the local communities living around the protected forests about the declining status of the natural resource stocks from the wild.
- iii. Regarding the scarcity of the three target species, on farms tree planting by local community living around these forests is need to be implemented and encouraged to supply the logs and fruits, nuts and seeds from different locations of the park via the tree domestication program of ICRAF for example.
- iv. Further studies have to assess the regeneration capacity and regeneration strategies of the target fruit species to understand their recovery ability if appropriate management strategies have to be implemented by the state (Seydack, 1991; Everard et al., 1995).

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Full Length Research Paper

Invasive weed risk assessment of three potential bioenergy fuel species

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Bioenergy crops are potential renewable sources of bio-diesel which have low emission profiles, environmentally beneficial, and capable of substituting petro-diesel. However, since most of them are introduced or are not native, it is essential to reduce the ecological and economic consequences of invasive pest introductions and the potential invasiveness of species not yet introduced. The Australian Weed Risk Assessment (WRA) is a plant screening method and has the highest accuracy. The objective of this study was to conduct an agronomic and invasive weed risk assessment of three potential bioenergy fuel species namely: moringa (*Moringa oleifera*), physic nut (*Jatropha curcas*), and castor bean (*Ricinus communis*) for the Caribbean Islands. The WRA gave overall scores for moringa (0), jatropha (13) and castor oil (13). Based on their climatic adaptation and distribution, jatropha (5) and castor oil (5), the dispersal mechanism score was high (5) for both of them. The study revealed that jatropha and castor bean should not be considered as bioenergy crops within the ecological limits of the study, and that moringa should be further evaluated as bioenergy crop against invasiveness, given its agronomic potential as a high yielding oil crop.

Key words: Weed risk assessment, *Moringa oleifera*, *Jatropha curcas*, *Ricinus communis*, bioenergy plants.

INTRODUCTION

The International Energy Agency has identified the development of renewable energy sources as a key element to mitigate climate change (Schmid, 2012) and solution to the volatility of petroleum prices (Haque et al., 2011). It has stimulated the growth of bioenergy plant species for co-generation, or as ethanol and bio-diesel

(Raghu et al., 2006; CAST, 2007; Bridgemohan 2008). The efficient production and processing of bioenergy crops are seen as suitable source energy for fossil fuel-based (Gaunt and Lehmann, 2008).

Several bioenergy spp. have exhibited desirable traits such as high yield, low inputs requirements, wide ecological

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adaptability, do not compete with food production or food grade oils, and are ideal for preventing desertification and erosion (Francis et al., 2003; Low and Booth, 2008). The bio fuels produced from these crops have high calorific value and improved lubricity (Lalas and Tsaknis, 2002) and lack sulphur and consume CO₂ (Choi et al., 1997; Szybist et al., 2005; Concieca et al., 2007). Some bio energy crops like jatropha (*Jatropha curcas*), have some toxicity which is sensed by animals and therefore not foraged (Devappa et al., 2012).

Several bioenergy species including moringa (*Moringa oleifera*), physic nut (*Jatropha curcas*), and castor bean (*Ricinus communis*) are adapted to the Caribbean (Bridgemohan, 2008). Moringa is adapted to semi-arid and humid conditions (Palaniswamy, 2004; Ramachandran et al., 1980), marginal soils (Palada and Chang, 2003) and has good oil yield potential (Sukarin et al., 1987). The monoecious jatropha (Dehagan and Webster, 1979) like castor bean are drought resistant shrub (Ghosh et al., 2007) and grow well on infertile soils without competing or interfering with food production activities (Sukarin et al., 1987).

There is a possibility that bioenergy species may have characteristics that may make them adaptable to the different ecological conditions and explode as invasive plants. As such, it is prudent that they should be assessed against the potential risk that the species might become invasive (Krivánek and Pyšek, 2006).

Bioenergy plants can be selected and bred from nonnative taxa which have few resident pests, tolerate poor growing conditions, and produce highly competitive monospecific stands-traits that typify much of our invasive flora (Barney and DiTomaso, 2008; Davis et al., 2010).

The Australian Weed Risk Assessment (WRA) system has been used to categorize the risk of plants becoming invasive (Pheloung et al., 1999). It has been modified for application to other locations (Gordon 2008), and was used to evaluate the potential invasiveness of species proposed as biofuels in Florida (Salisbury 2008; Gordon et al., 2011). It is a plant screening method developed for regulatory purposes against invasive plants and has high accuracy (Leung et al., 2002; Daehler et al., 2004; Krivánek and Pyšek 2006). It has been sufficiently tested both for screening of new species or species already in cultivation that may become invasive (Low and Booth 2008; Salisbury 2008; Gordon et al., 2010).

The WRA has been used to specifically assess invasion by bioenergy crop (Barney and DiTomaso, 2008; Buddenhagen et al., 2009; Koop et al., 2012; Quinn et al., 2014). They all found the model suitable and concluded given the economic and ecological impacts of invasive species, including the carbon expended for mechanical and chemical control efforts, cultivation of taxa likely to become invasive should be avoided.

The objective of this study was to conduct an invasive

weed risk assessment of three potential bioenergy fuel species viz., moringa (*M. oleifera*), physic nut (*J. curcas*), and castor bean (*R. communis*) for the Caribbean Islands.

MATERIALS AND METHODS

This study was conducted during the period of 2009 to 2012 at the Waterloo Research Centre, University of Trinidad and Tobago which is located in the southern Caribbean. Three observation plots were established with moringa, jatropha, and castor bean on the Waterloo Soil Series in June, 2009, at a density of 2,500 plants. ha⁻¹ on cambered beds. The plants were rain-fed, zero chemical and all operations were done manually.

The plant morphological and phenological characteristics (plant height, leaf area, flowers and fruit production, flowering cycle, and yield) were recorded throughout the plant juvenile and reproductive stages. The mature pods were harvested and yield analysis conducted. Similar observations were conducted from three other locations which were characterized by poor and marginal soils in Mc Bean Village, Carli Bay, and Caroni Village, Trinidad.

The WRA (Pheloung et al., 1999) was selected to assess invasiveness with additive approach for each of the 49 questions with set scores. This survey instrument covered distribution, agro-climatic conditions, invasive characteristic, and morphological and physiological traits of the species. All the questions are required for completion of the WRA on any species or taxon. If the summed scores are >6, the taxon is predicted to become invasive and should be rejected for import/production; if the sum is <1, the taxon is not predicted to become invasive and should be accepted; scores of 1 to 6 indicate that further evaluation is necessary before a prediction is possible (Gordon et al., 2010). The assessment was conducted by four assessors using the observations compiled over the study period and the mean scores used in the final report.

RESULTS

Phenology and reproductive characteristics

The phenological characteristics of the species under study indicated that there was no dormancy in the fresh seeds and they are viable and germinated 4 to 9 days after sowing. After one year, all three species maintained good germination (>95%) and viability (80 to 90 %). The vegetative / growth phase varied between 3 to 6 months while jatropha and castor bean had 3 distinct flowering cycles in the year, moringa was constantly flowering/ fruiting with 10 new flushes per year over the three year period of study (Table 1).

Jatropha maintained a medium height and hardy shrub-like structure (1 to 1.5 m), whilst castor bean and moringa were lush green architecture (4 to 5 m). Jatropha grew well despite the unusual dry season period of January to May, 2010, but did not produce any new vegetative structures, shed most of its leaves, and reduced its flowering and seed production. All the plants continued to produce normal seed yield without any dormancy or loss of seed viability. The dispersal distance for natural field emergence for both castor bean and jatropha varied

Table 1. Agronomic and phenological characteristics¹ of moringa (*Moringa oleifera*), physic nut (*Jatropha curcas*), and castor bean (*Ricinus communis*).

Phenology and reproductive characteristics	Bioenergy crops		
	<i>M. oleifera</i>	<i>J. curcas</i>	<i>R. communis</i>
Days to germination (1 year old seeds)	100	100	100
Length of vegetative growth (days)	180	90	140
flowering cycle / year	10	3	3
flower yield/ cluster (nos)	21	19.0 (2.83)	19 (1.14)
flower cluster yield / tree (nos)	25 to 36	34 (1.27)	23.2 (7.89)
Pod yield / cluster	2 to 4	28 (2.02)	16.96 (4.89)
new pods/tree/month	24 to 27	30 (3.01)	29 (6.34)
flowering to harvest (DAS)	45	82	80
harvest cycles / year	9 to 10	3 to 4	2 to 3
harvestable fruit pods / tree/ flush	30 (4.78)	646 (12.25)	408
Pod Yield . tree ⁻¹ . yr ⁻¹	750	2584	1020
Nos. seeds . pod ⁻¹	20	4	4
Weight 1000 seed (g)	350	36.4	113.36
Seed yield kg.tree ⁻¹ .yr ⁻¹	5.25	0.376	4.364
Seed yield (t.ha ⁻¹ .yr ⁻¹)	13.12	0.96	13.90
Oil yield (t.ha ⁻¹ .yr ⁻¹)	5.01	0.68	2.52

Values in parenthesis are SE.

between was 3 to 18 m². Moringa seeds remained in the pod, long after it shed and the dispersal range was less than 0.5 m from the edge of the canopy cover.

There was no germination of moringa seeds on the soil under the trees, and on examination, the fallen pods collected after 3 months revealed most (60%) of the seeds were damaged by insects and were not viable *in-situ*. Castor bean and jatropha seeds persisted in the soils were longer (3 to 6 months) than moringa, but all showed declined viability (10%). It was observed that there were no birds or animals feeding on the plants or seeds, and there were no assisted transfer of dissemination of seed by animal.

Biogeographical characteristics

The history and biogeographical characteristics which described the domestication/cultivation, climate and distribution, and weed elsewhere are presented in Table 2. Moringa has higher domestication scores (3) compared to jatropha (0) and castor bean (0), and is a highly domesticated plant which is used as an ethnic vegetable by the East Indian descendants in the Caribbean. It has naturalized and adapted to wide ecological conditions and is not considered as a weed. However, jatropha and castor bean are not domesticated or naturalized, and are considered as unwanted in agricultural and wastelands.

Under 'climate and distribution' (Table 2), there were no differences in the scores among moringa (4) compared to jatropha (5) and castor bean (5). Jatropha can tolerate very dry growing conditions, while castor bean flourished on the banks of water courses under dry to waterlogged

conditions. All the spp. adapted well to low or zero agricultural inputs, and survived under low soil moisture conditions in the dry season, and flowered and seeded profusely in the wet season.

Under 'weeds elsewhere' (Table 2), there were significant differences in the scores among moringa (1) compared to jatropha (-7) and castor bean (-7). Jatropha was introduced as an ornamental plant. However, because of its noxiousness, dispersal range, and tendency to form clumps that are difficult to manage, its cultivation is limited. Castor bean is a shrub weed and forms dense canopy and impenetrable clumps on the periphery of farmlands and moist abandoned fields. The overall scores for history and biogeographical characteristics (Table 2), showed that there were significant differences in the scores among moringa (3) compared to jatropha (-2) and castor bean (-2).

Biology and ecological characteristics

The biology and ecological characteristics of the undesirable traits (Table 3) revealed that there were significant differences in the scores among moringa (0) compared to jatropha (9) and castor bean (9), and that the latter two had more undesirable characteristics. The pods of jatropha and castor bean have burs which can attach themselves to animals passing through these trees. However, there were no grazing or wild animals observed in the areas under study. Both are fire hazards in the natural ecosystem due to the formation of impenetrable thickets compared to moringa which is sparse and widely spaced. All the spp. are tolerant to low

Table 2. History and biogeographical characteristics (domestication/cultivation, climate and distribution, and weed elsewhere) of moringa (*Moringa oleifera*), physic nut (*Jatropha curcas*), and castor bean (*Ricinus communis*) response according to the WRA.

Biogeographical characteristics		Response		
		<i>M. oleifera</i>	<i>J. curcas</i>	<i>R. communis</i>
Domestication/ Cultivation	highly domesticated	-3	0	0
	naturalized	1	-1	-1
	weedy races	-1	1	1
Climate and Distribution	suited to Trinidad and Tobago climates	1	2	2
	Quality of climate match data	1	1	1
	environmentally versatile	1	1	1
	Native or naturalized (extended dry periods)	1	1	1
	history of repeated introductions outside its natural range	0	0	0
Weed elsewhere	Naturalized beyond native range	1	1	1
	Garden/amenity/disturbance weed	0	-2	-2
	Weed of agriculture/horticulture/forestry	0	-2	-2
	Environmental weed	0	-2	-2
	Congeneric weed	0	-2	-2
	subtotal	3	-2	-2

Table 3. Biology and ecological characteristics of the undesirable traits moringa (*Moringa oleifera*), physic nut (*Jatropha curcas*), and castor bean (*Ricinus communis*) response according to the WRA.

Biology and ecological characteristics		Response		
		<i>M. oleifera</i>	<i>J. curcas</i>	<i>R. communis</i>
Undesirable traits	spines, thorns or burrs	0	1	1
	Allelopathic	0	1	1
	Parasitic	0	0	0
	Unpalatable to grazing animals	-1	1	1
	Toxic to animals	0	1	1
	Host for pests and pathogens	0	0	0
	allergies or toxic to humans	0	1	1
	fire hazard in natural ecosystems	0	1	1
	shade tolerant plant	0	0	0
	Grows on infertile soils	1	1	1
	Climbing or smothering growth habit	0	1	1
	dense thickets	0	1	1
	subtotal	0	9	9

soil moisture content, poor marginal soils, and can rejuvenate after fire.

Plant type and reproduction characteristics

The plant type and reproduction characteristics of the undesirable traits according to the WRA are presented in Table 4. All the species are hardy wood plants with no

nitrogen fixing abilities. They did not show evidence of reproductive failure, and under drought conditions produced viable seeds, although the yields were slightly reduced. The species are self-fertilized and do not require any specialist pollinators. Only moringa can be propagated and produced by cuttings. The plant type and reproduction characteristics (Table 4) revealed that there were differences in the scores among moringa (3) compared to jatropha (1) and castor bean (1), none of the

Table 4. Plant type and Reproduction characteristics of the Undesirable traits moringa (*Moringa oleifera*), physic nut (*Jatropha curcas*), and castor bean (*Ricinus communis*) response according to the WRA.

Plant type and Reproduction characteristics		Response		
		<i>M.oleifera</i>	<i>J.carcus</i>	<i>R.communis</i>
Plant type	Aquatic	0	0	0
	Grass	0	0	0
	Nitrogen fixing woody plant	0	0	0
	Geophyte	0	0	0
Reproduction	Evidence of substantial reproductive failure in native habitat	0	0	0
	Produces viable seed	1	1	1
	Hybridizes naturally	-1	-1	-1
	Self-fertilization	1	1	1
	Requires specialist pollinators	0	0	0
	vegetative propagation	1	-1	-1
	Minimum generative time (years)	1	1	1
	subtotal	3	1	1

plants exhibited the features outlined under plant type.

Dispersal mechanisms and Persistence attributes

The dispersal mechanism of propagules is seen as a major characteristic of a species which describes its invasiveness (Table 5). There were differences in the scores among moringa (-6) compared to jatropha (4) and castor bean (4). Moringa is mostly grown on cultivated or fallow fields, and usually involves human action and interference. The moringa pods shatter under very dry conditions while on the tree, but the seeds are not wind dispersed, although they appear anatomically structured to be windblown.

Under dispersal mechanisms and persistence attributes characteristics there were differences in the scores among moringa (4) compared to jatropha (1) and castor bean (1), suggesting that moringa was more likely to be more dominant than the others. However, the seeds are buoyant and can flow along water courses. It is unlikely that the seeds pass through animals undigested and remain viable, even though the seeds are fed to animals as a protein source. Jatropha and castor bean are not likely to be dispersed by human interference, even accidentally, but the shattering force could spread the seeds to short distances (Table 1). This is evidenced by the presence of clumps in proximity to the parent plant. The fruits are not eaten by animals while on the tree, but shells on the soil suggest that rodents feed on all species.

The persistence attributes (Table 4) based on seed prolificacy, tolerance to cultivation or fire and natural enemies revealed that all the species are similar in that regard. Jatropha and castor bean can be controlled by herbicides during the early vegetative phase. Under field conditions at the experimental site, moringa was observed

to be very sensitive to herbicide drift of paraquat, but is able to rejuvenate and re-grow.

Weed risk assessment characteristics

The summary of the WRA scores (Table 6) demonstrated that moringa (-3) was consistently more domesticated as a crop than jatropha (0) and castor bean (0). Moringa (0) was less likely to be colonized as 'unwanted plant' or weed compared to jatropha (-7) and castor bean (-7). Jatropha (9) and castor bean (9) have significantly more undesirable traits than moringa, but their plant type and architecture are similar. Moringa is higher yielding and can produce more seeds per tree, but it is the dispersal mechanism that characterizes jatropha (4) and castor bean (4) as invasive weeds. Moringa has more positive persistency attributes (3) than the other two species (1). The assessment indicated that the total score for moringa was zero (0), compared to jatropha and castor which was thirteen (13) each.

DISCUSSION

The application of the WRA in the determination of the agronomic and invasiveness of three potential bioenergy fuel species viz., moringa, physic nut and castor bean was justified. The tool is not simply a questionnaire but required specialist knowledge by the Assessors, and available published data to support its application. Further, it can determine invasiveness/noninvasiveness, but cannot be used as a regulatory instrument by plant quarantine or other agencies to declare weed invasive/non invasive unless the species is cultivated in the ecological zone to make that judgmental decision (Shay, 1993; Salisbury,

Table 5. Dispersal mechanisms and Persistence attributes characteristics of the Undesirable traits of moringa (*Moringa oliefera*), physic nut (*Jatropha curcas*), and castor bean (*Ricinus communis*) response according to the WRA.

Dispersal mechanisms and Persistence attributes		Response		
		<i>M.oliefera</i>	<i>J.carcus</i>	<i>R.communis</i>
Dispersal mechanisms Of Propagules	unintentionally	-1	1	1
	intentionally by people	-1	1	1
	produce contaminant	-1	1	1
	wind	-1	1	1
	buoyant	1	1	1
	bird	-1	-1	-1
	other animals (externally)	-1	1	1
	other animals (internally)	-1	-1	-1
Persistence attributes	Prolific seed production	1	1	1
	persistent propagule bank (> 1 yr)	1	1	1
	controlled by herbicides	1	-1	-1
	Tolerates/ benefits from mutilation, cultivation or fire	1	1	1
	Effective natural enemies present in Trinidad and Tobago	-1	-1	-1
	Subtotal	-3	5	5

Table 6. Weed Risk assessment characteristics of morning (*Moringa oliefera*), physic nut (*Jatropha curcas*), and castor bean (*Ricinus communis*) response according to the WRA.

Parameter	<i>M.oliefera</i>	<i>J.carcus</i>	<i>R.communis</i>
Domestication/ Cultivation	-3	0	0
Climate and Distribution	4	5	5
Weed elsewhere	1	-7	-7
Undesirable traits	0	9	9
Plant type	0	0	0
Reproduction	3	1	1
Dispersal mechanisms	-8	4	4
Persistence attributes	3	1	1
total	0	13	13
outcomes	evaluate	reject	reject

2008).

A short coming in this study was that the tool lacked an appropriate approach to assess the competitiveness ability for soil moisture, nutrient, light and mutual antagonism. It is accepted that Taxa predicted to be invasive in their introduced range are likely to incur ecological and economic harm if cultivated, including increased carbon expenditures for their mechanical or chemical control outside of cultivation sites (Jefferson et al., 2004). If the contribution of those species to renewable energy generation is considered to be significant, then the effective barriers to invasion and continuous monitoring and adequate resources management should be directed towards rapid detection and elimination of spp beyond

the area cultivated.

Moringa which could be considered as a silviculture crop is naturalized but not considered invasive. However, the expanded cultivation of a species previously only grown at low density could significantly alter propagule pressure that can shift dispersal and colonization frequency. It is generally accepted that the cultivation of native species as bioenergy crops may pose greater risk of invasion than do others.

The weed risk assessment characteristics gave overall scores for moringa (0), jatropha (13) and castor oil (13), which suggests that moringa should be further evaluated, whilst the other two should be rejected as bioenergy crops for the Caribbean. In both instances, it can be directly

related to their climatic adaptation and distribution; jatropha (5) and castor oil (5), and was further compounded by their dispersal mechanism (5) for both of them.

The study suggests that jatropha and castor bean should not be considered as bioenergy crops within the ecological limits in which this study was conducted, and that moringa should be further evaluated as bioenergy crop against invasiveness, given its agronomic potential as a high yielding oil crop.

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Full Length Research Paper

Attitudes of Maasai pastoralists towards the conservation of large carnivores in the Loliondo Game Controlled Area of Northern Tanzania

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Attitudes towards the conservation of lions, leopards, cheetah, spotted hyenas and African wild dogs were assessed in the Loliondo Game Controlled Area of northern Tanzania in January 2013. Our survey encompassed 181 individuals each representing one household, of which 30 were chosen randomly from six Maasai pastoralist villages. A semi-structured questionnaire was used to acquire the required information from the respondents. We found that the majority of the Maasai pastoralists, particularly females, expressed negative attitudes towards the conservation of large carnivores. The reasons given for disliking carnivores differed between the sexes, but the most common reasons were that the carnivores attacked the respondents' livestock at night and also purposefully and frequently attacked people. The Maasai pastoralists who had been to school, mostly males, expressed more positive attitudes than those who had not been to school. Those who liked at least two carnivore species had received greater benefits from conservation programs than those who liked only one or disliked all carnivore species. Therefore, to support the conservation of wild dogs and other large carnivores at large, we recommend that where possible, female Maasai should be allowed to access Protected Areas (PAs) resources during the time of hard ship or drought to improve their livelihood. In addition, they should be empowered by being involved in conserving large carnivores as "carnivore guardians", exposed to ecotourism activities and be educated. Furthermore, conservation performance payments for carnivores should be institutionalized in the area.

Key words: Large carnivores, conservation, human attitudes, Loliondo Game Controlled Area.

INTRODUCTION

Worldwide, previous studies have found that about 95% of the total range of all carnivore species, occurs outside

protected areas (Crooks et al., 2011). Only small numbers are able to survive in human-dominated landscapes

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(Woodroffe, 2000; Dolrenry, 2013; Hazzah et al., 2013). Previous studies have furthermore, pointed out that human attitudes which normally predict human behaviour from their behavioural beliefs as explained by the theory of reasoned action (Ajzen and Fishbein, 1980), or planned behaviour (Marchini and Macdonald, 2012), could be performed at any time towards the presence of large carnivores in their vicinity (Marchini and Macdonald, 2012). Such attitudes rather than natural conditions have been the main reasons for the decrease of large carnivores (Jackson et al., 2003; Treves and Karanth, 2003; Mannelqvist, 2010; Yirga et al., 2011). The assessment of such attitudes is frequently the first stage of proper conservation strategies (Jackson et al., 2003; Kaczensky et al., 2003; Lindsey et al., 2005; Lagendijk and Gusset, 2008; Mannelqvist, 2010; Carter et al., 2014). In most cases, it has been found that, wherever humans perform negative attitudes because large carnivores kill their livestock or attack people (Løe and Røskaft, 2004; Lagendijk and Gusset, 2008; Yirga et al., 2011; Carter et al., 2014; Lyamuya et al., 2014), or had experienced Protected Areas (PAs) policy during times of hardship (for example, access policies to grazing inside PA during drought) (Hazzah et al., 2013), as well as socio-economic factors (Hazzah et al., 2009); large carnivores are the ones to suffer as the consequence of such attitudes which undermine their management and conservation efforts (Ikanda and Packer, 2008; Kissui, 2008; Yirga et al., 2011; Carter et al., 2014; Masenga et al., 2013). Usually, humans have been found to be intolerable to loss by wild carnivores and thus retaliate by killing those problem carnivores which eventually reduce their numbers at both the population and species levels (Lindsey et al., 2005; Woodroffe et al., 2005; Lucherini and Merino, 2008; Shingote, 2011; Yirga et al., 2011; Carter et al., 2014).

A similar situation has been observed to occur among the Maasai pastoralists who inhabit the Loliondo Game Controlled Area and Ngorongoro Conservation Area in northern Tanzania, where the local people frequently retaliate by killing troublesome carnivores in their areas (Ikanda and Packer, 2008; Masenga et al., 2013) as well as in other pastoral areas in Africa (Kissui, 2008; Hazzah et al., 2009; Miner, 2011). Therefore, currently there is a global challenge in facilitating human-carnivore coexistence in human-dominated landscapes since it requires to first understand factors that influence human attitudes, particularly humans who have to bear the consequences of the presence of large carnivores in their vicinity (Jackson et al., 2003; Lagendijk and Gusset, 2008; Carter et al., 2014). On the other hand, there is a need to propose proper and conducive management measures that would enhance coexistence between humans and large carnivores in an area as previous studies have proposed and proved to be successful (Kissui, 2008; Zabel and Holm-Muller, 2008; Hazzah et al., 2009; Miner, 2011; Hazzah et al., 2014; McManus et al., 2014).

This study aimed at determining the main factors that cause negative attitudes among Maasai pastoralists

towards the conservation of large carnivores such as lions (*Pantheraleo*), leopards (*Pantherapardus*), cheetah (*Acinonyxjubatus*), spotted hyenas (*Crocutacrocuta*) and African wild dogs (*Lycaonpictus*) in the Loliondo Game Controlled Area (LGCA), northern Tanzania. We made the following hypotheses: 1) Because education helps in the development of positive attitudes (Røskaft et al., 2007; Dalum, 2013), the Maasai pastoralists who have been to school will express more positive attitudes towards large carnivores than those who have never been to school; 2) male Maasai pastoralists will express more positive attitudes towards the conservation of large carnivores than females because their culture favours men in terms of the right to speak; 3) the pastoralists who receive many benefits of having large carnivores in their vicinity (for example, being part of vaccination programs, having access policies for grazing, firewood collection and water fetching in PAs during times of hardship, or acquiring the benefits of tourism for example, employment and income generation) will exhibit more positive attitudes towards these species than those who receive few benefits. Because wild dogs are the main predators of livestock in our study area, we paid this species special attention.

MATERIALS AND METHODS

Study area

The study was conducted in the eastern Serengeti ecosystem in the Loliondo Game Controlled Area (LGCA; Figure 1). The LGCA is located in the Maasai ancestral land in the northern part of Tanzania and covers approximately 4500 km² (Lyamuya et al., 2014). The Maasai are nomadic pastoralists with a very low proportion of agro-pastoralists (Masenga and Mentzel, 2005; Masenga, 2010; Lyamuya et al., 2014). The Maasai depends entirely on livestock for their economic survival. The LGCA exhibits a bi-modal rainfall pattern with peaks that occur in December and April and a total yearly precipitation of 400-1200 mm precipitation per annum (Jaeger, 1982; Maddox, 2003; Masenga and Mentzel, 2005). The LGCA is dominated by open woodland and grassland. The open woodland is found primarily in the northern region on rolling hills that are interspersed with rocky outcrops. In the central region, there are mountains with steep slopes and densely vegetated gullies. The open areas in the lowlands are either cultivated or open woodlands. The southern portion of the area gives way to short grassland (Masenga and Mentzel, 2005).

Data collection

The data for this study were collected in January 2013. Our survey encompassed 181 individuals, each representing one household chosen randomly from six Maasai villages adjacent to the eastern Serengeti ecosystem. The methods used for data collection and sample size determination followed those that have been used in previous studies (Sancheti and Kapoor, 2003). No prior notice was given to the interviewees, although the village chairman was first consulted about the study and asked for permission to perform the interviews in his/her area. The sampling strategy was opportunistic, and the interviewees were chosen according to availability based on their age and gender. A semi-structured questionnaire was administered by two researchers. They asked questions in Swahili

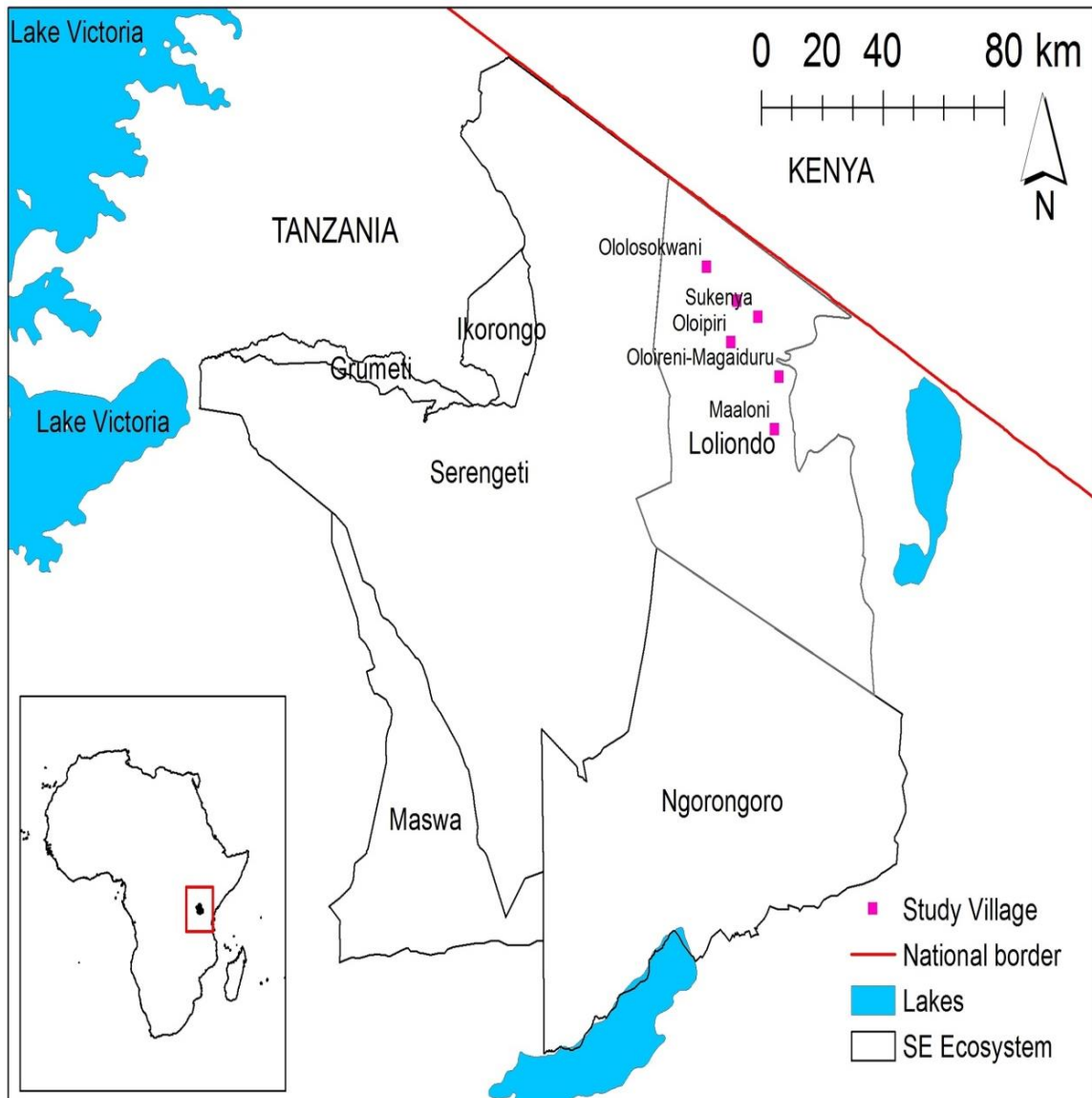


Figure 1. A map of the Serengeti ecosystem showing the study area of the Loliondo Game Controlled Area in northern Tanzania. The studied villages are indicated in purple.

which were then translated to the Maasai language with the help of Maasai translators. With this method, the researchers were able to record information on the attitudes of the Maasai pastoralists in relation to the conservation of large carnivores in their area. The data collected included basic information about the participant's age, age class (youths, adults and elders; however, rather than using these age classes in our analyses, we classified the participants into two age groups: those born before ($n = 77$) and those born after ($n = 104$) 1959), gender (males $n = 123$; females = 58), village centre GPS location, tribe (Maasai), and educational level (had been to school ($n = 74$), never been to school ($n = 107$)).

Next, we asked the participants whether they were aged between 54 - 100 years (e.g. old- born before the eviction from SNP) or between 30 - 53 years (e.g. young- born after the eviction from the Serengeti National Park (1959)). Thereafter, these participants were asked questions related to their attitudes toward the conservation of large carnivores, e.g., 1) "What carnivore species

(lion, leopard, spotted hyena, cheetah and wild dog) do you like/dislike in your area?", 2) "Why do you like/dislike the carnivores?", 3) "Do you think wild dogs have a right to stay in your area?", 4) "Do you receive any benefits (e.g., being part of vaccination programs, having access policies for grazing, firewood collection and water fetching in PAs during times of hardship or acquiring the benefits of tourism e.g employment and income generation) from the presence of wild dogs in your area?" and 5) "What do you think should be done to conserve wild dogs?"

Data analyses

All analyses were performed using Statistical Package for Social Science (SPSS) Statistics version 17.0 for Windows. Because most of the data were nominal, we primarily used non-parametric Chi-

Table 1. Percentages of the Maasai respondents who exhibited different attitudes based on gender, age class and educational level.

Number of carnivore species liked		≥ 2	1	0	Total
		N (%)	N (%)	N (%)	N (%)
Gender	Males	26 (21.1)	65 (52.8)	32 (26.0)	123 (100)
	Females	2 (3.4)	24 (41.4)	32 (55.2)	58 (100)
Age group	After 1959 (30-53 years)	19 (18.4)	52(50.5)	32 (31.1)	103 (100)
	Before 1959 (54-100 years)	9 (11.7)	36(46.8)	32 (41.6)	77
Education	Been to school	16 (21.6)	40 (54.1)	18 (24.3)	78 (100)
	No education	12 (11.2)	49 25.8)	46 (43.0)	107 (100)

Table 2. The different reasons given by the respondents of each gender why they liked or disliked the carnivores.

Reasons	Males	Females	Total
Dislike	N (%)	N (%)	N (%)
They purposely attack livestock at night	62 (50.4)	24 (41.4)	86 (47.5)
They are enemies of people	3 (2.4)	5 (8.6)	8 (4.4)
They attack livestock and people	16 (13.0)	19 (32.8)	35 (19.3)
Like			
They are easy to chase	21 (17.1)	6 (10.3)	27 (14.9)
They attract tourists and are source of income	7 (5.7)	1 (1.7)	8 (4.4)
They cause no problems	14 (11.4)	3 (5.2)	17 (9.4)
Total	123 (100)	58 (100)	181 (100)

square tests (Fowler et al., 2009; Zar, 2010) to determine the differences in the frequencies among different variables. Additionally, descriptive statistics were used to determine the frequencies of the respondents who reported liking or disliking the conservation of the different large carnivores in their area. Very few respondents liked the carnivores, and the patterns were similar for all four species; therefore, we pooled these categories. As a first step, we analysed the frequencies with which the participants' liked or disliked each of the four carnivores and produced five categories (liked zero species (N = 64), liked one carnivore species (N = 89), or liked two, three or four of the species (N = 28)). We then pooled the last three categories into one category termed like at least two (2-4) of the carnivores (lion, leopard, cheetah, spotted hyena; n = 28), and the other two categories were termed like one carnivore (n = 89) and dislike all carnivores (n = 64). We used these three categories of attitudes in the analyses. All statistical tests were two tailed, and the significance level was set at $P \leq 0.05$.

RESULTS

Our results revealed that out of the 181 respondents, males represented 67.6% while females represented 31.9%. About 59.1% of the respondents had never been to school which represent mostly females (82.8%) while

52.0% of males had never been to school ($\chi^2 = 19.7$, $df = 1$, $P < 0.001$). Most of those who were born after their eviction from the Serengeti National Park (1959) had been to school (51.0%), while most of those born before that period had never been to school (74.0%) ($\chi^2 = 12.6$, $df = 2$, $P = 0.002$).

To test Maasai pastoralists' attitudes toward conservation of large carnivores respondents' answers of like at least two species were taken to express positive attitudes, like one species as an indicator of an intermediate attitude and "dislike all species" as an expression of the most negative attitudes. From this, females expressed significantly more negative attitudes than the males ($\chi^2 = 18.5$, $df = 2$, $P < 0.001$, Table 1). The negative attitudes of the females were related to the different reasons given by the two sexes regarding why they liked or disliked the carnivores ($\chi^2 = 16.2$, $df = 5$, $P = 0.006$, Table 2).

Furthermore, those who had never been to school (71.9%) expressed significantly more negative attitudes toward large carnivores than did those who had been to school (28.1%) ($\chi^2 = 7.9$, $df = 2$, $P = 0.018$). However, no significant difference in attitudes was found between those born before and after eviction ($\chi^2 = 2.78$, $df = 2$, P

= 0.249). A linear regression analysis using carnivore attitudes (likes ≥ 2 , 1, 0) as the dependent variable and gender, born before or after eviction and education level as independent variables was statistically significant ($r^2 = 0.120$, $F = 7.971$, $df = 3$, $P < 0.001$). However, only gender significantly explained this variation ($t = 3.73$, $P < 0.001$). The other two variables (born before or after eviction and education) did not explain any significant additional variation.

Generally, most of the Maasai pastoralists expressed negative attitudes towards the conservation of wild dogs (like = 34.1% and dislike = 65.4%). To further investigate the attitudes toward the conservation of wild dogs we used the following question: "Do you think wild dogs have a right to stay in your area"? Answers of "yes" express positive attitudes and "no" express a negative attitude". Generally, the male pastoralists expressed significantly more positive attitudes (56.1%) than the females (30.4%) ($\chi^2 = 10.2$, $df = 1$, $P = 0.001$). A logistic regression analysis with "Do you think wild dogs have a right to stay in your area"? as a dependent variable with gender, age class and education level as independent variables, was statistically significant (Cox and Snell $r^2 = 0.107$, Nagelkerke $r^2 = 0.143$, $\chi^2 = 20.327$, $df = 3$, $P < 0.001$). All independent variables explained some of the variation statistically significant (education level, Wald = 7.53, $P = 0.006$; age class, Wald = 5.27, $P = 0.022$; gender, Wald = 4.43, $P = 0.035$). This was due to the fact that males (52.0%,) were more educated than females (17.2%) ($\chi^2 = 19.7$, $df = 1$, $P < 0.001$).

Furthermore, those who liked at least two carnivore species (39.3 %) were significantly more likely to have been benefited by having wild dogs in their area as compared to those that liked one (11.2%) or disliked all carnivores (4.7%) ($\chi^2 = 20.8$, $df = 2$, $P < 0.001$). Those who had never been to school expressed more negative attitudes (60.7%) towards the rights of the wild dogs to stay in their area as compared to those who had been to school (38.3%, $n = 41$) ($\chi^2 = 9.2$, $df = 2$, $P = 0.010$). A logistic regression analysis using the answers to the question "Do you receive any benefit from the presence of wild dogs in your area?" (yes, no) as a dependent variable and gender, education level and born before or after eviction as independent variables proved to be statistically significant (Cox and Snell $r^2 = 0.074$, Nagelkerke $r^2 = 0.136$, $\chi^2 = 13.802$, $df = 3$, $P = 0.003$). However, only gender (Wald = 5.47, $df = 1$, $P = 0.019$) significantly explained the variation in receiving benefits; that is, the males generally received more benefits than the females. Education level and born before or after eviction did not significantly contribute in explaining the variation.

The results of a linear regression analysis using the "like none, one or ≥ 2 carnivores species" as the dependable variable and do you receive any benefit from having wild dogs in your area? and gender as independent variables proved that both of these factors significantly explained the attitudes of the Maasai pastoralists ($r^2 = 0.172$,

$F = 9.09$, $P < 0.001$). Both gender ($t = 3.079$, $P = 0.002$) and do you receive any benefit from having wild dogs in your area? ($t = 3.330$, $P = 0.001$) explained significantly the variation, but education level and born before or after eviction did not significantly explain any additional variation.

There were significant differences in the advice given by male and female Maasai regarding the proper strategies for wild dogs conservation in their area; the males (76.4 %) advised that local people should be involved in their conservation, while the majority of the females offered no advice (51.7 %; $\chi^2 = 20.1$, $df = 3$, $P < 0.001$; Table 3). Additionally, most of those who had been to school (82.4 %) advised that local people should be involved in wild dog conservation, while those who had not been to school (42.0 %) were more likely to offer no advice ($\chi^2 = 14.2$, $df = 3$, $P = 0.003$; Table 3). There was also a statistically significant difference between those born before and after eviction; those born after were more eager to express opinions regarding conservation ($\chi^2 = 20.1$, $df = 3$, $P < 0.001$; Table 3).

DISCUSSION

Overall, the attitudes of the Maasai pastoralists are important tools that should be considered regarding the value of conserving large carnivores in the Loliondo Game Controlled Area, northern Tanzania (Maddox, 2003; Ikanda and Packer, 2008; Kissui, 2008; Masenga et al., 2013) and other areas of Africa (Hazzah et al., 2009; 2013, 2014). Our findings support the hypothesis that females generally express more negative attitudes toward the conservation of large carnivores than males. These negative attitudes might be related on one hand to their behavioural beliefs as the result of not receiving any benefits from the presence of large carnivores in their area due to their denied access to PA resources (such as grazing their livestock, firewood collection and fetching water) during time of hardship or drought (Hazzah et al., 2013). While on the other hand, by reasons given by both of them that include the notion that carnivores cause livestock losses due to their predatory behaviour (Maddox, 2003; Lyamuya et al., 2014). Hazzah et al. (2013) found that when people are given access to PAs resources during the times of hardship they usually perform positive attitudes towards wildlife as seen near Tsavo and Nairobi national parks in Kenya. According to theory of reasoned action developed by Ajzen and Fishbein (1980) and that of planned behaviour by Marchini and Macdonald (2012), the behavioural beliefs usually determine the attitude of a person whether positive or negative towards an object. This eventually generates his or her behavioural intention as well as moral behaviour. Despite the fact that females in the Maasai culture are neglected from their right to speak, they still have negative attitudes towards large carnivores, which is of conservation concern as they might through their behavioural intention and moral

Table 3. Different reasons given by the respondents regarding the types of conservation strategies that the Maasai pastoralists would like to see implemented in relation to wild dogs.

Variable	Reason	Local people should be involved in wild dog conservation	Compensation schemes should be established	Wild dog should be taken away from people	No advice
		N (%)	N (%)	N (%)	N (%)
Gender	Males	31 (25.2)	12 (9.8)	51 (41.5)	29 (23.6)
	Females	3 (5.2)	2 (3.4)	23 (39.7)	30 (51.7)
Age group	After 1959	19 (18.4)	9 (8.7)	51 (49.5)	24 (23.3)
	Before 1959	15 (19.5)	5 (6.5)	22 (28.6)	35 (45.5)
Education	Been to school	19 (25.7)	8 (10.8)	34 (45.9)	13 (17.6)
	No education	15 (14.0)	6 (5.6)	40 (37.4)	46 (43.0)

behaviour influence their children and husbands to dislike such animals, hence they hinder conservation efforts (Ikanda and Packer, 2008; Kissui, 2008; Yirga et al., 2011; Carter et al., 2014; Masenga et al., 2013). To overcome this problem, it is required that females be empowered by being involved in the conservation of large carnivores as e.g. guardians. Previous studies have shown that guardians of large carnivores have been successful where it has been applied. A good example is the Maasai land in Kenya (Hazzah et al., 2014). Moreover, since most of the females have never been to school it is predicted that they are more likely to work and entirely depend on livestock keeping for their survival. Thus they suffer from losses to wild carnivores, and become more negative than males. It has previously been found that people who have not been to school or have low levels of education hold more negative attitudes toward the conservation of large carnivores in their areas (Lindsey et al., 2005; Røskaft et al., 2007; Lucherini and Merino, 2008; Li et al., 2010; Mannelqvist, 2010; Carter et al., 2014; Dalum, 2013). Previous studies indicate that if female Maasai pastoralists were to be taken to school to improve their understanding and knowledge, this would in most cases shape their attitudes in a positive way towards large carnivores and thus enhance their coexistence (Røskaft et al., 2007; Li et al., 2010; Carter et al., 2014).

Interestingly, the strongest effects in our study were the difference in attitudes between the two genders. According to Dalum (2013) factors such as age, gender and general education level cause variation in attitudes toward wildlife conservation. Moreover, factors such as culture, economy, social status and exposure to an event have also been found to influence attitudes (Røskaft et al., 2003; Yirga et al., 2011). Thus, in our case, gender was found to be the most significant factor in explaining the negative attitudes of the Maasai pastoralists (Røskaft et al., 2007; Mannelqvist, 2010). This is because females Maasai are less educated and do less outdoor activities than males reducing their chances of encountering species that are in conflict with them which might be the

reason for the increase in negativity towards such carnivores (de Pinho et al., 2014). According to Pinho et al. (2014) facilitation for local residents, in our case female Maasai, visiting PAs increases their familiarity with species that are rarely seen or most frequently seen in conflict with their interests and hence increases their tolerance and positive attitudes towards them. The males' more positive attitudes may be explained by the preference of male to wild animals and education level (Li et al., 2010).

Furthermore, positive attitudes were related to the income generating activities of the tourist industry, and the males were more frequently involved in these activities than the females. Moreover, previous studies have indicated that older people might continue to be influenced by the potentially negative attitude that was prevalent during their childhood (Røskaft et al., 2007).

Generally, most Maasai pastoralists expressed negative attitudes towards the conservation of wild dogs in their area. These negative attitudes were associated with the participants' beliefs (Ajzen and Fishbein, 1980; Marchini and Macdonald, 2012) that the wild dogs prey on their livestock and cause economic losses. Similar reasons have been reported in previous studies (Lindsey et al., 2005; Lucherini and Merino, 2008; Mannelqvist, 2010; Dalum, 2013). We found that the males expressed more positive attitudes towards the conservation of wild dogs than the females because the males frequently see them and received more benefits from their presence than the females. The males benefited from tourism activities more frequently and generated more income than the females. The importance of such benefits in shaping positive attitudes has also been found elsewhere (Røskaft et al., 2007; Lagendijk and Gusset, 2008; Mannelqvist, 2010).

CONCLUSION AND MANAGEMENT IMPLICATIONS

We conclude that female Maasai pastoralists generally expressed more negative attitudes toward the conservation

of all five large carnivore species in their area as compared to the males. Additionally, the males who mostly had been to school were more likely to visit wilderness and more frequently observe large carnivores and receive benefits from having them in their area than females.

Therefore, to support the conservation of wild dogs and other large carnivores at large, we recommend that where possible, female Maasai should be allowed to access PAs resources during the time of hardship or drought to improve their livelihood. In addition, they should be empowered by being involved in conserving large carnivores as “carnivore guardians”. Moreover, frequent visits to PAs should be increased on the side of females Maasai to increase their chances of encountering the rarely seen conflicting large carnivores in their area. In addition, females should be taken to school to receive more education on the ecological importance of large carnivores in their area because environmental education has been a frequently used tool in attempts to foster positive attitudes towards wildlife conservation (Jackson et al., 2003; Dalum, 2013; Straube, 2013). Also, female Maasai pastoralists should be exposed to ecotourism activities in their areas. Such tourism activities are frequently attracted to local areas because of the presence of such carnivore species, which might help the female Maasai to increase their income and hence improve their livelihood and attitudes towards carnivores’ conservation (Lucherini and Merino, 2008). Furthermore, conservation performance payments for carnivores (Zabel and Holm-Muller, 2008) should be institutionalised in the area.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Appendix I

Questionnaire survey on the historical perspective of human-wild dog conflict and local people attitudes towards large CARNIVORES in the north eastern part of the serengeti ecosystem

A. RESPONDENT'S GENERAL INFORMATION

- 1A. Respondent name:
- B. Gender:
- C. Age
- D. Age class:
- E. Education level:
- F. Village name:
- G. Occupation:
- H. Tribe:
- GPS location:
- I. Place of residence:
- J. Household numbers:
- K. Livestock numbers:
- L. Date:

B. HISTORICAL INFORMATION

- 1: Living information
 - a) Where you born before or after independence?
 1. Before independence (<1960) 2. After independence (>1961)
 - b) Where you born in Loliondo game controlled area?
 1. Yes 2. No
 - c) If not where were you born and when did you come to this area?
- 2: WILD DOGS INFORMATION
 - a) Since you were young, did you see any wild dogs in this area? 1. Yes 2. No
 - b) If yes, how often do people in your village see them? 1. Daily 2. Weekly 3. Monthly 4. Rarely
 - c) What do you think about the population trend of wild dogs in your area when you compare your sightings today with those of previous days? 1. Increasing 2. Stable 3. Decreasing 4. Don't know
 - d) Is there any reason for that?
 - e) Are the denning areas the same today as they used to be? 1. Yes 2. No
 - f) If not, where did they den before compared to now?
 - e) Since you were born, have you ever herded livestock in your area? 1. Yes 2. No
 - f) If yes, were you herding livestock when you were young or Moran? 1. Young 2. Moran 3. Both
3. HUMAN-WILD DOG CONFLICT

- a) Do you think wild dogs are a problem to you? 1. Yes 2. No
- b) If yes, what kind of problem do they cause to you? 1. Killing livestock 2. Attack people 3. Spread diseases
- c) Do you think this problem arose recently or has it existed since you were born? 1. Arose recently 2. Existed since I was born 3. Am not sure
- d) Since you were young, have you ever seen wild dogs preying on your livestock? 1. Yes 2. No
- e) How often do you see that? 1. Very often 2. Often 3. Rarely
- f) What domestic species are most frequently attacked? 1. Cattle 2. Goat/sheep 3. Donkeys 4. Domestic dogs
- g) What did you do when you saw that happening? 1. I chased them away 2. I ran away to look for assistance 3. I killed them 4. I did nothing 5. Others
- h) If you compare livestock attacks by wild dogs during old days and today, what do you think is the trend? 1. Increasing 2. Stable 3. Decreasing 4. Don't know
- i) Is there any reason for that?
4. PERCEPTIONS OF LOCAL PEOPLE
- a) What carnivore species do you like most?

Species	Like them	Dislike them	Why?
Lions			
Leopards			
Spotted hyenas			
Wild dogs			
Cheetah			

- b) Do you think wild dogs have a right to stay in your area? 1. Yes 2. No 3. Don't know
- c) If yes or no, why?
- d) What do you think should be done to conserve wild dogs?
- e) Do you receive any benefits by having wild dogs in your area? 1. Yes 2. No
- f) If yes, what benefit do you receive?
- g) If you compare with the old days, do you think you are currently benefiting more than during the old days by having wild dogs in your area? 1. Yes 2. No 3. Don't know
- h) If yes or no why?
- i) What is your advice to the future generations?



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