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Full Length Research Paper

Customs and traditional management practices of coastal marine natural resources in Lower Casamance: Perspectives of valorisation of endogenous knowledge

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In southern Senegal, specifically in Lower Casamance, many marine and coastal resources are of significant sociological importance for Jola populations. They are essential both for worship and for sustenance. Thus, through different customs and practices, the Jola helps to preserve their natural environment, even if their primary motivations were hardly conservation. Perceptions, beliefs, and avoidance practices with regard to different types of places and resources decreed sacred, as well as the symbolism of certain animal or plant resources, indicate the very identity of the people. However, with respect to these sociocultural customs and practices, some are specifically aimed at preserving certain resources for economic and ecological interests. This article proposes an analysis of the contribution of Jola traditions and practices in the conservation of marine and coastal resources. To this end, the methodological approach was based on the principles, methods and tools of the participatory approach. It combined an empirical and participatory approach through semi-structured interviews and observations on the ground.

Key words: Customs, ecological practices, marine coastal natural resources, Lower Casamance, endogenous knowledge.

INTRODUCTION

The populations of Lower Casamance, especially the Jolas, derive from nature the products for their livelihood and for the realization of certain rites and traditional ceremonies. Many marine and coastal resources are considered as sacred. Indeed, the Jolas constitute the majority ethnic group with 57.8% of the total population of the Lower Casamance. Their settlement in the area was prior to the 16th century (Gueye, 2007). This ethnic group is known for its intimate links with its environment and more specifically with the natural resources of the locality (Thomas, 1959; Pélissier, 1966; Palmeri, 1995). For customary practices, the exploitation of these resources

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is limited, if not prohibited. It is important to know that these practices are customary, in order to address the unsustainable use of these resources. Among other practices common among the Jola ethnic group are: totemism, prohibitions, worship of fetishes, worship and initiation rituals. These practices not only safeguard spiritual and cultural wealth, but also play a leading role in conservation.

Unfortunately, these practices and customs are losing momentum these days. The traditional religion that kept them going is being relegated to the background for the benefit of Islam and Christianity. Certain management rules are increasingly abandoned in certain areas, particularly in the north of the region. However, today, repeated shortcomings and failures offer opportunities to develop these customary practices previously discarded (Cormier-Salem et al., 2002; Geoffroy, 2009; Koy and Ngonga, 2017). In Senegal, particularly in Lower Casamance, this promotion of local customs is still timid even if traditional rules are associated with the management of protected areas such as ICCAs.

This article aims to show the contribution of traditional customs and practices in the conservation of marine and coastal natural resources in Lower Casamance. It highlights local knowledge in a perspective of sustainable resource management. After a presentation of the framework of the study and the methodology deployed, we focused on the practices that have an impact on the conservation of marine and coastal resources. We conclude this paper with a discussion of the foundations of these practices.

MATERIALS AND METHODS

Study area

The Lower Casamance in southern Senegal falls within the administrative region of Ziguinchor. It consists of three departments including Bignona, Oussouye and Ziguinchor. Lower Casamance extends on both sides of the Casamance River and goes from the Atlantic Ocean to Soungrougrou. It is bordered to the east by the Sedhiou region, to the west by the Atlantic Ocean, to the north by the Gambia and to the south by Guinea Bissau. The region covers an area of 7339 km^2 and an estimated population of 549,152 according to the census of 2013, or about 4% of the population of Senegal (ANSD, 2015). The coastal South-Sudanian climate is relatively humid with average rainfall exceeding 1000 mm in general. The region is dominated by plateaus and vast plains.

In terms of physical geography, Lower Casamance is made up mainly of waterfalls and forests and belongs to the complex and vast West African ecosystem described by Guilcher (1954) and known as the "Rivers of the South" (GRDR-UASZ-IRD, 2017). The terrestrial part includes forest formations dominated by Guinean species such as *Elaeis guineensis, Bombax costatum, Borassus aethiopium*, etc. The marine area consisting of bolongs (or inlets), shallows and lowlands corresponds to the limit zone of penetration into the continent of the ramifications of the Casamance main stream (Badiane, 2012).

The majority of ethnic Jola, 57.8% of the population, live with the Mandingos (11.10%), Pulaars (10.5%), Ouolofs (3.9%), Manjacques (3.5%), the Balante (2.9%), Mancagnes (2.4%), the Sereres (2.70%) etc. (ANSD, 2015). They are divided into several subgroups identified by a language, a denomination, and a separate location. The space inhabited by the Jolas is subdivided into several territories. Each terroir bears the same name as the subgroup that occupies it. We thus speak of Kassa, the soil of Kassa Jola, Karone, Bandial, Blouf, Jola Fogni, Kalounaye, etc.

The study extends to the three departments of the region, namely Ziguinchor, Bignona and Oussouye. In fact, divided into several subgroups, the Jola people, occupy separate territories in the region. Thus, according to the scopeof our study, we chose to focus our research onfive Jola countries of the region of Lower Casamance. It is in the department of Bignona of the Blouf country to the north, and those of Bliss-Kassa and Bliss-Karone to the West of the North shore. At the level of the departments of Ziguinchor and Oussouye we have the Bandial and Kassa counties respectively situated in the West and in the extreme south of the Ziguinchor region. The municipalities covered in the study in Blouf are Mangagoulack, Kartiack, Mlomp (Blouf), Thionck-Essyl. The other communes of the study are Kafountine located in the Bliss-Kassa / Bliss-Karone area, Djembering, Oukout, Mlomp (Kassa) and Oussouye located in Kassa and Enampore in Bandial.

The villages affected by our study in the department of Oussouye are Djembering, Cabrousse, Ourong, Cagnoute, Mlomp / Kadjinole, Kahinda, Siganar, Eloubaline and Oussouye commune. In Oussouye, only the villages of Kalobone, Sinkine and Etyas are concerned. In the department of Ziguinchor; these are the villages of Bandial, Essyl, Kamobeul and Selecky. And finally in that of Ziguinchor, it is the villages of Hitou, Haer, Niomoune, Abene, Kafountine, Hillol, Kailo, Saloulou, Mangagoulack, Tendouck, Mlomp Blouf, Tiobon, Kartiack, and Thionck Essyl (Figure 1).

Approach

In this study, we utilised the qualitative method because of the objectives of the study and the nature of the data sought call for a greater emphasis on contextual understanding of the perspectives of the people.In fact, the method consists in contacting the target actors and their practices, questioning and observing them. This approach aims to analyze actions and interactions taking into account the stakeholders' intentions (Dumez, 2011).

For this purpose, a certain number of parameters were taken into account for the choice of the study sites. These are mainly criteria related to the coastal character of the sites and the conservation potential of traditional practices and local management methods. In doing so, geographical areas covering both the maritime and the terrestrial sides of the shoreline, and integrating bolongs (or inlets) and wetlands in contact with the sea or the river are particularly targeted.

Data collection tools include interviews (individual, group or focus-group, informal) and direct observation. The survey covered5% households in the study area corresponding to a headcount of 376 heads of households, divided according to the proportion of the targeted villages (Table 1). The choice of respondents was not random. The snowball method identified the people who could provide us with the right information. Indeed, some people are distinguished by their knowledge. The snowball method has therefore identified those who could provide us with the right information.

RESULTS AND DISCUSSION

Traditional religion is a basic element in the Jola of Lower Casamance. It is a cornerstone in the management of the natural environment and associated resources. It plays a role in the establishment of particularly close links

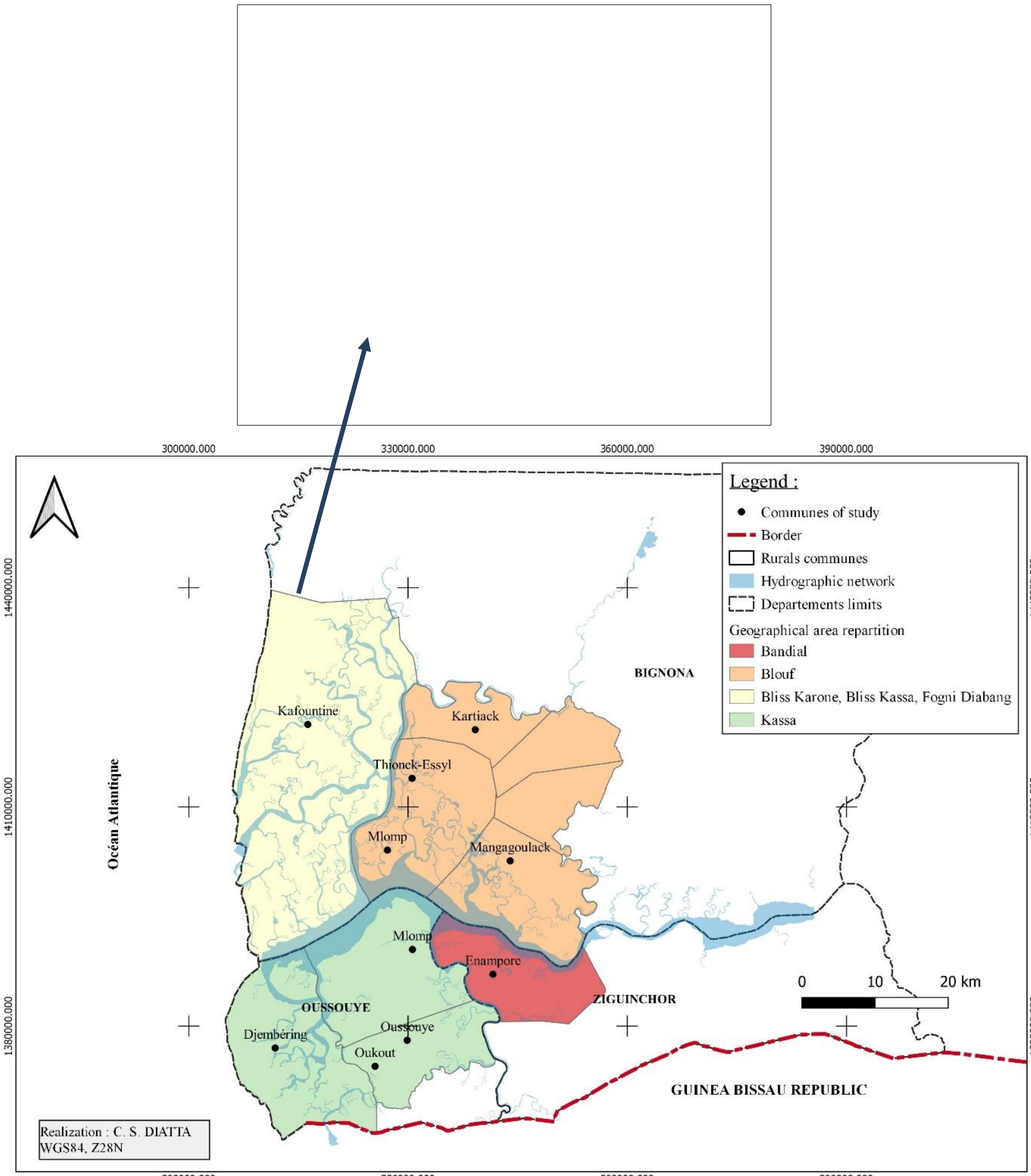

Figure 1. Location of the study area.

between the nature, the people and the supernatural powers of the environment.

Customs and practices conducive to conservation

In Lower Casamance, many marine and coastal resources are of significant sociological importance. They figure in many West African societies protected for cultural or cultural reasons (Dugast, 2002). The system of taboos, conventions or prohibitions totem, sacred sites, rites are among the traditions that preserve resources. These management practices are still prevalent and are rooted in traditional systems. However, even though they

Table 1. Number of households surveyed by villages in the study area.

Communes	Villages	Total population	Number of households	Weight of households by village in %	Number of households interviewed per village	Resource persons
Kafountine	Niomoune	807	181	12	8	1
	Hitou	374	52	3	2	1
	Haer	294	41	3	2	2
	Abéné	2611	322	21	14	1
	Kafountine	6417	776	51	34	2
	Kailo	183	22	1	1	1
	Hillol	56	56	4	2	----
	Saloulou	65	65	4	3	----
Kartiack	Kartiack	1708	287	59	15	1
	Tiobon	1593	202	41	11	1
Mangagoulack	Mangagoulack	587	107	25	10	1
	Tendouck	1938	316	75	30	1
Mlomp (Blouf)	Mlomp Blouf	2427	300	100	10	1
Thionck-Essyl	Thionk Essyl	8087	1022	100	29	1
Djembering	Djembering	2269	409	36	21	1
	Cabrousse	3993	665	59	33	
	Ourong	390	60	5	3	
Mlomp Kassa	Cagnoute	1015	238	20	12	1
	Mlomp /Kadjinole	4478	939	80	45	1
Oukout	Kahinda	362	60	15	7	1
	Eloubaline	243	69	17	8	1
	Siganar	1272	271	68	30	1
Oussouye	Oussouye (Kalobone, Esinkine et Etya)	4135	611	100	18	2
Enampore	Bandial	317	78	17	5	1
	Essyl	306	75	16	5	1
	Kamoubeul	480	119	26	7	2
	Selecky	373	194	42	12	1
Total		**46 780**	**7 537**	**1000**	**376**	**27**

Source: Diatta et al. (2018).

often move away from the rational by Western standards, they remain important for the conservation of resources.

Sacred sites in Jola environment

As natural and cultural heritage, the sacred natural sites are distinct archetypes pertaining to the cultural, social and spiritual identity of the Jola. They include streams, ponds, forests commonly known as sacred woods, groves, glades, etc. In Lower Casamance, sacred sites are now the only traditional reserves of biodiversity conservation (Fall et al., 2011; Badiane, 2012). The implementation of traditional legislation has helped to preserve these sacred areas. Moreover, thanks to the mysteries surrounding them and the beliefs associated with them, these sacred spaces are at the origin of the rules and practices that guarantee the conservation of resources. It is the same for the stability of the ecosystems of these environments (Fall et al., 2011).

Thus, the results reveal the existence of sacred sites (sacred water sources, forests or sacred groves, sanctuaries) are jealously guarded by the populations in all the villages of the study. The woods and sacred places (glades) are the most representative (Table 2).

Tributaries (bolongor inlets) traditionally considered sacred by local people are of several types. The most representative are:

i) totem residences comprise 81% of the listed sites, a total of 89 sites. Some of these sites also represent djinn[1]

[1]Djinn are supernatural creatures inhabiting the Earth and are generally invisible. They can take different forms (plant, animal, etc.). They live near water points, in deserted places, cemeteries and forests ... Their existence is attested by the current which states it in Sura 51 - Verse 56 ": I did not create the jinns and men only to worship me".

Table 2. Sacred sites listed in the study area.

Localities	Wood sacred	Sacred sea sites	Sacred places (sanctuaries)	Sacred mares	Sacred wells
Bandial	19	11	43	23	-
Kassa	89	21	69	17	1
Bliss-Kassa, Bliss-Karone	20	48	34	6	-
Blouf	44	27	25	39	-
Fogni Diabang	3	2	11	4	2
Total	**175**	**109**	**182**	**89**	**3**

Source: Surveys (2015).

residences. This is the case of the sites of Ethintou Pissala, Kessito and Fussabe. On the other hand, others are places of ritual practices where the education of the members of the community takes place, in this case, the sites of Etenia, Djata Hounouha Ehindou and Fièques);
ii) cockpits of geniuses, (13%);
iii) sites intended for initiatory rites with or without a fetish (4%) and
iv) sites protected by a fetish (2%). One of these sites (Mitij) is specifically designed for the protection of fisheries resources (Figure 2).

Like the bolong, ponds in Jola countries are also subject to rules of use and access. Their story is directly related to the cultural life of local people. These expanses of sacred water are used for various purposes, the most remarkable of which remain linked to initiatory practices (Figure 3). The majority of the ponds used for religious purposes are related to the rites of passage in Casamance of El Hadji Oumar Foutihou Tall, a Muslim dignitary. The latter would rely on the water or would have ‘dug himself’ to do his ablutions during his campaign of Islamization. The people come to gather in these sites and invoke the divine graces.

Ponds are good for both men and animals. From an ecological point of view, they fulfil important functions. They serve as habitats and breeding grounds for some species of fish such as carp and catfish. Some ponds, such as Bitini, and Hiyew Katouki are frequented by important bird fauna and reptiles such as crocodiles. They also serve as watering places for wild and domestic animals. Outside the ponds, there are sacred wells. The water from these wells is used during casting rituals. This is the case of the wells of Conon, Jola Karone of Abene, Djinabantang Kafountine and Houwedj in the village of Siganar.

Outside the bolongs and ponds, we have the woods and places or sacred clearings that are of great importance for the Jola populations. Animist places of worship and identity vector of the populations, the sacred groves exist in all the villages of the sample and cover 31% of the sacred sites inventoried (Figure 4). The results of the study reveal that these sites are more present in the highly animist zones notably Kassa, Bandial, Bliss-Kassa and Bliss-Karone (Figure 5). This considerable number of sacred sites is explained by the vivacity of ancestral religious beliefs. In the Blouf and Fogni Diabang areas located in the Bignona department, many sacred sites have considerably deteriorated or completely disappeared.

The rites

Several rites favour the conservation of marine and coastal resources. They help maintain the balance with nature, but also aim to promote the abundance of natural resources, rains, and the well-being of the community.

The ritual of initiation

In Lower Casamance, rites of passage are of major importance. The sacred woods that house these ceremonies or those attached to these practices such as ponds and sanctuaries obey very strict rules that must not be transgressed under any pretext. The culprits are severely punished with curses that can sometimes extend to their family and/or their offspring.

The considerable number of sacred reserved for initiatory practices reveals the important place this rite occupies in traditional society (Figures 6 and 7). Thanks to the taboos that surround them, these places provide direct benefits to the natural environment.

The rites of offering to exploit the resources of nature

For the Jolas, some resources retain lasting links with ancestors and harmony with the natural environment. They think, like many other African populations (Goedefroit, 2002; Wala et al., 2003; Koy and Ngonga, 2017), that certain animal and plant resources are possessed or inhabited by the spirit of their ancestors and that maintaining good relationships with them is essential in order to ensure a peaceful life. Animal and

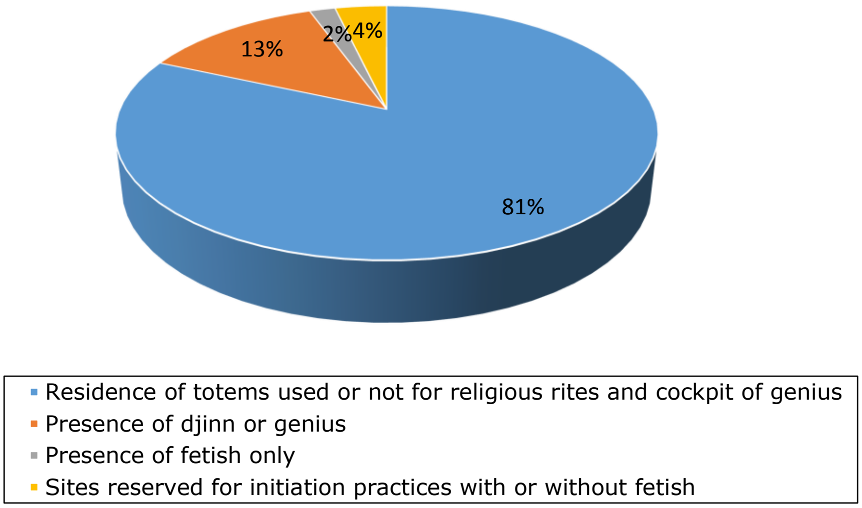

Figure 2. Categories of marine sacred sites encountered.
Source: Surveys (2015).

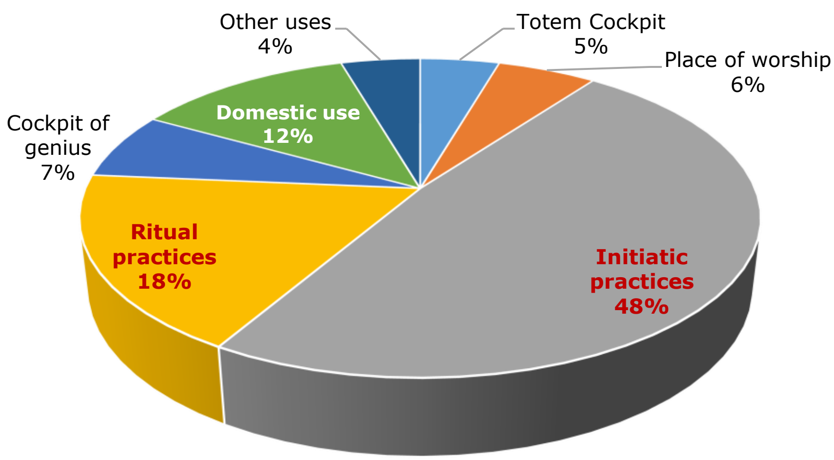

Figure 3. Uses reserved for sacred ponds.
Source: Surveys (2015).

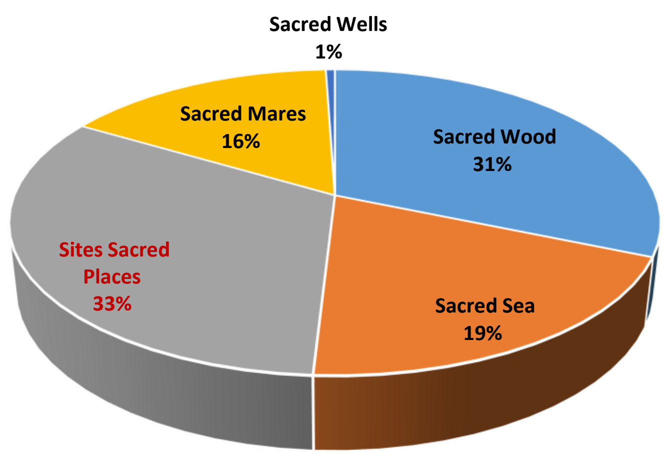

Figure 4. Weight of different types of sacred sites.
Source: Surveys (2015).

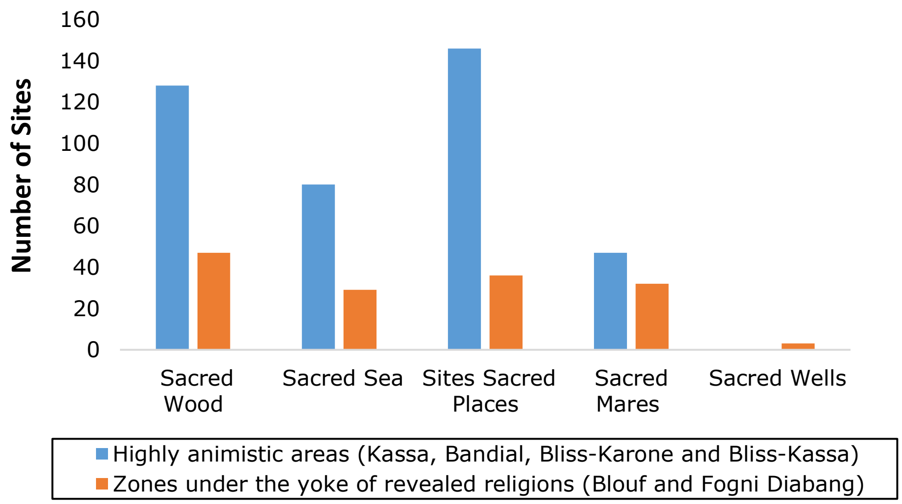

Figure 5. Spatial distribution of sacred sites.
Source: Surveys (2015).

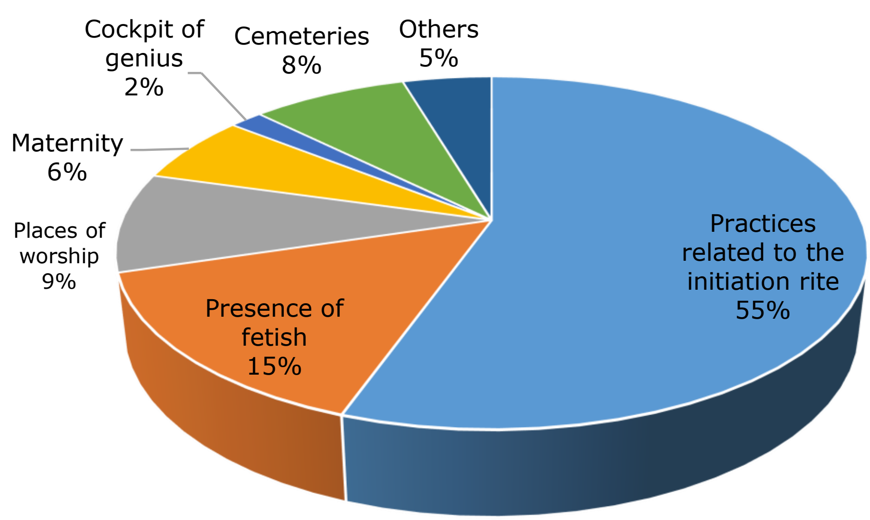

Figure 6. Characteristics of the sacred groves.
Source: Surveys (2015).

plant resources can be used to solicit favours and to repair breaks in these relationships. It is the same for the rites of incantation.

This indigenous view of nature explains the ritual that allows access to certain plant species used for medicinal purposes and sacrifices to protective genius. The latter, by his good will, decides to authorize or oppose the puncture (Gueye, 2007). This rite is a guarantee that allows the sampler to have the agreement of the tutelary entity. Several ritual procedures are used by the Jola, but the most common are the offerings of millet, tobacco or rice. The authorization to puncture can be obtained with a silver coin offering as a replacement for tobacco. If the tree is housed in a sacred place that houses a fetish, it is the palm wine that is given as an offering.

In other cases, no offering is made, just a piece of root is required. The agreement of the genie is testified by the welding of the two extremities where the piece of root was taken the day before. In reality, in the jola environment, many plant species serve as a habitat for geniuses and the most famous are *Ceiba pentanda* (L.) Gaertn.,*Khaya senegalensis* (Desr.) A. Juss., *Adansonia digitata* Linn, *Dialium guineense* Willd. Nevertheless, there are some trees with peculiar features as smooth trunks (free from any human action).

In addition to the rituals that precede the collection of

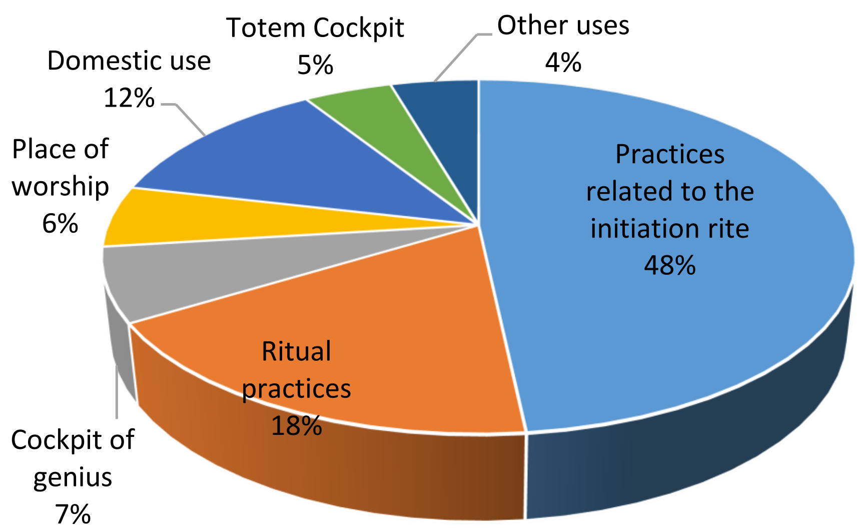

Figure 7. Uses reserved for the sacred ponds.
Source: Surveys (2015).

medicinal products from plants, there are those that precede the felling of a tree. Indeed, the felling of a haunted tree is always preceded by a prayer in which the genius is requested to leave their home. Thus, a few times, a week before slaughtering a cheese-maker, the trunk of the tree is carefully surrounded by gray-gray wrapped in a piece of red cloth, adorned with cowrie shells, having the effect of dislodging the spirits which haunt it (Thomas, 1959).

Unlike plant resources, access to animals is almost non-ritual even though some villages such as Thionck-Essyl and Tiobon used to employ rituals before capturing the manatee. It is an animal considered to be mystical and could not be captured without first performing a demystification ritual to guard against the bad fate that could result from its capture. For this reason, it is not given to anyone to hunt manatees. In the past, its capture required a purification bath. This is still the case today, because even though the manatee is one of the protected mammals, it is sometimes captured accidentally. In this case, the hunter is obliged to carry out the purification rite to protect himself against any misfortune that may result from his act.

Rites for natural resources and abundant rains

Essential elements for survival and the natural resources are the subject matter of ceremonies organized in honor of the deities (ukin) in order to appeal to ensure an abundance of marine and coastal resources. Several sanctuaries namely Oudjireho, Geutoumbuleugi to Eloubaline, Baliba or Balipa to Abene, Hutene to Haer host this type of ceremony. For example, the sacred site of Gniback in the village of Thionck Essyl, people used to gather once perto ask for resources in abundance. During the ritual, a sample of each resource (fish and forest) is offered to the spirit that lives in the area. In Tendouck, a ceremony known as the *fussabe* is performed to get the fish out of their hiding places and encourage their capture by fishermen.

In the village of Kafountine, a ceremony of prayer and offering is made to geniuses for a successful fishing season. The ceremony takes place at the beach, usually during the opening of the fishing season. The fishermen accompanied by peoples go to the beach where the ritual will take place. At the beginning of the ceremony, milk is poured first into the sea water. An ox that must always be white is then slaughtered, prepared and eaten on site. Nothing should be taken away. The utensils, lids and pots that were used for the preparation of the offering are all cleaned on the spot with sea water.

This ritual is not specific to the natives; it is the Lebu fishermen who settled in the village that practiced it. Over time, this ritual was eventually adopted by all other fishermen[2], including the natives. However, in the distant past, before the start of the fishing activities, a local rite was practiced in the sacred site of Sougoutoukala[3]. During the ceremony, a virgin girl was offered to the sea before going fishing to ensure good captures. The virgin girl was then thrown alive in the waters as a sacrifice to the genie.

[2]The village of Kakountine is home to Lebou, Guet-Ndarien and Niominka fishermen from northern Senegal.
3Soungoutoukala is a sacred forest which is located not far from the village of Abene precisely near the beach of the village of Diannah. It is a Mandingo word that refers to the gift of a virgin girl to the genius of the sacred wood of Kala. The young virgin left in the river near the sacred wood was swallowed by the waters, hence the name of Soungoutoukala. This offering was made every year at the same place.

Photo 1. Altar of libation from Baliba to Abene.
Source: Diatta (March 2014).

Rites also concern natural phenomena such as rain. Indeed, rain is crucial for the regeneration of mangrove, oysters, fish and for the production of rice, an essential commodity for the conduct of certain rites (initiation, ritual practices). Thus, when they are slow to fall, rites are usually performed at the altar of ukíin to implore deities and ancestors. The sanctuaries where these rites and prayers are performed are numerous. The best known in Lower Casamance is the sacred altar Hussila of Queen Priestess Aline Sitoé Diatta.

Branches of this altar exist almost in each village of Kassa. However, many other altars are known. Among other altars are those of Fiyaye in Eloubaline installed by Queen Aline Sitoe, Baliba or Balipa[4] in Abene (Photo 1) and in the Karone Islands, Esingilite and Badiankussor in Thionck-Essyl, Bahayaye in the village of Cagnoute, etc. There are special rites designed to produce rainfall. This is the case of the ritual known as the Gahule practiced in the Bandial to implore the occult forces to cause the rain to fall. During this ritual, the dances of Signalen or Djibasse are performed. The Edijl rite in Thionck-Essyl also has the power to bring rain even outside of winter. This cult has not been celebrated for many years because of adherence to revealed religions (Islam in particular). With the scarcity of rains, he was resuscitated in 2007 to try to remedy this situation (Photo 2). These rites are often accompanied by songs to attract divine providence. In the Kassa, during the rites of invocation for the rain a song is sung:

Wowahé baliba /Wantantigoé, God does not forget His children.

Rituals for opulence still have great importance for the Jola people. Their execution also promotes the sustainable use of resources making it possible to lessen the impacts of human actions. Hence, the interest of practicing these rites. However, it seems that some rites do not originate in Lower Casamance. This is the case of the ritual for the abundance of fish resources (fish in particular) carried out in Kafountine in the west of Lower Casamance and which was adopted by the natives. Kafountine being a land of welcome, benefited from practices of populations Lebou came from the north of the country. Maintaining this practice suggests that it has a positive effect on the resource, which is why the practice has been preserved.

Taboos

The exploitation of some marine and coastal resources is governed by numerous prohibitions that make it possible to protect against misuse and other destructive practices. Some animal and plant resources are taboo, so their use is generally forbidden. Totems and parts of the mangrove reserved for cultural or cultic practices are among the most obvious examples. Similarly, spaces of cultural interest serving as a refuge for mythical beings (geniuses, ancestors, totems) or used for such ritual practices. In these places, the prohibitions are specific. For some, the taboo involves all resources and leads to prohibitions ranging from exploitation to consumption. For example, totems should not be consumed and their

4 Fetish received from the late Queen of Cabrousse Aline Sitoe Diatta and who was installed in the village of Abene by one of these relatives, Queen Anna Sambou. Currently it is the latter who provides supervision of this fetish. People come from everywhere to express their needs so that the fetish intercedes with God to answer their prayer.

Photo 2. Celebration of the rite Edijl in Thionck-Essyl.
Source: Surveys (2015).

habitat is protected.

On the other hand, for other species, the prohibited resources can be forbidden to certain people according to the sex and the social position (Leblic, 1998). For example, at some sites used for the rituals, namely Etenia (in Hitou), Djata Hounouha and Ehindou (in Haer), oysters are taboo. Their consumption is prohibited by the uninitiated and women. In other words, the location of resources in these sacred places determines their conditions of use (Appendix 1).

Often, to preserve places of ecological interest, regulate or organize the use and exploitation of certain resources, taboos are instituted. With the system of defense (in Jola Hubene or Hutongh according to villages), one invests for an indeterminate time the environment (zones of spawning) or the resources (seashell) which it contains a sacred power.

In the Jola country, taboos are the basis of natural resource management. It is dangerous to break them, as this can lead to serious consequences for the offender. In doing so, they participate in the maintenance of ecosystems (Artaud, 2014) and the respect of standards established by the community.

Totemism among the Jola of Lower Casamance

In Jola country, each lineage has at least one totem, ewoum in jola considered as the incarnation of the deceased ancestor, the look-alike and protector of the living individual. He is mystically protected by geniuses and ancestors. However, this protection is reciprocal, since totems watch over the individuals who themselves constitute themselves as guardians of these species. In fact, in jola beliefs, the person can, after death, reincarnate in an animal or in the body of a newborn in the same family. Among the jola of Kassa in particular, Badiane (2012) writes in this connection that: "*the jola kassa grows to the preservation of life. For him, man is an eternity: if he dies, his strength is destroyed, but his vital energy, that is, his spirit remains. His life is then recreated elsewhere and differently. He can be reborn or according to his state of sin, he can go through ways of reincarnation* ".

The totemic species found in the Jola environment are generally fish (catfish, carp, rays, sharks, etc.), mammals (dolphin, whale, manatee, porpoise, hippopotamus, antelope, elephant, etc.), or reptiles (Nile monitor, earth monitor, crocodile, snake, etc.) (Appendix 2).

Outside the totems, some animals such as beef and goat are subject to an arbitrary prohibition of slaughter in some Jola countries including Kassa and Bandial. In these countries, these animals are considered sacred. Beef is slaughtered only at specific events such as religious, cultural, funeral ceremonies. In Kassa, for example, if you hurt or accidentally kill the ox, the offender must declare his crime to the fetish named Eloungh in Djivente. Through the priest, the fetish sets the fine to pay.

The goat enjoys this sacred status because of its use in ritual sacrifices. As with the Jola, there are also animals in some parts in Senegal and elsewhere. This is the case in Kaolack where the monitor is highly respected, because the tutelary genius of the city known as Mbosse is manifested in the form of this animal. This status gives it a sacred character in which rites and offerings are made in his honor. People are forbidden to hurt or kill the animal. According to Chretien et al. (1999), "if they are accidentally hit or injured, you can become crippled, or the body may become covered with scales. One falls into a crisis of madness, one spits blood, and death occurs if, quickly, the priestess does not make the appropriate rites to purify the delinquent. If finally the monitor is killed, no one can save the person responsible for the bite of the snake, double the peaceful little saurian. Of course, it is also forbidden to eat the monitor at Kaolack".

Mystic deterrence, an effective way of managing natural resources

When it comes to upholding established rules for resource management, custodians of tradition use mystical deterrence to discourage or warn potential actors. Indeed, while it is true that the belief in supernatural resource managers is still present in the jola environment, these same powers form the bedrock of a sustained mechanism of mystical deterrence.

In the Jola society, the desire for sustainable stability and sensible use of marine and coastal resources has led to the development of standardization techniques which aim to prevent over-exploitation. This has resulted in dissuasive practices in the supernatural realm. The preservation of natural resources within society and between different communities is so appreciated that there is an institutional and religious organization among the Jola that ensures respect for the established laws. Among the institutions that contribute to the management of resources, prominent fetishes or ukíin (boekin singular) feature prominently. The same term, boekin, also refers to the genie, the altar and the sanctuary and where the libations of blood or palm wine are made during the sacrifices (Journet-Diallo, 2007).

The ukíin represent invisible elusive forces and play the role of intermediaries between humans and Ata Emit or God the Creator, Master of the sky and the rain. They are hierarchical in individual, lineage or community. Their sacred or genial nature and their purpose are recognized by all. The esoteric field of their activities makes them dominant organs within the Jola society. In fact, they participate in the management of resources by exerting a mystical or at least psychological deterrence on local populations (Badiane, 2012). The permanence of their prerogatives makes them very feared and the prohibitions associated with them enjoy a deep respect.

Penalties imposed on offenders

The taking of resources especially in the sacred spaces is done with an arsenal of constraints. In the event of violations of the rules governing a taboo resource or a sacred site, sometimes very heavy penalties are imposed on the guilty parties. The arrangements for repairing the offences are established by the Boekin.

Compensation for the fault is mandatory because the penalty is generally not limited to the offender. It can be extended to other members of the offender’s family if the wrong is not repaired. The penalty depends on the extent of the fault. Among the most common sanctions are diseases that can sometimes lead to death if the boekin is consulted late or refuses to forgive. Expiatory sacrifices to repair the harm include libations (palm wine) and animal offerings (beef, pork, rooster) in front of the boekin altar.

Basics of traditional marine and coastal resource management practices in Jola countries

In Lower Casamance, certain marine resources are of great cultural importance for the populations. As a result, they are subject to a strong regulatory system that derives from traditional rules and protective geniuses. These regulations deal with total, partial or temporary prohibitions and ensure the survival of the population but also the continuity of certain rituals which performance necessarily depends on some biological resources. The guardians (priests, traditional chiefs) of the tradition remain the guarantors of the respect of the established rules.

Other practices are based on relevant knowledge of ecology. This is the case, for example, of the defensive policy better known as hubene or hutongh in jola language. This practice is to taboo some resources because they are lucrative and thus subject to overexploitation. This is the case of some fruit trees (*Elaeis guineensis* Jacq., *Parkia biglobosa* Jacq., *Adansonia digitata* Linn., Etc.), oyster / *Crassostrea gasar*, and the ark / *Senilia senilis*). It is also used to preserve places of ecological interest such as the Kiling-Kiling bolong located in the Kawawana Aboriginal and Community Heritage Area (Diatta et al., 2017).

Some popular beliefs were not conducive to harvesting oysters and in some cases for harvesting wintering mangrove wood. It was firmly believed that it could cause misfortune in the village or a bad harvest. In fact, as soon as the rice is thrown until it matures, picking is not allowed. The mangrove was also subject to such beliefs. Returning the mangrove wood to the village by fagot from the beginning of rice transplanting was likely to lead to a misfortune that would force people to stop rice works. To avoid this, it was necessary to cut the mangrove into small pieces and put it in a basket to bring it to the village (Diatta, 2018).

These beliefs made it possible to limit the exploitation of the mangrove and to show both the importance of rice cultivation in Jola countries. Although beneficial in terms of conservation, these beliefs are now disappearing unfortunately. Nevertheless, the policy of defense, still retains all its value because of the consequences that may result from non-compliance with the prohibition.

Valorization of traditional knowledge and practices

Local knowledge regarding the marine and coastal environment is little known and little valued in Lower Casamance which is the case for nearly the entire world. Yet the importance of this knowledge in the conservation of marine and coastal resources is very real. This conservation is reflected in the protection of the natural environment, animals, forests, etc. Traditional practices that still exist in this southern part of Senegal have the advantage of allowing sustainable conservation of resources by relying on the sacred that involves taboos. Consequently, they should be protected and valued even at the level of the Convention on Biological Diversity (Ibo, 1994; Cormier-Salem et al., 2005; Da Cunha, 2012).

Thus, neglect of local knowledge can unfortunately lead in the future to their marginalization and annihilation. The traditional religion that helps to maintain practices associated with local knowledge is less and less practiced as people are increasingly opting for monotheistic religions whose practices are not in line with animism. The loss of this knowledge can therefore have a negative impact on resources. In the case of Basse Casamance where nature still exists, it is largely due to practices associated with animism and local knowledge since the sacred still remains today an effective mechanism of protection and regulation in the exploitation of resources. Thanks to the fetishes, natural resources are still preserved and many rites and traditions have been kept intact in several localities (in the southern part of the region). Taking all these features into account, we maintain that the Jola resource conservation policy must be supported and encouraged. Animistic practices should not be banned but must be maintained in order to conserve resources.

DISCUSSION

Traditional Jola society is based on a discipline made up of prohibitions and obligations. Even if some customs are currently getting bogged down, there are still mechanisms to manage natural resources rationally and guarantee community well-being. Our results concerning the customs relating to the sacred sites, confirm those highlighted by numerous research works in black Africa and in several countries of the world.

Sacred natural sites, marine and forest areas of great ecological importance have been saved. In these places, specific species of fish, mammals, reptiles, birds and crustaceans are protected. All over the world, these sacred areas exist (UNESCO-CNRS-MNHN, 1998; UICN/CEESP, 2010; Wild et al., 2012). Because of the spiritual values attached to them, these sacred natural spaces enjoy great respect. "Restrictions on access or use often apply, and many sites remain in a natural state or almost" (Wild et al., 2012). Thus, in Côte d'Ivoire, it formally prohibits fishing for fish in the Sransi River which shelters sacred catfish. It is also forbidden to make fields around the river to conserve the massif intended to protect the watercourse against drying up (Ibo, 1999).

In the Philippines, some sacred lakes on Coròn Island are only for community members, especially the Tagbanwa people. These lakes are generally used for religious or cultural purposes and to access bird nests, a valuable resource sold to Chinese merchants (Dave De Vera, 2010 cited in UICN/CEESP, 2010). In New Caledonia, especially in the region of Ponérihouen, shelters for totem poles are taboo and may be forbidden for some individuals. This is the case of reefs that are tabooed periodically as they become breeding grounds for some fish species (Leblic, 1998). In the Vanuatu society (an archipelago located in South West Pacific), the taboo areas supposed to be governed and protected by the spirits that reside there contribute to protect the resources by means of prohibitions (Hickey, 2007).

In Lower Casamance, sacred sites are among the least degraded areas. Their access is strictly subject to authorization. Failure to comply with the prohibitions leads to sanctions that can sometimes lead to the death of the offender (Leblic, 1998). The sacredness of these sites justifies their preservation. Moreover, most of them show a better state of conservation compared to spaces that do not have this status. Endogenous secular practices that have preserved these sites have made them habitats of remarkable biodiversity. Accordingly, their cultic and cultural designation gives them a biodiversity conservation status that must be preserved.

Unfortunately, nowadays the customary system has become considerably weakened and many prohibitions have disappeared with the development of Islam and Christianity, just as the modernization of traditional society has led to their deterioration.

The alteration of those sites has been caused by the weakening of the customary system, the disappearance of numbers of taboos with the expansion of Islam and Christianity, as well as the modernization of traditional society. As Dugast (2010) has shown on the impact of Togolese Bassar clan solidarity in the preservation of their sacred groves, this is also "a set configured in a system and whose elements, consequently, have a certain degree of solidarity with each other". This is why, as with the Bassars, the weakening of the clan solidarity makes the existing system falter and affects the durability of the sacred groves, which makes clear that the loss of ancestral customs has consequences for the protection of these sites. As Dugast (2010) writes, sacred groves "only find their meaning in the global system insofar as it preserves its overall coherence".

The conservation of natural resources is also favoured by certain rites of passage like that of bukut5. Indeed, his practice entails the imposition of taboos on certain sites and associated resources such as plants, fruits, mangrove, animals, etc. This is the case in many parts of Africa and Oceania (Butare, 2003; Hickey, 2007; Koy and Ngonga, 2017). The prohibitions also concern the practice of agricultural activity strictly prohibited in these spaces of initiation. Koy and Ngonga (2017) highlighted similar prohibitions among Turumbu residents of the Yangambi Biosphere Reserve in the Democratic Republic of Congo (DRC). Moreover, for many other African populations and elsewhere, breaking these rules is punishable by severe penalties (Butare, 2003; Stevens, 2008; Dugast, 2010).

The cultural importance of the initiation of bukut lies in instilling in the initiates the virtues of dignity, courage, responsibility, wisdom, endurance, in order to instil respect for cultural values, prohibitions, cardinal social values, and to become familiar with religious dogmas. But, in addition to this function, the initiation of bukut also teaches respect for the natural environment (Badiane, 2012). In doing so, it has a significant ecological significance, since it instills into the initiates a respectful attitude towards nature. The various "physical trials and esoteric revelations of all kinds to which he is subjected, dictate to him a profound respect for the community and solidarity with other members of society. They also dictate to him a duty of respect vis-à-vis the elements of nature with which he has a complementary relationship "(Gueye, 2007).

Furthermore, the dependence of Jola populations on natural resources for their livelihood explains the perpetuation of many rites. Among these rites is to ensure the benevolence of the divinities and invisible powers that rule the natural world. In general, among African traditional societies nature is a sanctuary populated by supernatural powers. The latter have specific physical habitations such as streams or forests and would have the ability to watch over the well-being of the living, but also to chastise them when they offend them (Sanogo and Coulibaly, 2003). For example, some Senegalese communities such as the Lebous and the Serere believe that spirits take up residence in certain trees. In most cases, these trees serve as an altar for libations. They are sacred and surrounded by prohibitions. Trees, among other receptacles, serve as residences for Pangool6 in the Serere society (Cisse et al., 2004; Diouf, 2011; Djigo, 2015). Thus, it is forbidden to cultivate to their trunks, they are not easily pruned and they avoid collecting dead wood (Gravrand, 1973). Their access depends on the prohibitions and taboos fixed by the venerated power (Diouf, 2011). Among the Bassar, certain places, especially those identified as being occupied by the ikpalibi supernatural powers, are among those that are avoided. At some times during the day (Dugast, 2010), "to cross such a place at such a time is to disturb them and to have a violent correction imposed on them in such a way as to dissuade forever the imprudent one from committing to such odd future ".

In many societies, these beliefs subsist. The rites for having the approval of the tutelary genius to make punctures on medicinal trees for example stem from these beliefs. Siny (2001) writes that in Cambodia, "before cutting down a tree, the dog prei must make a request to the spirits of the tree, roukhtevoda, to the geniuses of the soil that govern the space concerned, neak to the spirits who keep the forest, bang beats. The request must always be accompanied by offerings". There is therefore in the consciousness of the individual the need for a counterpart without which the resource is not accessible (Gueye, 2007).

There are also rites to solicit the generosity of the deities with a view to the opulence of natural resources as reported by Seck (2014) among the Lébou and Guet-Ndarien fishermen from Senegal and those from the island of Phú Quý in Vietnam (Nguyễn Quốc-Thanh, 2016). In fact, the cult of the geniuses of water is present in many coastal Senegalese communities including that guet-ndarienne who still practice that of the protective genius of "Mame Coumba Bang" at the opening of fishing campaigns. During the ceremony, offerings of milk are made to the protective genius under the direction of a marabout. This rite can ensure luck and protection from the tutelary genius (Seck, 2014).

Propitiatory rituals are, in some ways, a system of sustainable management of natural resources. Indeed, as soon as we are aware that the resource is under the control of a superior being and that its accessibility is subject to the agreement of that being, threats of permanent degradation are minimized. Thus, with an ecological approach, it can be said that these practices affect the balance of nature and are beneficial. However, the sustained exploitation of certain species such as medicinal plants contributes to the reduction since the rate of natural regeneration is slow. In addition, the impacts of overharvesting certain plants can, as Bolendjele et al. (2013) wrote in their work, result in deforestation and the disappearance of certain species of trees and herbaceous plants. However, in Africa, medicinal plants are a precious resource for the vast majority of rural populations who use them to provide health care (Mpondo et al., 2012).

Moreover, in the current context where Africa appears as one of the most vulnerable continents to climate change, deforestation will only accentuate the greenhouse gas emissions responsible for this phenomenon. It goes without saying that not all traditional practices favour the conservation of biodiversity. Some practices also have weaknesses that deteriorate

[5]Bukut is also referred to as foutamp (in the Fogni region), bugut or geurur (in some Blouf villages, including Thionck Essyl and Bandial).
[6]Spirits of the deified ancestors (Diouf 2011) o the bush (Cisse 2004)

biodiversity (Bolendjele et al., 2013).

The taboo also constitutes a determining principle of the process of biological renewal of species (Artaud, 2014). Indeed, thanks to the obligations to be respected by the various prohibitions, anthropogenic pressures on resources are reduced. Among the bans, the totems attract attention. For the jolas, as for many communities in Senegal (Sereres Niominka, Sereres Ndut, Lebous, etc.) (Dupire, 1991; Dumez and Ka, 2000; Diouf, 2011) and Africa, the totem is the consanguineous relative (Gadou, 2003).

It is strictly prohibited to harm the life of the totem and consume it. For example, among the Bakwe people of Sassandra hunting and eating of the panther is prohibited, as is the warthog among the Niambezeria people of Lakota and mannongoble fish for many Keita families in the Niger Valley (Gadou, 2003). Among the Malinke people of Ivory Coast, the totemic animal is neither killed nor consumed because it is the incarnation of the ancestors (Diomande, 2011). The situation is the same in the Ndut country and in the Lebous where it is forbidden to kill the totem because it is linked to either an ancestor or a genius (Dupire, 1991; Dumez and Ka, 2000). Elsewhere in the world, many cultural groups in Vanuatu (an archipelago in the Western South Pacific) are endemic species of fish, octopus, giant clam, turtle, shark or moray eel, or terrestrial species. In fact, they are strictly forbidden to consume these totemic species out of respect for their ancestors (Hickey, 2007). Prohibitions can vary and bring in some populations the way to hunt or fish animals (Artaud, 2014).

Among the Hindoos, most of the population do not consume the cow for religious reasons (Ferry, 2017). This bovine is presented as the pet of the gods Krishna and Shiva and is endowed with a special character of sanctity and inviolability (Brown, 2016). It occupies a special niche in the Indian psyche, although a large proportion of Muslims, Christians and tribal people, as well as the lower echelons of lower castes has no problem with the consumption of its meat (Desquesnes, 2016).

According to this author, this symbolism of the cow took, in the late nineteenth century, an obvious political dimension because of the presence of British settlers and racists, as well as Muslims who were described as abusers of sacred cows. Indeed, thanks to the Hindu nationalist movements of resistance to the British Empire, the cow becomes a unifying symbol promoting Hinduism as a cultural identity (Ferry, 2017). Beef eaters are then stigmatized. Very quickly, we go from a simple protection of this cattle species to a speech and clearly anti-Muslim acts. This allows high castes, who represent less than 15% of Hindus, to consolidate their political, economic and cultural domination of minorities. In Vietnam, particularly in the coastal villages of the center and the south, the sanctity of cetaceans removes any possibility of their being exploited (Robineau, 1998).

It is clear that all these traditions favor the protection of animals. For example, the worship of the totem reflects its real interest in the preservation of these species. Indeed, by defending the totemic-animal, this practice protects the species. It is clear in this case that the maintenance of the harmony with the ancestors, the geniuses and the divinities motivate this protectionist impulse in the totemic system. Here, the protection of the totem species is the motivation rather than the conservation of resources (Journet-Diallo, 1998).

However, this protection allows conservation of biological diversit, desecration of the sacred and the violation of the prohibitions to threaten the stability of the environment. As evidence, the development of shark fishing in Casamance has resulted in a deep degradation of this resource. Sharks symbolize for many jola populations, the totem have become rare. For example, the saw shark (*Pristis pristis*) has disappeared from Senegalese waters (DPM, 2005). In the West African region, experts are not certain if it has completely disappeared or if there are still one or two small relict populations on the coast of Sierra Leone, and perhaps in Guinea-Bissau (Weigel et al., 2007).

In sum, it must be recognized that, like many communities in the world, several Jola customs and practices seem to have a significant interest in sustainable conservation. Consequently, today, in view of the repeated failures and shortcomings noted in the field of conservation, it is urgent to take into account these traditional practices which have long been shelved (Ibo, 1994; Cormier-Salem et al., 2002).

Conclusion

The behavior of jola populations for certain aspects of their daily lives is determined by ancestor worship, belief in supernatural beings, totemism, and above all, a single God, Ata Emit. The purpose of rites, propitiatory sacrifices, is to allow the living to continue to enjoy the grace and assistance of the invisible whose primary function is a connection with Ata Emit.

The jola people, through different habits and customs (fetish system, sacred natural sites, taboos and forbidden) have helped to preserve the natural environment of Lower Casamance, even if the primary motivations were not the protection of natural resources. As evidence, for most sacred natural sites where biodiversity has been preserved, it is for cultural and not ecological reasons (Dugast, 2002). Nonetheless some resources are preserved for economic and ecological interests. Accordingly, the role of traditional practices in the conservation of natural resources is essential.

In fact, the preservation of animist practices is beneficial for conservation, because if local knowledge is lost, if there are no more taboos or taboos, people will exploit the resources without mercy. It is therefore necessary, in the context of biodiversity conservation, to preserve the knowledge that still remains and to value those that are disappearing. Significant progress towards the protection of animist practices has been made in some cases. Senegal has chosen to empower local populations in order to cope with the increasingly increasing degradation of marine and coastal resources. In addition, the awareness of the need for more sustainable management of marine and coastal resources has fostered many legal and institutional reforms over the last decade. For example, the environmental code was revised in 2001 for better environmental management.

In 2004, a decree designed to protect natural resources and ecosystems representative of the marine environment resulted in the creation of five MPAs. The most recent measure is the revision of the Fisheries Code, which defines provisions for the management of fisheries resources. These strategic frameworks put at the forefront the participation of local populations in the development and the implementation of the plans of development and local management of the marine and coastal resources. Thus, the State of Senegal has laid the foundations for a new management paradigm that meets local requirements and includes participatory management. The management of marine and coastal resources is based on Laws No. 96-06 and 96-07, namely, the Code of Local Authorities and Transfer of Competences to the Regions, to the Communes and Rural Communities in order to implement these co-management projects for marine and coastal resources. This has led today to the creation of community protected areas, the establishment of CLPAs, etc.

In conclusion, the equitable management of marine and coastal natural resources will result only when a code of management is adopted with rules that are elaborated in collaboration with the local populations

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

ANSD (2015). Service Régional des Pêches et de la Surveillance de Ziguinchor (SRPSZ), Situation économique et sociale régionale 2013. 126p.

Artaud H (2014). De l'« efficacité » symbolique des interdits à leur fonctionnalité écologique. Revue d'ethnoécologie [Online], 6| 2014:1-17. URL: http://ethnoecologie.revues.org/; DOI: 10.4000/ethnoecologie.2055.

Badiane SD (2012).*Espaces forestiers de la Casamance amphibie (Sénégal). Déterminisme territorial, biodiversité et stratégies de conservation*. Thèse de doctorat unique. Spécialité: Environnement littoral. UCAD :Dakar.

Bolendjele W, Risasi E, Kitambala V (2013). « Limites des pratiques ancestrales de la conservation de l'environnement », in *REVUE DE L'IRSA* N° 19 Décembre, Accès sur ; HTML du fichier http://www.unikis.ac.cd/sites/default/files/BOLENDJELE%20W%E2%80%99Afi%20%3B%20RISASI%20Etutu%20et%20KITAMBALA%20Vangehania.pdf.

Brown WN(2016).La vache sacrée dans la religion hindoue. In Annales. Economies, Sociétés, Civilisations. 19ème année, N. 4:643-664; Accès http: //www.persee.fr/doc/ahess_0395-2649_1964_num_19_4_421195., consulté le 15 juillet 2016.

Butare I (2003). Pratiques culturelles et conservation de la biodiversité en Afrique de l'Ouest et du centre. Actes du Séminaire-Atelier de Ouagadougou (Burkina Fasso) du 18 au 21 juin 2001. IDRC/CRDI, Zoom Edition, 251P.

Chretien JP, Triaud JL (1999). *Histoire d'Afrique, les enjeux de mémoire*, Editions Karthala/Paris 503p.

Cormier-Salem MC, JUHE-Beaulaton D, Beautrais J, Roussel B (2002). Patrimonialiser la nature tropicale. Dynamiques locales et enjeux internationaux, Editions *IRD*, 467p.

Cormier-Salem MC, JUHE-Beaulaton D, Beautrais J, Roussel B (2005). Patrimoines naturels au Sud. Territoires, identités et stratégies locales, Editions IRD, 551p.

Da Cunha CM (2012). Savoirs autochtones : quelle nature, quels apports ?. Paris, Collège de France / fayard, coll. Leçons inaugurales du Collège de France, N° 227, pp. 17-60.

Diatta CS, Diouf M, Karibuhoye C, Sow AA (2017). Sites naturels sacrés et conservation des ressources marines et côtières en milieu traditionnel diola (Sénégal). *Revue d'ethnoécologie* 11:1-22. http://ethnoecologie.revues.org/2900

Diatta CS (2018). Savoirs locaux et modes traditionnels de gestion des ressources naturelles marines et côtières en Basse-Casamance : perspectives de leur intégration dans le système conventionnel. Thèse de doctorat unique.Spécialité: Géographie, option Environnement. UCAD/Dakar, 315p.

Djigo A (2015). *Patrimoine culturel et identité nationale : construction historique d'une notion au Sénégal*. Journal des Africanistes 85-1/2:312-357.URL: http://journals.openedition.org/africanistes/4617

Diouf I (2011). Croyances et pratiques magico-religieuses traditionnelles à Rome et en milieu sérère: étude comparative, Thèse de doctorat unique. Spécialité: Histoire/Sciences de l'Antiquité. UCAD Dakar.

Diomande BI (2011). Évolution climatique récente dans les régions nord-ouest de la Côte d'Ivoire et ses impacts environnementaux et socio-économiques, Thèse de doctorat unique. Spécialité: Climatologie et Environnement. UCAD Dakar, 208 pages.

Desquesnes N(2016).Lynchés au nom de la vache sacrée. *Le Monde diplomatique*, 2016/2 (N°743), P. 17.URL : https://www.cairn.info/magazine-le-monde-diplomatique-2016-2-page-17.htm

DPM Sénégal (2005).Plan national d'action pour la conservation et la gestion des requins Sénégal, 37p. http://www.fao.org/3/a-bl358f.pdf.

Dugast S (2002). Modes d'appréhension de la nature etgestion patrimoniale du milieu. In: Cormier-Salem M.C., Juhé-Beaulaton D., Boutrais J., Roussel B. (dir.), Patrimonialiser la nature tropicale. Dynamiques locales, enjeux internationaux, Paris, éditions de l'IRD, Colloques et seminaries, pp. 31-78.

Dugast S(2010). Bois sacrés, lieux exceptés, sites singuliers, Un domaine d'exercice de la pensée classificatoire, (Bassar, Togo).In : Juhé-Beaulaton D. (dir.) Forêts sacrées et sanctuaires boisés : des créations culturelles et biologiques (Burkina Faso, Togo, Bénin) (Eds) Paris: Karthala, pp. 159-183. http://horizon.documentation.ird.fr/exl-doc/pleins_textes/divers18-02/010050187.pdf

Dumez H (2011). Qu'est-ce que la recherche qualitative? Le Libellio d'AEGIS, Libellio d'AEGIS, 7 (4 - Hiver), pp.47-58. ffhal-00657925f. En ligne : https://hal.archives-ouvertes.fr/hal-00657925/file/pages_47_A_58_-_Dumez_H._-_2011_-_Qu_est-

ce_que_la_recherche_qualitative_-_Libellio_vol._7_nA_4.pdf
Dumez R, Ka M (2000). « Territoire assiégé Yoff. Un village lébou dans la banlieue de Dakar ». Collection Dossiers régions côtières et petites îles 7. Ed. UNESCO.CNRS – Programme Environnement Université Cheikh Anta Diop de Dakar – Chaire UNESCO, 81 pages. Accès sur: http://www.unesco.org/csi/pub/papers2/yoff.htm.
Dupire M (1991). *Totems sereer et contrôle rituel de l'environnement*. In: L'Homme, 1991, tome 31 n°118 : 37-66. http://www.persee.fr/doc/hom_0439-4216_1991_num_31_118_369379.
Fall SM, Diouf M, Badiane SD (2011). Identification et caractérisation des sites naturels sacrés côtiers et marins en Afrique de l'ouest. Etude de Cas du Sénégal, Rapport du Sénégal, 39 p.URL:http://www.rampao.org/IMG/pdf/identification_et_caracterisation_des_sites_naturels_sacres_cotiers_et_marins_en_afrique_de_l_ouest_sn.pdf.
Ferry M (2017). Le terrorisme de la vache.laviedesidees.fr. 13 pages. https://laviedesidees.fr/Le-terrorisme-de-la-vache.html.
Gadou D(2003). Préservation de la biodiversité: les réponses des religions africaines. In: Butare I. (2003), *Pratiques culturelles et conservation de la biodiversité en Afrique de l'Ouest et du centre*. IDRC/CRDI, (Eds) Zoom Edition, pp. 47-68.
Geoffroy ADB (2009). Le passage à l'écriture. Mutation culturelle et devenir des savoirs dans une société de l'oralité. Thèse de Doctorat de Sociologie, Université de Nantes/Université d'Abomey-Calavi. 386P.
Gueye M(2007). *Sociétés rurales et développement durable. Transformations récentes des agricultures, stratégies paysannes et soutenabilité des systèmes ruraux en Afrique sahélo-soudanienne : cas du département de Bignona (Sénégal méridional*). Thèse de doctorat, Université de Montréal, Département de géographie, Faculté des arts et des sciences.
Goedefroit S, Chaboud CB, Reton Y (2002). *La ruée vers l'or rose. Regards croisés sur la pêche crevettière traditionnelle à Madagascar*. *IRD Editions*.
GRDR-UASZ-IRD (2017). Un littoral en mouvement. Diversité, dynamiques et mutations des territoires frontaliers du sud-ouest du Sénégal et du nord-ouest de la Guinée-Bissau(Ziguinchor, Sédhiou, Oïo et Cacheu). GRDR-IRD.https://grdr.org/IMG/pdf/grd-_atlas_littoral_2017_bat-ld4.pdf
Gravrand HRP(1973).Le symbolisme serer.*Psychopathologie africaine,* IX,2 : 237-265. http://psychopathologieafricaine.refer.sn/IMG/pdf/Gravrand-H-Le_Symbolisme_Serer-73IX2.pdf.
Guilcher A (1954). Morphologie et dynamique des côtes sableuses de l'Afrique atlantique. Cahier d'inf.géogr. n° 1.Paris, pp. 57-68.
Hickey FR (2007). Gestion traditionnelle des ressources marines à Vanuatu : reconnaître, appuyer et renforcer les systèmes autochtones de gestion des ressources. Ressources marines et traditions, Bulletin de la CPS 20:11-23. URL: http://www.spc.int/DigitalLibrary/Doc/FAME/InfoBull/TRAD_VF/20/TRAD20VF_11_Hickey.pdf.
Siny HC (2001). Le touk khmer. Techniques and Culture 35-36:509-521. http://tc.revues.org/313.
Ibo GJ (1999).La gestion coutumière de l'environnement en Côte-d'Ivoire. Bulletin du GIDIS-CI 17:6-36.
Ibo GJ (1994). « Perception et pratiques environnementales en milieu traditionnel africain : l'exemple des sociétés ivoiriennes anciennes ». ORSTOM, 17P.
Journet-Diallo O(1998). Un monde diffracté. Théories joola du double animal. *Systèmes de pensée en Afrique noire* 15:203-230, accès : Https://span.revues.org/1598. HTML visité le 15 février 2015.
Journet-Diallo O (2007).Les créances de la terre. Chroniques du pays jamaat (Joola de*Guinée-Bissau). Paris, Bibliothèque de l'École des hautes études.*
Koy JK, NgongaAMM (2017). Pratiques Traditionnelles de Conservation de la Nature à L'épreuve des Faits Chez Les Peuples Riverains de la Réserve de Biosphère de Yangambi (RDC). European Scientific Journal 13:328-356. URL:http://dx.doi.org/10.19044/esj.2017.v13n8p328
Leblic I(1998). Caractère naturel ou anthropisé des lieux tabous ou rituels : exemple de la région de Ponérihouen (Nouvelle Calédonie). *In* UNESCO-CNRS-MNHN. Natural Sacred Sites, Cultural Diversity and Biological Diversity P 52.
NGUYỄN QUỐC-THANH (2016). Les cultes maritimes sur l'île de Phú Quý : maintien et préservation des traditions des pêcheurs vietnamiens. Moussons 27:131-146: http://moussons.revues.org/3563.
Mpondo E, Dibong DS, Priso RJ, Ngoye A, Yemeda CFL (2012). État actuel de la médecine traditionnelle dans le système de santé des populations rurales et urbaines de Douala (Cameroun). Journal of Applied Biosciences 55:4036- 4045.
Palmeri P (1995). Retour dans un Village Diola de Casamance, Chronique d'une recherche anthropologique au Sénégal. Edition L'Harmattan, Paris. 397 p.
Pélissier P (1966). Les paysans du Sénégal, Les civilisations agraires du Cayor à la Casamance », Fabrègue St Yrieux. 939p.
Robineau D (1998). Contribution des temples dédiés aux cétacés à l'inventaire de la biodiversité (Vietnam).*In:* UNESCO-CNRS-MNHN (1998), Natural sacred sites, cultural diversity and Biological diversity. P. 72.
Sanogo Z, Coulibaly N (2003). Croyances animistes et développement en Afrique subsaharienne. Horizons Philosophiques 13(2):139-152.
Seck A(2014). Les pêcheurs migrants de guet-ndar (Saint-Louis du Sénégal) : analyse d'une territorialité diverse entre espaces de conflits et espaces de gestion, Thèse de doctorat unique de Géographie, Université de Liège et Université Cheikh Anta Diop de Dakar.
Stevens S (2008). The Mount Everest Region as an ICCA : Sherpa conservation stewardship of the Khumbu Sacred Valley, Sagarmatha (Chomolungma/Mt. Everest) National Park and Buffer Zone, report for Cenesta. IUCN/CEESP and GTZ.
Thomas LV (1959).*Les Diola: essais d'analyse fonctionnelle sur une population de Basse Casamance*. Mémoire IFAN, Dakar, n°55.
UNESCO-CNRS-MNHN (1998).Natural sacred sites, cultural diversity and Biological diversity. International symposium, 89p.
UICN/CEESP n°10 (2010). Document d'accompagnement à la note d'information. La diversité bio-culturelle conservée par les peuples autochtones et les communautés locales. Exemples et analyses 71p.
Wala K, Amegadze M, Guelly KA,Kokou K, BATAWILA K, AKPAGANA K (2003).«Connaissances endogènes et gestion de la diversité végétale au Togo ».pp. 123-133. I*n:* BUTARE I (2003), « Pratiques culturelles et conservation de la biodiversité en Afrique de l'Ouest et du centre ». Actes du Séminaire-Atelier de Ouagadougou (Burkina Fasso) du 18 au 21 juin 2001.IDRC/CRDI.*Zoom* Edition.
WeigelJY, WormsJ, CheikhAWO,FallOR, Da Silva AS, Cardoso L, Da Silva AO, Diémé S, Mohamed-Saleck AO, Morand P (2007). Les enjeux des aires marines et côtières protégées ouest-africaines. Presses universitaires de Perpignan, pp 39-60. https://books.openedition.org/pupvd/2328.
Wild R, Mcleod C(2012).Sites naturels sacrés : Lignes directrices pour les gestionnaires d'aires protégées. Gland, Suisse: UICN.

APPENDIX

Appendix 1. Sacred places where the rites of intercession for the rain are realized.

Zones	Villages	Sacred Places	Purpose or reason for Sacrality	Access conditions by gender	
				Man	Woman
Bandial	Essyl	*Guounih*	Royal fetish	having access to the royal court	Strictly forbidden
		Gueuvi	Royal fetish (only exists in the village of Enampor and Essyl	having access to the royal court	Strictly forbidden
		Djirengh baval	Fetish	Accessible/Only men have the right to make libations	except women those who have their periods
	All villages of the Bandial kingdom	*Ufulung*	Royal fetish exists in every concession	Accessible	Women except those who have their periods participate in ceremonies but stay away from the sacred place.
	Eloubaline	*Fiyaye*	Fetish	Accessible	except those stained by menstruation
Kassa	All villages	*Hussila*	Fetish	Accessible	except those stained by menstruation
	All villages	*Ehunia*	Fetish	Men can access or attend the ritual while staying away from the sacred place.	except those stained by menstruation
	Cabrousse	*Buculabe*	Fetish	Man	except those stained by menstruation
	Djembering	*Tanoundarité*	Place of worship	Men initiated	Strictly forbidden
	Cagnoute	*Bahayaye*	Fetish	Man	except those stained by menstruation
	Ourong	*Keuyeukou*	Fetish of the king of the village of Esaoute	Man	Strictly forbidden
Blouf	Tendouck	*Bakine*	Fetish / Place of worship		except those stained by menstruation
	Thionck Essyl	*Gniback*	Place of worship	Men	except those stained by menstruation
		Badjonkossor	Place of worship (current location of the Grand Mosque of Batine district)		except those stained by menstruation
		Fukankoul	Place of worship	Man	except those stained by menstruation
		Esingilite	Place of worship	prohibited	except those stained by menstruation
Bliss-Karone	Hillol	*Ewateteninkine*	Fetish	Man	except those stained by menstruation
	Saloulou	*Sonkokounda*	Fetish	Man	except those stained by menstruation
		Samou	Fetish	Man	except those stained by menstruation
	Abéné	*Baliba*	Fetish	Man	except those stained by menstruation

Source: Our investigations.

Appendix 2. Pet totems listed.

Totemic species living in the marine environment	Scientific names	Families	Villages
Saw Shark	*Pristis pristis*	SAGNA	Babuteume de Thionck Essyl
Saw Shark	*Pristis pristis*	DIEME	Thionck Essyl
Hippopotamus	*Hippopotamus amphibius*	DIATTA abanbanta	Mangagoulack

Hippopotamus	*Hippopotamus amphibius*	DIATTA Oulempane	Mangagoulack
		MANGA Eboune and MANGA Elouboureuye,	Enampor
		TENDENG	Keumeubeul
		DIASSY, DIEDHIOU, and DIATTA	Haer
Manatee	*Trichechus senegalensis*	DIEDHIOU Bourombone	Tendouck
		DIATTA	Haer
		DIATTA	Cabrousse
		SAMBOU	Cagnoute
		DIATTA	Mlomp Kassa/ district of Kaddjinol
		COLY djifalon	Mlomp Blouf
Hammerhead shark	*Sphyrna* Spp	DIEME	Hitou
		Bassene	Etama and Bandial
		DIASSY et DIEDHIOU	Saloulou
		TENDENG	Essy
		SAMBOU	Cagnoute
		DIATTA and all families of the district of Kandianka	Mlomp Kassa district of Kadjinole,
		DIASSY, DIEDHIOU, and DIATTA	Haer
Crocodile	Crocodilus(*Crocodylus niloticus, Crocolylus cataphractus*)	DIATTA de Diammo	Hitou
Heron	Unidentified species	DIASSY, DIEDHIOU, and DIATTA	Haer
Crab, Shark	Unidentified species	DIATTA and DIASSY	Haer
Dolphin	*Tursiops truncatus*	DIATTA and DIEDHIOU	Hae
		Bassene	Etama and Bandial
		DIATTA	Djembering
		DIATTA	Cabrousse
		SAMBOU	Cagnoute
Whale	Unidentified species	DIASSY and SADIO	Saloulou
		DIATTA	Djembering
		DIATTA	Cabrousse
Partridge	*Pternistis bicalcaratus*	DIASSY of Thiathies	Saloulou
Carp	Unidentified species	SADIO	Saloulou
Captain	*Polydactilus quadrifilus*	SADIO	Saloulou
Ark	*Anadara senilis*	DIASSY	Saloulou
Caiman	Unidentified species	DIABANG	Abene
Catfish	*Naja Spp.*	Family	Bouteme
Porpoise	*Phocoena Spp.*	DIATTA Adiona	Djembering
Ray	Unidentified species	Families	Cagnoute

Crocodile	Crocodilus	DIATTA, SAMBOU and all families of the district of Kadjifolong and Kandianka	Mlomp Kassa
Mermaid	Unidentified species	MANGA	Oussouye
Crane	*Balearica pavonina*	DIATTA	Djembering
Earth Monitor or Savannah Monitor or Mouth-Typed Varan of the nill	*Varanus exenthematicus exenthematicus* *Varanus niloticus niloticus*	TENDENG	Seleky
		DIATTA	Djembering
		DIATTA Etebemay	Mlomp Kassa/ district of Kaddjinol
Elephant	*Loxodonta*	BASSENE	Seleky
Panther	*Pantherus pardus*	SAMBOU, DIATTA and MANGA	Seleky
		TENDENG	Essyl
		DIATTA	Djembering
		DIATTA	Etebemay of Mlomp/Kaddjinol
Snake	*Naja viridis* *Naja nigricolis*	TENDENG	Essyl
		DIATTA	Djembering
		DIASSY and DIATTA of the community Karone	Abéné
		DIASSY	Saloulou
Hyena	*Crocuta crocuta*	DIATTA	Djembering
Monkey	Unidentified species	DIATTA	
Lion	*Felis leo*	DIATTA	
Doe	Unidentified species	DIATTA Etébémay	Mlomp Kassa/ district of Kaddjinol
Buffulo	*Syncerus caffer*	DIATTA Etébémay	
Antelope	Unidentified species	DIATTA Etébémay	

Source: Our investigations.

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Full Length Research Paper

Tree's spatial pattern, diversity and distribution in sub humid mountains ecosystems in south-west Togo

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West African Guinean forests are among the most diverse and threatened ecosystems in the world. The study aims to provide new insights about tree species patterns, abundance, and diversity for better management in Togo. Species diversity and density of trees were assessed in 170 plots randomly selected in the study area. Each tree with DBH >10 cm was identified and measured. Stem density, basal area, and diversity indices were calculated. In total, 243 species belonging to 170 genera and 44 families were identified in the study area. Five floristic groups were recognized. They are characterized respectively by *Lophira lanceolata, Pterocarpus erinaceus* and *Daniellia oliveri* association in Group 1; *Theobroma cacao, Elaeis guineensis* and *Morinda lucida* association in Group 2; *Elaeis guineensis, Persea Americana* and *Albizia zygia* association in Group 3; *Cola gigantea*, *Senna siamea* and *Erythrophleum suaveolens* association in Group 4 and *Pycnanthus angolensis, Ceiba pentandra* and *Pseudospondias microcarpa* association in Group 5. The Fabaceae, Moraceae and Malvaceae are the most represented families in the study area. The highest tree species diversity was observed in Group 4 (2.05 ± 0.61) and the lowest diversity in Group 2 (1.19 ± 0.64). Mean tree density ranges from 408.96± 202.17 (Group 1) to 273.90 ± 193.19 (Group 4). The highest tree basal area (27.99 ± 25.58 m^2/ha) is obtained in Group 3 and the lowest (15.84 ± 13.44 m^2/ha) is in Group 4. The presence of pioneer species in the study areas proves that the habitat has undergone serious anthropogenic disturbance events, which contribute to species loss.

Key words: Diversity, sub humid mountains ecosystems, Togo, richness, tree species, disturbance factors.

INTRODUCTION

Many factors have been attributed to tree species lost in tropical forests, it is believed to be generally driven by a complex interplay of various forces. These factors vary from demographic changes, poverty, policy responses of countries to ecological (such as fires), anthropogenic disturbances (such as logging, agricultural expansion) and climate change (Kolb and Diekmann 2004; Novick et al., 2003).

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The damaging consequences of biodiversity reduction include the loss of ecological services (such as biodiversity and watershed protection), the loss of many goods(such as timber and non-timber forest products),and the loss of means of existence for forest communities (ITTO, 2002). Repeated forest destruction, has resulted in the elimination of indigenous species and the development of degraded landscapes dominated by invasive species (Powell et al.,2011). Therefore, the possibility of species composition changing from species with hard wood to species with softer wood is created (Ter Steege, 2003). Native species populations generally decline in human-impacted habitats while exotic species often benefit (Jesse et al., 2018).

In many cases, natural recovery is unlikely because the degraded site has become subject to recurrent disturbances such as fire or grazing (Lamb et al.,2005). These disturbances are known to increase the vulnerability of forest species through micro-environmental changes that drastically influence the composition of forest understory (Appiah, 2013). Disturbances associated with anthropogenic activities have overruled natural disturbances in many tropical landscapes. If the human induced disturbance starts in a system, the degradation will continue until or unless some protective measures are introduced (Anitha et al., 2009).

Togo sub-humid mountainous zone is the domain of dense semi deciduous forests and Guinean savannas, now very degraded and disappearing (Ern, 1979). This domain is an integral part of the rainforests of west Africa, one of the world's hotspots of biodiversity and are referred as the Upper Guinean forests (Myers et al., 2000). The present vegetation is seriously under threat with considerable loss of tree cover. The area in Togo is called the ecological zone IV and is one of the places where habitat fragmentation and forest degradation are highly perceptible due to the development of cash crops (coffee, cocoa, cotton, etc.) which led to a conversion of forests into coffee and cocoa plantations (Adjossou, 2009). The remaining forests of the sub humid mountainous zone today is highly fragmented and is practically limited to forest buffers in hard-to-access area (Adjossou, 2009). This fact highlights a first research question: what are the current spatial patterns of tree distribution in terms of structure after these profound changes? It is important to characterize the communities in human dominated landscape in terms of its richness, diversity and assemblages for knowing the stability and viability of the system for long term existence (Anitha et al., 2009).

Though several studies have investigated vegetation structure in the rain forests of Togo (Adjossou, 2009; Akpagana, 1989) many years ago, there is a need to update the knowledge about the state and tree species composition of these forests in current time. Based on these facts, the composition and vegetation structure in the ecological zone IV was studied by collecting data to answer the second research questions: what is the species composition of the remaining tree community?

The disturbance from the surrounding population in the form of cutting and illicit felling, lopping and fuel wood collections, Non timber forest products (NTFP) collection, conversion of forest into coffee and cocoa farms, grazing etc. are a subject of concern in the long term existence of the forest area. In this context, it is important to answer the third research question: what are the disturbance factors in the study area?

Furthermore, the country has recently joined the international Reducing emissions from deforestation and forest degradation (REDD+) initiative with the ambition to create a new incentive system to protect and restore the degraded forests and ecosystems(MERF[1], 2013).The objectives of this study are: (i) to assess the spatial patterns of tree species; (ii) to study species diversity of tree communities; and (iii) to characterize the surrounding human activities and its impact on tree species in the study area. The present study is significant in generating useful baseline data in order to manage remaining forests in the region and to guide the policies in the strategic choices and implementations of REDD+ projects in order to conserve and manage the native tree species in this area.

MATERIALS AND METHODS

Description of the Study area

The ecological zone IV, which is the study area, is located in the southern part of Togo Mountain, south-west of Togo, on the border between Togo and Ghana. The ecological zone IV, occupies a territory, which extends between the latitudes 6° 15 and 8° 20 and the longitudes 0° 30 and 1°. It covers an area of about 65 000 ha (Figure 1).

The climate prevailing in this area is a Guinean mountain climate characterized by a long rainy season (March-October) interrupted by a slight decrease in August or September. The average annual temperatures vary between 21 to 25°C and the total annual rainfall varies between 1400 to 1700 mm. This zone contributes significantly to species richness in Togo (Adjossou, 2009). It is the current domain of semi-deciduous forests. The main species encountered are *Khaya grandifolia, Antiaris africana, Milicia excelsa, Terminalia superba, Parinari glabra, Erythrophleum suaveolens* (Adjossou, 2009; Akpagana, 1989).

The study area shows a strong topographic heterogeneity. The average altitude is 800 m, with peaks at Djogadjèto (972 m) and Liva (950 m). A network of complex secondary rivers covers the area with three catchment areas: the basin of the lake Volta in the west of the Mounts, basins of the Mono River and Zio River in the east of the mounts. The population distribution and land management varies across the area, with implications for changes in tree species composition, abundance, and diversity.

Data collection

Data were collected from 170 randomly selected plots over the

[1]Ministry of Environment and forestry resources

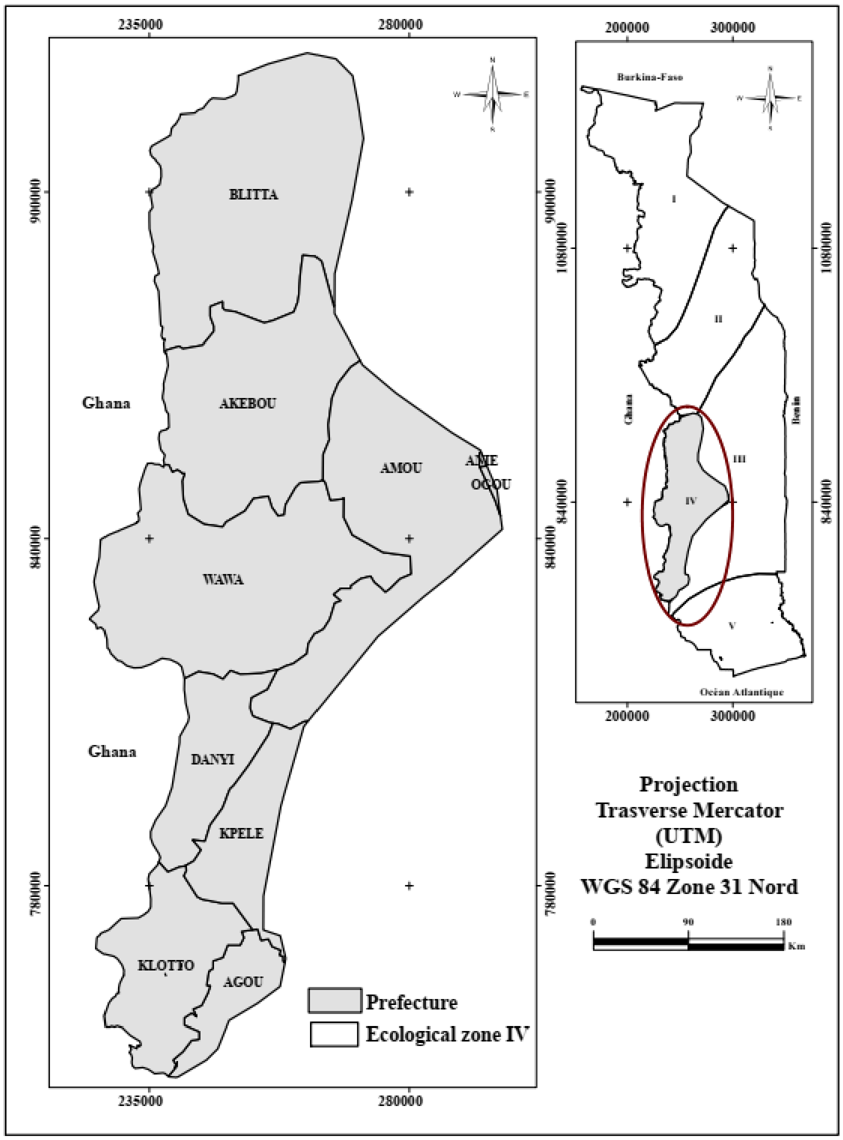

Figure 1. Study area.

entire study area. Circular plots were selected for dense forests, agroforests, plantations and woodland / wooded savannas and rectangular plots (Kokou 1998) for gallery forests. In the circular (20 m radius) and the rectangular plots (50m x 10m) all woody plants with Diameter at Breast Height (DBH) >10 cm were identified at species level, counted, and height was measured. Forest strata were defined using an available land-cover map of the area. In order to characterize the ecology of the species, topographic situation, vegetation type, stratum overlap and surrounding human activities were characterized in each of the 170 plots.

Data analysis

For the first objective, an ascending hierarchical classification (AHC) was performed, using Bray-Curtis dissimilarity metric, and Ward's minimum variance, which are clustering methods recommended for vegetation cluster analysis (Borcard et al., 2018). The AHC allows examining and validating the presence of ecologically meaningful clusters among our sampled plots designed for the study. First, the Bray–Curtis distance matrix was computed using the abundance data, with species in the columns and sites in ascending order of altitude in rows. Then, hierarchical Ward's minimum variance clustering on the Bray–Curtis distance matrix was performed. The Bray-Curtis index varies from 0 (same species composition and relative frequencies) to 1 (no shared species) for each pair of land cover type (Abotsi et al., 2020). Structural composition was analyzed by comparing the distribution of tree diameter classes. Based on the individuals recorded in the discrete plot samples, vegetation data were quantitatively analyzed for relative density, relative frequency, and relative dominance. The importance value index (IVI) of tree species was determined as:

IVI= Relative frequency + Relative density + Relative dominance (1)

Based on the IVI values, species associations within these assemblages and characterized each community by these species

Table 1. Scoring of level of perturbation.

Classification	Description
1	Excellent, with few signs (<2%) of human disturbance through logging or farming or fire damage with a good canopy
2	Good, <10% disturbance. Logging damage restricted or light and well dispersed. Fire damage none or peripheral
3	Slightly perturbation. Obviously disturbed or degraded and usually patchy, but with good forest predominant; Maximum 25% with serious scars and poor regeneration. Maximum 50% slightly disturbed, with broken canopy
4	Obviously disturbed and patchy, but with bad tree predominant; 25-5% serious scars and poor or no forest regeneration; or almost all heavily burnt, about 75% degraded
5	Very poor, more than three quarters disturbed (forest with coherent Canopy >75% broken)
6	No forest left, deforested with plantation or farm. Less than 2% forest

associations were identified. Tree basal area (BA_i) was calculated using the following equations:

$$BA_i\,(m^2) = \frac{(\mathrm{DBH}\,/100)^2}{4*\pi}, \quad (2)$$

Where DBH is the diameter at breast height in centimeter. The total BA for each plot was obtained by adding all trees BA in the plot. Species accumulation curve for tree species was obtained by computing the cumulative number of species encountered with increase in the number of plots (or total area) sampled (Anitha et al., 2010). The species accumulation curve is the cumulative number of species recorded as a measure of sampling effort.

For the second objective, several measures were formulated for biological richness. The most common species diversity indices are Shannon index and Simpson's heterogeneity indices (Kouki,1994; Swindel et al.,1984). Shannon and Simpson's indices integrate both species number and the relative abundance of the different species, and their numerical value rises as the number of species increases and their occurrences even out. The Shannon and Simpson indices were calculated from the cover-abundance of species in each plot. The Shannon Index is defined as:

$$H' = -\sum_i^s pi \log_2 pi \quad (3)$$

Where s equals the number of species and *pi* is the proportion of the total number of trees belonging to species i.
The Simpson Index is defined as:

$$D = \Sigma\, pi^2 \quad (4)$$

Where *pi* is the proportion of the total number of trees belonging to species i. As biodiversity increases, the Simpson Index decreases. Therefore, to get a clear picture of species, dominance (Do) I s defined as:

$$D_0 = 1\text{-}D \quad (5)$$

The Pielou Index (E) is defined as:

$$E = H'/\log s \quad (6)$$

where, H'= Shannon index, S= number of species in the sample.

The Simpson Index(D) and the Pielou Index (E) are considered as a measure of species dominances and a measure for evenness of spread, respectively (Magurran, 1988). R studio version 3.4 a free software environment for statistical computing and graphics, was used for the estimation of species diversity (Gotelli and Colwell, 2011).

Statistical significant differences in tree density and diversity between trees communities analyzed using analysis of variance (ANOVA), and Kruskal–Wallis test when data could not meet the assumptions for parametric tests when transformed. The assumption of normality was assessed using the Shapiro–Wilk tests (Crawley, 2012). If they are normal, then an ANOVA for comparison among trees communities was used. If data are not normal, a non-parametric Kruskal Wallis test was used. Descriptive statistics (frequencies, and percentages) generated using Excel were also used to analyze the data.

In order to characterize the disturbance factors in the area, the surrounding human activities, in each of the 170 plots were noted in the field. This characterization is based on field observation. The six points score was used in describing level of perturbation (Table 1) (Appiah, 2013). The frequency of disturbance factor was assessed in the study.

RESULTS

Tree species distribution in Togo ecological zone IV

Tree species communities

The cluster analysis revealed that five forest communities could be formed based on the composition of tree species at different sites, although few plots deflected from its designated categories (Figure 2). The dendrogram obtained from the distance matrix of land cover types indicates that there are affinities between the flora within each group (Figure 2). Indeed, 5 floristic group are identified for species in ecological zone IV according to land cover types.

In Group 1: A total of trees (DBH>10cm) belonging to 110 species were recorded. Most dominant tree species represented in this group according to IVI value are *Lophira lanceol*ata (IVI =29.22), *Pterocarpus erinaceus* (IVI= 25.21), *Daniellia oliveri* (IVI= 23.70), *Crossopteryx febrifuga* (IVI= 17.84) (Table 2). Based on IVI value, it can be concluded that the area is dominated by *Lophira lanceolata, –Pterocarpus erinaceus*, *–Daniellia oliveri, –Crossopteryx febrifuga association* (Table 2).The other major species in this group are *Ficussur, Margaritaria discoidea, Lanne abarteri, Lannea acida, Terminalia glaucescens, Burkea africana, Afzelia africana, Vitex*

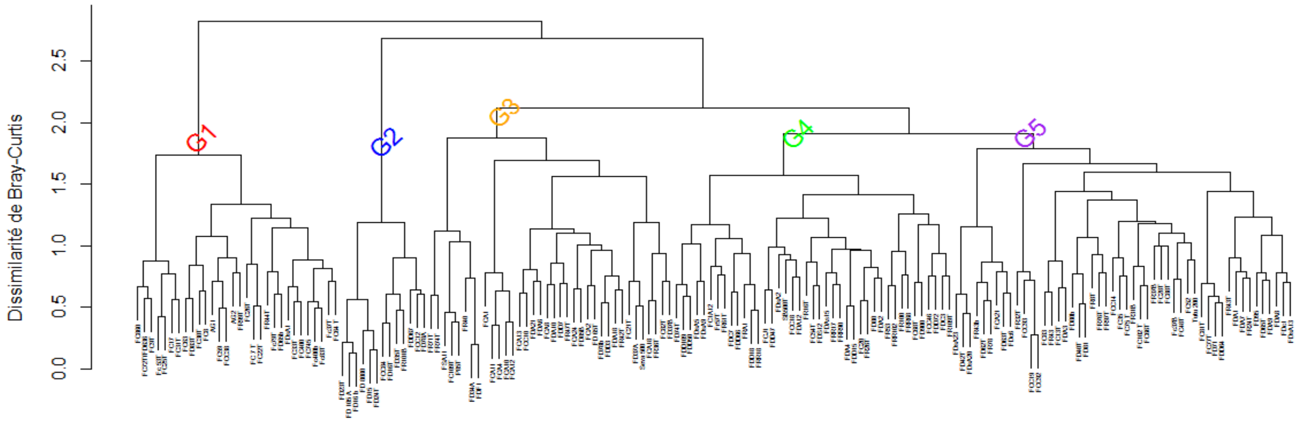

Figure 2. Hierarchically clustered dendrogram on the Bray–Curtis distance estimated using abundance data. Hierarchical clustering was done using Ward's algorithm, the y-axis represents the Bray–Curtis distance shared among each cluster.

doniana, Cussonia arborea, Syzygium guineense and Albizia zygia. This group is characterized by guinea savannah species.

In Group 2: A total of trees (DBH>10cm) belonging to 53 species were recorded in the group 2. The area is dominated by *Theobroma cacao* (IVI = 102.65), *Elaeis guineensis* (IVI = 13.74), *Morinda lucida* (IVI = 9.53*) and Pseudospondias microcarpa* (IVI = 9.03*)* association (Table 2). The group is also characterized by the presence of *Ceiba pentandra, Milicia excelsa, Ricinodendron heudelotii, Terminalia superba, Triplochiton scleroxylon, Sterculia tragacantha, Pycnanthus angolensis, Albizia adianthifolia, Albizia lebbeck, Spathodea campanulata, Discoglypremna caloneura.* The group 2 is characterized by cocoa plantation system species.

In Group 3: The area is characterized by *Elaeis guineensis- Persea americana-Albizia zygia- Alstonia boonei- Terminalia superba* (IVI-26.88, 25.32, 18.97, 12.96 and 12.83 respectively). This formation is also distinguished by species such as *Ceiba pentandra, Khaya grandifoliola, Theobroma cacao, Albizia adianthifolia, Cola gigantea, Cola nitida, Pseudospondias microcarpa, Mangifera indica, Erythrophleum suaveolens, Ficus mucuso.* This group is characterized by agroforestry system species.

In Group 4: This group is a dominant association of *Cola gigantea–Senna siamea–Erythrophleum suaveolens* species (IVI values of 16.00, 13.81 and 13.58 respectively). This group is characterized by the presence of species such as *Anogeissus leiocarpa, Holarrhena floribunda, Margaritaria discoidea, Manilkara obovata* and *Gmelina arborea.* This group is a characterized by secondary forest species.

In Group 5: This group is mainly a composition of species such as¨ *Pycnanthus angolensis, Ceiba pentandra, Pseudospondias microcarpa, Albizia adianthifolia, Aubrevillea kerstingii, Morinda lucida, Khaya grandifoliola* and *Ficus sur*. The major species association is *Sterculia tragacantha–Funtumia africana–Milicia excelsa* (IVI values of 12.95, 12.32 and 11.15 respectively). This group is characterized by dry deciduous species.

Tree communities growing dynamics

Stems were classified into various size classes and higher number of individuals was found in the lowest classes indicating a regenerating population. The size class distributions exhibited the roughly negative exponential or 'inverse J', curves typical of natural forests (Figure 3). The big trees >= 100 cm are scare in the area. As the diameter increased, there was a decrease in the number of stems. The lowest diameter class (10 - 20 cm) had the highest number of stems, species and family.

Species composition and richness

The species accumulation curve indicates that most species present in the study area were included in samples because the curves approach an asymptote (Figure 4).

In total, 5782 trees (DBH >10 cm) representing 243 species belonging to 44 families (170 genera). Out of these, 30 families comprising 86 genera, 110 species, and 1457 trees were recorded in group 1; 19 families representing 41 genera, 53 species, and 590 trees were recorded in group 2; 116 species belonging 89 genera, 30 families, and 1131 trees were recorded in Group 3 and 4 recorded 1441 trees belonging to 158 species among 124 genera and 37 families and Group 5 recorded

Table 2. Important value index (IVI) of 15 most important species > 10 cm in the different group.

S/N	Group 1		Group 2		Group 3		Group 4		Group 5	
	Species	IVI		IVI		IVI		IVI		IVI
1	*Lophira lanceolata*	29.22	*Theobroma cacao*	102.65	*Elaeis guineensis*	26.88	*Cola gigantea*	16	*Sterculia tragacantha*	12.95
2	*Pterocarpus erinaceus*	25.21	*Elaeis guineensis*	13.74	*Persea americana*	25.32	*Senna siamea*	13.81	*Funtumia africana*	12.32
3	*Daniellia oliveri*	23.7	*Morinda lucida*	9.53	*Albizia zygia*	18.97	*Erythrophleum suaveolens*	13.58	*Milicia excelsa*	11.15
4	*Crossopteryx febrifuga*	17.84	*Pseudospondias microcarpa*	9.03	*Alstonia boonei*	12.96	*Anogeissus leiocarpa*	12.05	*Pycnanthus angolensis*	10.62
5	*Ficus sur*	10.13	*Ceiba pentandra*	8.95	*Terminalia superba*	12.83	*Holarrhena floribunda*	10.04	*Ceiba pentandra*	10.39
6	*Margaritaria discoidea*	10.02	*Milicia excelsa*	8.14	*Ceiba pentandra*	12.56	*Margaritaria discoidea*	8.24	*Pseudospondi asmicrocarpa*	10.3
7	*Lanne abarteri*	9.99	*Ricinodendron heudelotii*	7.46	*Khaya grandifoliola*	10.76	*Manilkara obovata*	6.16	*Albizia adianthifolia*	8.93
8	*Lannea acida*	7.75	*Terminalia superba*	6.98	*Theobroma cacao*	10.36	*Gmelina arborea*	5.76	*Aubreville akerstingii*	8.83
9	*Terminalia glaucescens*	7.73	*Triplochiton scleroxylon*	6.8	*Albizia adianthifolia*	10.01	*Terminalia glaucescens*	5.66	*Morinda lucida*	8.3
10	*Burkea africana*	6.77	*Sterculia tragacantha*	6.77	*Cola gigantea*	8.72	*Macaranga barteri*	5.32	*Cola gigantea*	7.3
11	*Afzelia africana*	6	*Pycnanthus angolensis*	6.55	*Cola nitida*	7.52	*Pseudospondias microcarpa*	5.2	*Trilepisium madagascariense*	6.85
12	*Vitex doniana*	5.89	*Albizia adianthifolia*	6.38	*Pseudospondias microcarpa*	5.69	*Terminalia macroptera*	4.92	*Ficus sur*	5.93
13	*Cussonia arborea*	5.37	*Albizia lebbeck*	6.26	*Mangifera indica*	5.51	*Mangifera indica*	4.61	*Trichilia prieuriana*	5.66
14	*Syzygium guineense*	5.32	*Spathodea campanulata*	5.92	*Erythrophleum suaveolens*	4.79	*Ficus sur*	4.58	*Cleistopholis patens*	5.49
15	*Albizia zygia*	5.09	*Discoglypremna caloneura*	5.59	*Ficus mucuso*	4.56	*Albizia adianthifolia*	4.53	*Khaya grandifoliola*	5.33

1163 trees belonging to 140 species among 107 genera and 36 families.

The most abundant species at the scale of the study area included species with high economic values belonging to the categories of timber species (*Khaya grandifoliola, Milicia excelsa, Terminalia superba* etc.), medicinal species (*Alstonia boonei*) and spice species (*Monodora myristica* and *Xylopia aethiopica*). In addition to multipurpose species (fertilization, soil restoration, shading, firewood, fruits etc.) and pioneer species like *Albizia adianthifolia, Funtumia Africana, Ficus mucuso, Ficus sur*, *Holarrhena floribunda, Margaritaria discoidea, Morinda lucida,* etc. The presence of pioneer species proves that the habitat had undergone serious anthropogenic disturbance event (logging, clearing, vegetation fires).

Figure 5 indicates families with at least 3% composition in the tree community. The Fabaceae families collectively comprised more than 20% of the entire trees sampled. Other families substantially represented in the vegetation are the Malvaceae, Moraceae and the Combretaceae. Collectively, they comprised 43.55% of ecotone trees. The studied forests communities showed differences in terms of density, diversity, and species richness. The various ecological parameters such as density, species richness, and different diversity indices have been measured/calculated for species > 10 cm (Table 3). Mean tree density varied spatially across different groups, ranging from 408.96±202.17 (Group 1) to 273.90± 193.19 (Group 4) (Table 3). The higher basal area of trees (27.99 ± 25.58 m^2/ha) is in Group 3 (agroforestry system species) and the lower basal area (15.84 ± 13.44 m^2/ha) is in Group 4 (secondary forest).

Diversity of tree species in the study plots calculated using the Shannon Weiner index (H') showed that the highest diversity was in Group 5 (2.05 ± 0.61) and the lowest diversity was in group 2 (1.19 ± 0.64). The Pielou index was the highest (0.87 ± 0.11) in Group 5 (dry deciduous forest). This result showed that the group 5 is facing few disturbances and the vegetation is the most closed to natural vegetation.

The One-Way ANOVA was carried out for the species richness ($F_{(1, 168)}$= 0.246, p (0.621) >0.005), the Shannon index ($F_{(1, 168)}$= 0.547,p (0.46) >0.005) and the tree density ($F_{(1, 168)}$ = 6.842, p (0.00972) >0.005) in the five groups. The result revealed that the means are not significantly different at 95% confidence limits for species

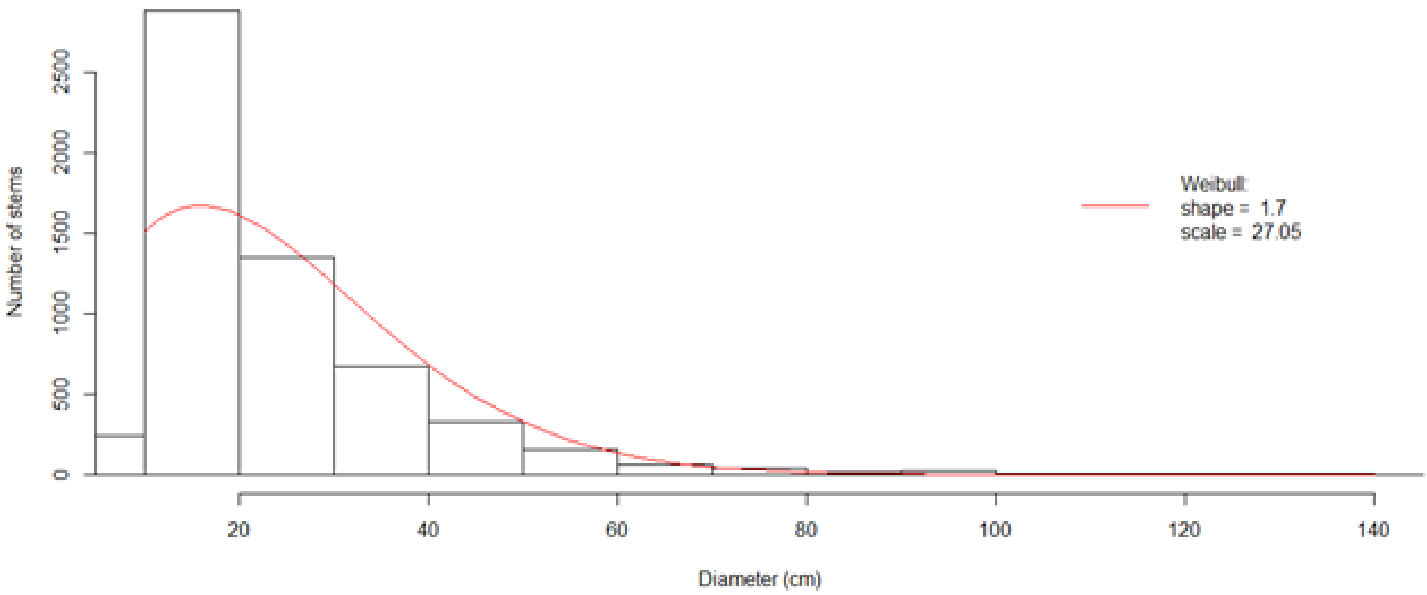

Figure 3. Class distribution of tress with DBH>10 cm recorded in the study.

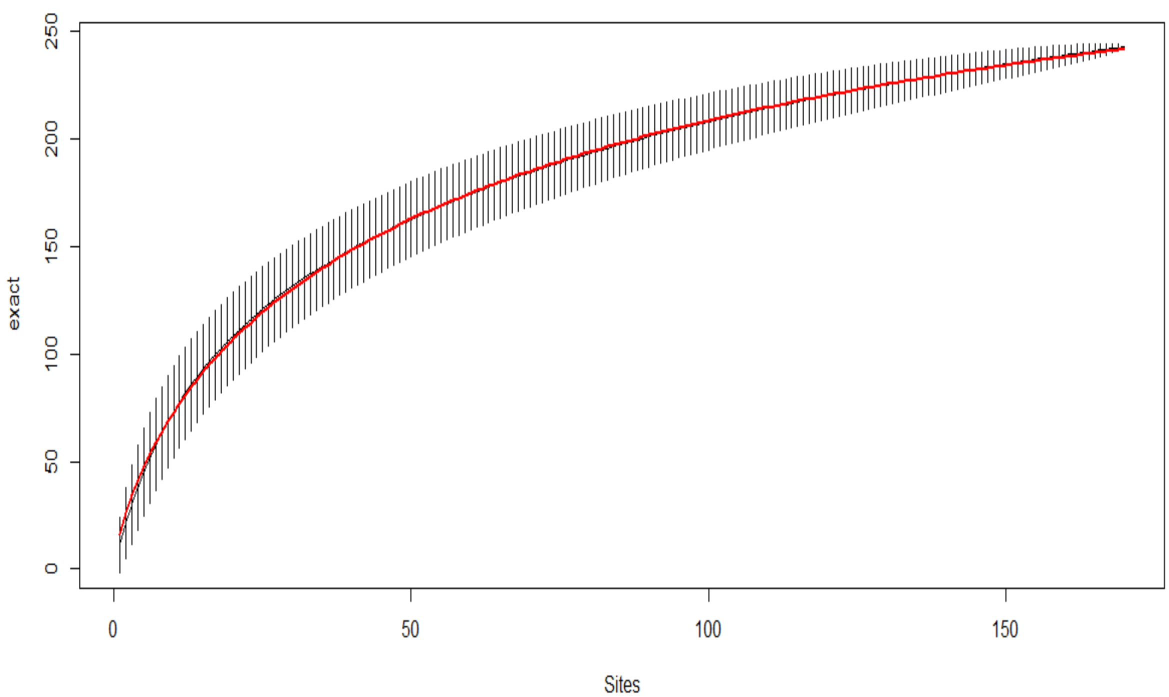

Figure 4. Species accumulation curve for tree species at study sites as a function of sampling effort.

richness, Shannon index and tree density.

Disturbance factors in the study area

Based on field observations in the study area, disturbance factors were identified in the study area. The analysis of the disturbances factors showed that more than 50% of the plots in the study area are threatened by agriculture, 23% by logging and 13% by wildfire. Only 4% of the plots are undisturbed (Figure 6).

Others disturbances factors like grazing, cutting and

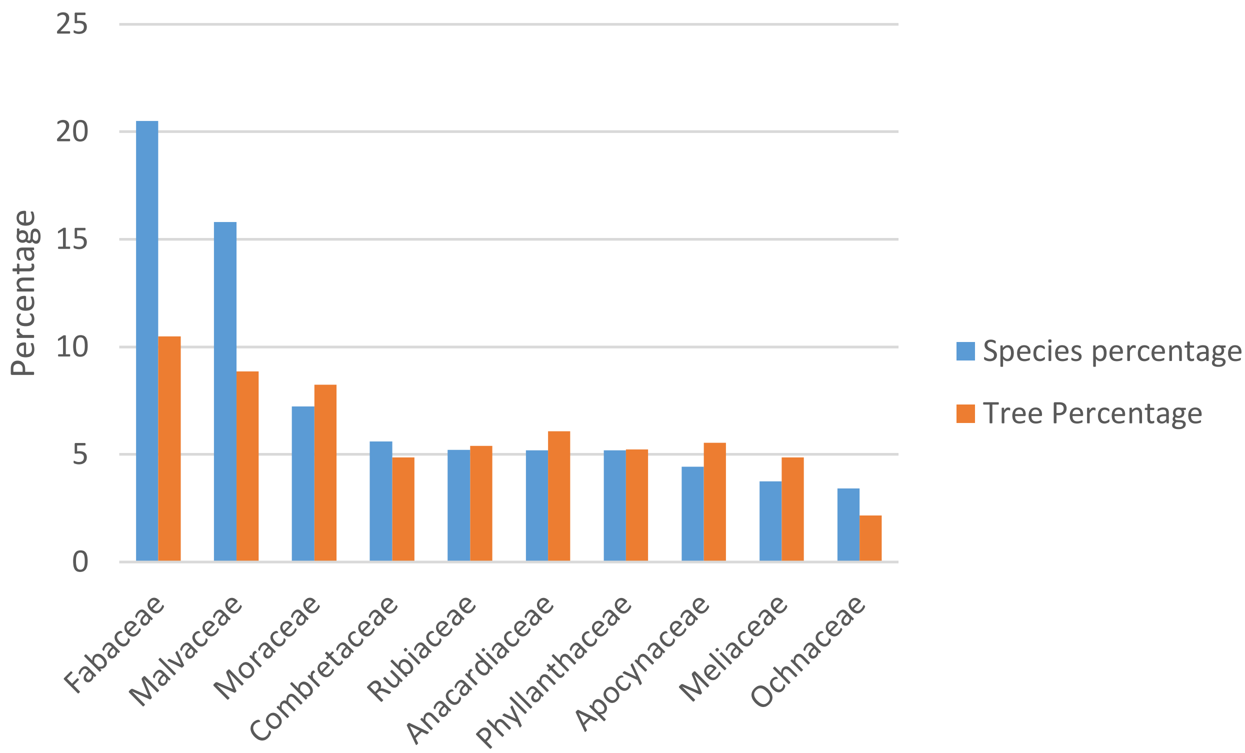

Figure 5. Families with at least 3% in tree population.

Table 3. Basal area, diversity and Pielou equitability index.

Group	Number of plot	Basal area	Density (tree/ha)	Shannon index	Pielou equitability index
1	30	16.59 ± 10.64	408.96± 202.17	2.00 ± 0.71	0.82 ± 0.10
2	13	21.28 ± 14.89	402.84± 239.41	1.19 ± 0.64	0.56 ± 0.23
3	36	27.99 ± 25.58	313.90 ± 215.53	1.92 ± 0.58	0.83 ± 0.12
4	50	15.84 ± 13.44	273.90± 193.19	1.74 ± 0.68	0.80 ± 0.20
5	41	27.77 ± 21.16	310.91± 205.79	2.05 ± 0.61	0.87 ± 0.11

illicit felling (Photos 1 and 2), fuel wood collections and NTFP collection were noted in the study area. Grazing from cattle, goat and sheep is also source of disturbance in the area. The area is also surrounded by the conversions of secondary forest and fallow areas to agroforestry and monoculture plantations.

DISCUSSION

Compared to Adjossou (2009) and Akpagana (1989) researches, diversity index recorded in this study is very low. Two possible explanations to these marked differences were identified. First, the methodology used in this study is different from the one used in Adjossou (2009). In this study, all species with DBH > 10 cm when the previous studies recorded all species found in the area were recorded. Secondly, low diversity indices in this study compared to previous studies in the same area is probably due to species loss. Extinction of species in the study area has already been reported by Adjossou (2009). Several studies (Hoffmeister et al., 2005) has also shown extinction of species in very fragmented habitats.

The presence of many pioneer species or secondary species in the study areas proves that the habitat had undergone serious anthropogenic disturbance events, which can contribute to species loss in the area. When the anthropogenic disturbance is more intense than the natural disturbance regime, the forest shows a lager seed bank mostly composed of pioneer species or secondary species (Eilu and Obua, 2005). Further research is needed to update the complete floristic list of forest zone in Togo according to the methodology used by Adjossou (2009) and Akpagana (1989). Different categories of threats to species loss were examined and described in

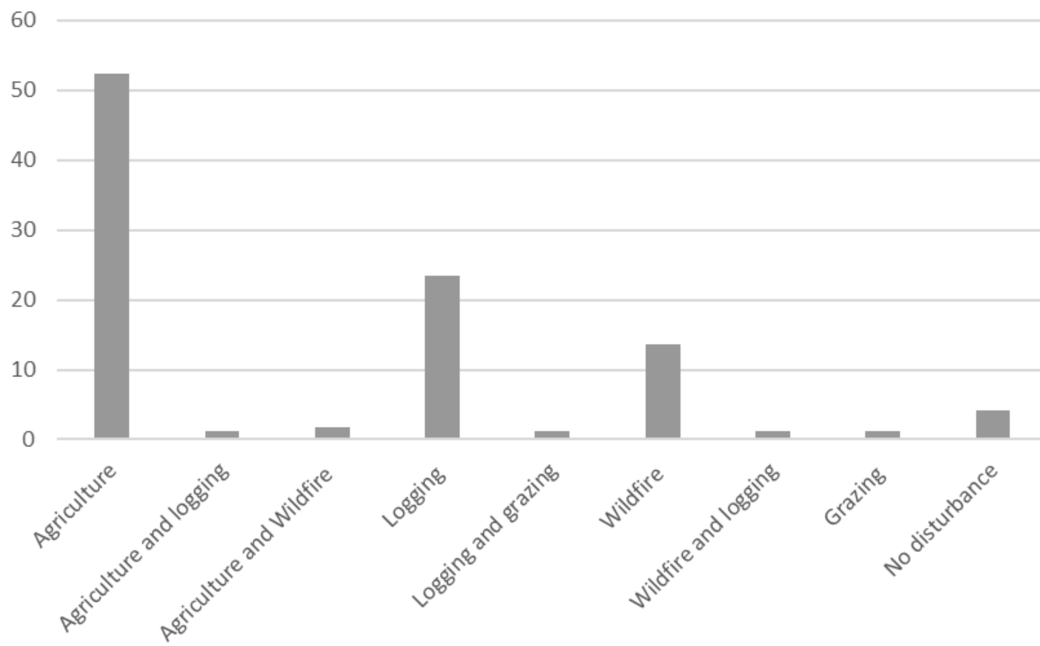

Figure 6. Type of disturbance identified in the study area.

Photo 1. Tree felling and burning.

the study area: increasing anthropogenic pressure, such as grazing, tree felling and clearing for forest for agriculture, wildfires and logging practice, as well as climate change effects. These threats have been also

Photo 2. Tree felling for agriculture.

observed by Adjossou (2009) study in that area. Under intense wildfires, and extensive extraction of timber and wood products or other disruptive land uses, forests are sometimes left fragmented leading to the extinction of certain seed-dispersing animals, and severely limiting regeneration of rare plant species (Appiah, 2013).

Grazing was another major source of disturbance. The area is also surrounded by the conversions of secondary forest and fallow areas to agroforestry and monoculture plantations. Until 1989, most forest in the study area were converted into high-yielding coffee and cocoa fields. Conversion was possible thanks to the introduction and use of chainsaws.

Globally, many factors have been attributed to forest loss in the tropical forest; it is believed to be generally driven by a complex interplay of various forces. These range from demographic changes, poverty, policy responses of countries to fires, and anthropogenic disturbances (such as logging, agricultural expansion) and climate change (Novick et al., 2003). Several forest areas fragmentation, as well as repeated forest destruction, has resulted in the elimination of indigenous species and the development of degraded landscapes dominated by invasive species (Powell et al., 2011).

Spatial variations in plant density and diversity occur from complex interactions based on local ecological conditions, among other factors. In this study, mean tree density varied spatially across different formation, ranging from 408.96± 202.17 (Group 1) to 273.90± 193.19 (Group 4). The stand density in Group 1 (guinea savannah species) is comparable to the one reported by Adjossou (2009) (507 ind/ha) in the same area. The density rate is also comparable to mean tree density per hectare(for trees with DGB>10 cm) reported from Asase and Tetteh (2010) (of 470 in a natural forest). However, the tree density is also comparable to other tropical forests of Ghana (231.81 tree/ha; Attua (2003)), tropical forest in India (556 mean stand density trees/ha) (Naidu and Kumar, 2016).

The diameter distribution of trees has been often used to represent the population structure of forests. The present assessment presented a reverse J-shaped distribution, suggesting uneven-aged forests for sustainable reproduction and regeneration (Vetaas, 2000), with a sufficient number of young individuals with intermediate DBH between [10, 30] cm to replace the old mature stand. Tree distribution across different diameter classes revealed larger trees species with DBH > 80 cm are few in the area. The finding could be associated with forest degradation and deforestation reported by earlier studies (Adjossou, 2009).

This study identified the Fabaceae, Malvaceae and Moraceae as the most represented families in the tree vegetation of the study area. Other also substantially represented families were the Meliaceae, Rubiaceae, Euphorbiaceae, and the Combretaceae. This observation is in close agreement with the findings of Adjossou (2009) that the most represented families in the forest zone in Togo in term of number of species are Rubiaceae, Euphorbiaceae, Fabaceae, Moraceae and Apocynaceae. Another study of Asase and Oteng-Yeboah (2007) and Asase et al. (2009) found that the Fabaceae and Combretaceae were dominant tree families in Guinean savanna vegetation. Elsewhere, Felker (1981) had attributed the abundance of Fabaceae trees to their role in maintaining nitrogen balance of agro-ecosystems for which reason they are protected and managed on farms. The study also found that *Theobroma cacao*, *Pterocarpus erinaceus*, *Persea Americana* and *Cola gigantea* were abundant. Most of these trees are of nutritional and economic significance in the study area. The abundance of economic trees in the study area is mainly due to the forestland use in the area. Most of the forestland is converted to agriculture land by agroforestry system. The results are also in line with those obtained by Adjossou et al. (2019) who studied the Forest land use and native trees diversity conservation in Togolese mega hotspot, Upper Guinean in West Africa. The Shannon index (H’) values for tree species reported from this study ranged from 2.05 ± 0.61 (Group 5) to 1.19 ± 0.64 (Group 2). The type of forest for these two groups can explain the different Shannon index in the two groups. The Group 5 (dry deciduous forest) is more diverse than Group 2 (cocoa plantation). This observation also revealed that Group 5 is a forest with low disturbance from human activities compared to Group 2. The results are comparable to those reported by Uniyal et al. (2010; 0.70-3.08) from other different tropical forests.

In this study, mean basal area (m^2/ha) which varies from 15.84 ± 13.44 (Group 4) to 27.99 ± 25.58 (Group 3). These values are lower than those reported by Adjossou (2009; 50-113 m^2/ha) in the same area and may be explain by the reduction of species in the area since 2009. The differences in the basal area of tree layers among the study plots may be due to differences in altitude, species composition, age of trees, and extent of disturbances and successional strategies of the stands (Naidu and Kumar, 2016).

Conclusion

Tree species density, distribution, and population structure analyzed in this study should be useful to effective management of tree diversity in sub humid mountains ecosystems in south-west of Togo. Documenting the patterns of tree diversity and their distribution provides a good database, useful for management measures in these forests. The preservation of these ecosystems is crucial not only for conservation of their rich biodiversity, but also for meeting the basic needs of the local population. Therefore, this paper calls for an urgent conservation plan to conserve biological diversity.

The localized processes or disturbances such as wildfires, shifting cultivation, and logging appear to have had a significant impact on the community composition and species distribution pattern at the study area. The study area is poor in richness and diversity compared to previous studies in the area. Many tree species usually found in sub humid mountains ecosystems in south-west Togo that have economic significance are in very low numbers, especially in the adult populations. The impact of human activities is significant on the plant resources by reducing the population of larger plants.

Quantitative analysis of tree species diversity recorded in this study may provide baseline information for formulating conservation and management strategies for these forest zones.

Several measures must be taken to support recovery of the trees species and ecosystem in the study area: (i) develop reforestation based on assisted natural regeneration, which encourages the promotion of fast growing indigenous species; (ii) establish plantations in severely degraded areas of the site ;(ii) limit dependence of the population on wood energy; and (iii) raise farmers' awareness of biodiversity, its importance and the need to preserve it through sustainable management.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Abotsi KE, Bose R, Adjossou K, Deblauwe V, Rouhan G, Segla KN, Atsri KH, Kokou K (2020). Ecological Drivers of Pteridophyte Diversity and Distribution in Togo (West Africa). Ecological Indicators 108:105741.

Adjossou K (2009). Diversity, structure and dynamics of the vegetation in the fragments of rainforests of Togo: the challenges for biodiversity conservation. Phd thesis, Togo: University of Lome.

Adjossou K, Dangbo FA, Houngbedji T, Abotsi KE, Koda DK, Guelly AK, Kokou K (2019). Forest Land Use and Native Trees Diversity Conservation in Togolese Mega Hotspot, Upper Guinean, West Africa https://doi.org/10.5897/jene2019.0799 .

Akpagana K (1989). Research on the dense humid forests of Togo. Phd thesis, France: University of Bordeaux III, U.F.R. Planning and Natural Resources.

Anitha K, Shijo J, Chandran RJ, Ramasamy EV, Narendra S (2010).

Tree Species Diversity and Community Composition in a Human-Dominated Tropical Forest of Western Ghats Biodiversity Hotspot, India. Ecological Complexity, Eco Summit 2007 Special Issue, Part Two 7(2):217-24.

Anitha K, Shijo J, Ramasamy EV, Narendra S (2009). Changes in Structural Attributes of Plant Communities along Disturbance Gradients in a Dry Deciduous Forest of Western Ghats, India. Environmental Monitoring and Assessment 155 (1-4):393.

Appiah M (2013). Tree Population Inventory, Diversity and Degradation Analysis of a Tropical Dry Deciduous Forest in Afram Plains, Ghana. Forest Ecology and Management 295:145-154.

Asase A, Ekpe P, Amponsah JY (2009). Floristic Composition, Abundance, and Distribution Pattern of Woody Plants in a Tropical Savanna in Northern Ghana. Journal of the Botanical Research Institute of Texas, pp. 309-316.

Asase A, Oteng-Yeboah A (2007). Assessment of Plant Biodiversity in Wechiau Community Hippopotamus Sanctuary in Ghana.. Journal of the Botanical Research Institute of Texas, pp. 549-556.

Asase A, Tetteh DA (2010). The Role of Complex Agroforestry Systems in the Conservation of Forest Tree Diversity and Structure in Southeastern Ghana. Agroforestry Systems 79(3):355-368.

Attua EM (2003). Land Cover Change Impacts on the Abundance and Composition of Flora in the Densu Basin. West African Journal of Applied Ecology 4:1.

Borcard D, Gillet F, Legendre P (2018). Numerical Ecology with R. Springer.

Crawley MJ (2012). The R Book. John Wiley& Sons.

Eilu G, Obua J (2005). Tree Condition and Natural Regeneration in Disturbed Sites of BwindiImpenetrable Forest National Park, Southwestern Uganda. Tropical Ecology 4(1):99-112.

Ern H (1979). The vegetation of Togo. Outline, Conservation. Willdenowia. pp. 295-312.

Felker P (1981). Uses of Tree Legumes in Semi arid Regions. Economic Botany 35 (2):174-186.

Gotelli NJ, Colwell RK (2011). Estimating Species Richness. Biological Diversity: Frontiers in Measurement and Assessment 12: 39-54.

Hoffmeister TS, Vet L, Biere A, Holsinger K, Filser J (2005). Ecological and Evolutionary Consequences of Biological Invasion and Habitat Fragmentation. Ecosystems 8(6):657-667.

ITTO (2002). Guidelines for the Restoration, Management and Rehabilitation of Degraded and Secondary Tropical Forests.

Jesse W, Behm JE, Helmus MR, Jacintha E (2018). Human Land Use Promotes the Abundance and Diversity of Exotic Species on Caribbean Islands. Global Change Biology 24(10): 4784-4796.

Kokou K (1998). Forest Mosaics in Southern Togo: Biodiversity, Dynamics and Human Activities. PhD Thesis, Montpellier 2.

Kolb A, Diekmann M (2004). Effects of Environment, Habitat Configuration and Forest Continuity on the Distribution of Forest Plant Species. Journal of Vegetation Science 15(2):199-208.

Kouki J (1994). Preface: Biodiversity in the Fennoscandian Boreal Forests: Natural Variation and Its Management. In Annales Zoologici Fennici, 3-4. JSTOR.

Lamb D, Erskine PD, Parrotta JA (2005). Restoration of Degraded Tropical Forest Landscapes. Science 310 (5754):1628-1632.

Magurran AE (1988). Ecological Diversity and Its Measurement. Princeton university press.

MERF (Ministry of Environment and forestry resources). (2013). Readiness preparation proposal (R-PP). The Forest Carbon Partnership Facility (FCPF).

Myers N, Mittermeier RA, Mittermeier CG, Da Fonseca G, Kent J (2000). Biodiversity Hotspots for Conservation Priorities. Nature 403(6772): 853.

Naidu MT, Kumar OA (2016). Tree Diversity, Stand Structure, and Community Composition of Tropical Forests in Eastern Ghats of Andhra Pradesh, India. Journal of Asia-Pacific Biodiversity 9(3):328-34.

Novick RR, Dick CW, Lemes MR, Carlos N, Adalgisa C, Eldredge B (2003). Genetic Structure of Mesoamerican Populations of Big-Leaf Mahogany (Swietenia Macrophylla) Inferred from Microsatellite Analysis. Molecular Ecology 12(11):2885-2893.

Powell KI, Chase JM, Knight TM (2011). A Synthesis of Plant Invasion Effects on Biodiversity across Spatial Scales. American Journal of Botany 98(3):539-548.

Swindel BF, Conde LF, Smith J (984). Species Diversity: Concept, Measurement, and Response to Clearcutting and Site-Preparation. Forest Ecology and Management 8(1):11-22.

Ter Steege H (2003). Long-Term Changes in Tropical Tree Diversity: Studies from the Guiana Shield, Africa, Borneo and Melanesia.

Uniyal P, Pokhriyal P, Dasgupta S, Bhatt D, Todaria NP (2010). Plant Diversity in Two Forest Types along the Disturbance Gradient in Dewalgarh Watershed, Garhwal Himalaya. Current Science (Bangalore) 98(7):938-943.

Vetaas OR (2000). The Effect of Environmental Factors on the Regeneration of Quercus Semecarpifolia Sm. in Central Himalaya, Nepal. Plant Ecology 146(2):137-144.

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Diurnal activity pattern and social behavior of Swayne's Hartebeest in Maze National Park, Southern Ethiopia

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Swayne's Hartebeest (SHB) is an endangered endemic animal to Ethiopia. However, its activity pattern and social behavior are not well documented. Hence, we investigated the diurnal activity pattern and social behavior of SHB in the Maze National Park. Data were collected by direct observation of focal-animal from October 2018 to April 2019 and analyzed using descriptive statistics and X^2-test. A total of 1004 observations were made for activity pattern study. The SHB were performing four major activities (remain standing: 37.6%, grazing: 32.9%, walking: 15.7%, lying: 11.2%) showing significant differences in the total observation frequencies (X^2 = 205.69, P < 0.05). Standing was the dominant activity followed by grazing in the wet season and vice versa in the dry season. Observation frequency for standing showed significant difference between seasons (X^2 = 6.614, P < 0.05). Observation frequency for the activities within season (wet season: X^2 = 120.6, P < 0.05; dry season: X^2 = 100.38, P<0.05) showed variation. A total of 951 observations were made for social behavior study. We found significant differences in the total observation between types of social groups (X^2 = 109.52, P<0.05) and between seasons (X^2 = 22.722, P<0.05). Female SHB with young calf showed the dominant vigilant behavior. The findings revealed a decrease in the rate of occurrence for vigilance behavior with increasing social group size. We suggest the management plan of the park shall consider the findings of this study as a useful input for sustainable conservation of this endangered endemic species.

Key words: Social organization, Swayne's hartebeest, time budget, vigilance.

INTRODUCTION

The Swayne's Hartebeest (SHB) is a large antelope, endemic to the southern Rift Valley of Ethiopia (East, 1999). It was distributed throughout the Rift Valley of the country in the past and extended eastward into northwestern Somalia (IUCN, 2013). Today, its distribution is limited to two protected areas in Ethiopia that is, Maze National Park and Senkelle Swayne's Hartebeest Sanctuary (Abiot, 2013; Simon, 2016; Shibru et al., 2020). Therefore, for the conservation of this species knowledge of its diurnal activity pattern and behavior is one of the essential prerequisites.

The change of activity patterns in ungulates, including

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SHB, serves as an evolutionary adaptation to optimize fitness in frequently fluctuating environments (Yerushalmi and Green, 2009; Kurauwone et al., 2013). Thus, the seasonality of activity patterns might be highly flexible in response to seasonal fluctuation in food supply, habitat, predator avoidance and corresponding temperature (Vasey, 2005; Ruckstuhi and Neuhaus, 2009). Seasonal variation in the activity patterns of SHB and other ungulates (Wondimagegnehu and Afework, 2015) were influenced by the quality and quantity of food, human disturbance, accidental fire, habitat fragmentation, tourism service, hunting and livestock grazing (Norris et al., 2010). Livestock pressure on habitats of wild animals in Maze National Park was reported by Wondimagegnehu and Afework (2013). Based on the information obtained from Maze National Park, about 50,000 heads of livestock were grazing in the park per day during the dry season. The human activities and overgrazing on forage resources adversely affect the daily activity patterns of SHB in the dry season (Shibru et al., 2020) in Nech Sar National Park. These findings were in line with a number of studies on the other ungulates in different protected areas (Liu et al., 2008;; Chu et al., 2009; Lin et al., 2012).

The event of non-prescribed fire has disturbed the diurnal activity pattern of SHB during the dry season in Maze National Park (Almaz, 2009; Wondimagegnehu and Afework, 2011; Abiot, 2013). Disturbances from livestock and human activities caused the highest vigilance of Swayne's hartebeest, which reduces and confuses their usual diurnal activity pattern during the dry season. Similar studies were reported for ungulates of *Goiter gazelles* (Xia et al., 2011).

Although detailed information on the diurnal activity pattern and social behavior of wild ungulates is essential for their effective conservation, yet such data are lacking for most of the Ethiopian endemic species (Lewis and Wilson, 1979; Yosef et al., 2015). Likewise, though the Swayne's Hartebeest was endemic and critically endangered, no previous research was conducted on its activity patterns and social behavior in Maze National Park. Therefore, this study investigated diurnal activity patterns and social behavior of SHB in Maze National Park.

MATERIALS AND METHODS

Study area

Maze National Park is located at 460km south of Addis Ababa in the Southern Nations, Nationalities and People's Regional State (Figure 1). It lies between 06°3' to 06°30'N latitude 37°25' to 37°40'E longitude. Its altitude ranges from 900 to 1200 masl and covers total area of 202 km^2 (Befekadu and Afework, 2006). The area was known for its bimodal rainfall pattern and is one of the semi-arid agro-ecological zones in Ethiopia. The annual rainfall ranges between 843 and 1321 mm (Befekadu, 2005). The rainy season runs from March to October, while the dry season is from November to February (Befekadu, 2005; Yosef et al., 2012). The minimal temperature in the wet season is 15.3°C in June and the maximal (33.5°C) is in February in the dry season (Wondimagegnehu and Afework, 2011; Yosef et al., 2012). The Park is home of 39 species of large and medium mammals and 196 bird species (EWCA, 2012). It is also known for hosting a critically endangered endemic Swayne's Hartebeest. Most of the plains of the Park are covered by open *Combretum-Terminalia* wooded grasslands (Siraj et al., 2016).

Diurnal activity pattern

Data were collected using scan sampling method (Altman, 1974; Jarman, 1974). Direct observations were made on focal animals. The wet season data were collected from October 2018 and March to April 2019. The dry season data were collected from November to December 2018 and January 2019. A total of 1004 observations were made (Wet season: 50.8%; Dry season: 49.2%). Observations were recorded on grazing, standing, walking, lying, grooming, defecating, watering, nursing and playing. The activities between the age and sex structures were also recorded. Individual animal was randomly selected for age and sex category. However, when the focal animals were in group, the dominant activity of the group was recorded at the beginning of the observation. Each observation was carried out for 5 min at 15 min interval from early morning (6:00 h) to late afternoon (18:00 h) across seasons. Time of the day is recorded for each activity. The durations of each activity were recorded using stopwatch. Pictures were taken for further confirmation using digital camera. The activity pattern was observed two times per month for a total of 12 observation days. Animals were observed using unaided eye and/or binocular from appropriate place for their clear visibility. The observed individuals were designated as adult males, adult females, sub-adult males, sub-adult females and young ones (Kingdon, 1997; Wondimagegnehu and Afework, 2015). Age and sex were determined based on body size, size and shape of the horn and body color. Individuals small in body size were recorded as young ones, individuals medium in body size were recorded as sub adult males and sub adult females, individuals large in their body size were recorded as adult males and adult females (Kingdon, 2015).

Social behavior

Data were collected using focal-animal sampling method (Altman, 1974; Jarman, 1974). Observations were done on focal individual at a time. The wet season data were collected from October 2018 and March to April 2019. The dry season data were collected from November to December 2018 and January 2019. Two or more individuals were taken as a focal sampling when those animals were continuously visible throughout the sampling period. A total of 951 observations were made for social behavior study of the species. The predominant social behavior was recorded. Each observation was carried out for 5 min at 15 min interval from early morning (6:00 h) to late afternoon (18:00 h) across seasons. The durations of each displayed social behavior were recorded using stopwatch. The social behavior of SHB was observed two times per month for a total of 12 observation days. After the social groups were identified and defined; the observation for their social behavior such as agonistic, vigilance, territoriality, and intraspecific competition or competition for resources within and between their social groups were recorded.

Data analysis

Data were checked and organized into excel sheet before analysis. Descriptive statistics and Chi-square test were used to analyze the

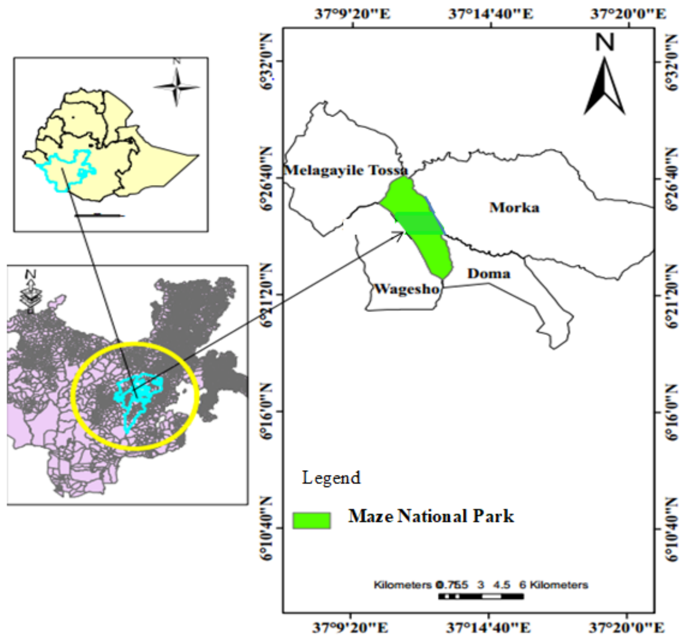

Figure 1. Map of Maze National Park.
Source: Abraham Tolcha (18/01/2018).

Table 1. Observation frequency of diurnal activity for SHB during wet and dry seasons in Maze National Park.

S/N	Diurnal activity	Observation		Percentage		Total observation
		Wet	Dry	Wet	Dry	
1	Grazing	149	182	29.21	36.84	331
2	Standing	214	164	41.96	33.2	378
3	Walking	73	85	14.31	17.2	158
4	Lying	63	49	12.35	9.91	112
5	Others	11	14	2.15	2.83	25
	Total	510	494	100	100	1004

data in SPSS version 20 and r-program (α = 95% level of significance, $P < 0.05$). Observation frequencies were compared using Chi-square test across season and between activities. The occurrence frequencies in each social behavior for each age/sex group during dry and wet seasons were computed by Chi-square test.

RESULTS

Diurnal activity pattern

The diurnal activity pattern for SHB in the study area is presented in Table 1. The diurnal activity of the species in the park for the hours of the day is presented in Figures 2 and 3 for the dry and wet seasons, respectively. The diurnal activity pattern of the species among age/sex group is depicted in Figure 4. The observational frequency of SHB was 37.6% for remain standing, 33.0% grazing, 15.8% walking and 11.1% lying. Significant differences were revealed in the total observation frequencies between the diurnal activities (X^2 = 205.69, df =3, $P < 0.05$). Standing and grazing were the major activities during the wet and dry season, respectively. Observation frequency for standing showed significant difference between the dry and wet seasons (X^2 = 6.614, $P<0.05$). However, we did not reveal significant differences for grazing (X^2 = 3.29, df = 1, $P>0.05$), walking (X^2 = 0.911, df = 1, $P>0.05$) and lying (X^2 = 1.75, df = 1, $P>0.05$) between the dry and wet seasons. Observation frequency for diurnal activity within each season showed significant differences (X^2 = 120.6, df = 3, $P<0.05$). There were significant differences in the frequency of the hour of the day for various daily activity patterns of SHB within a season (Wet: $\chi2$ = 153.91; Dry: $\chi2$ = 163.82, $P< 0.05$).

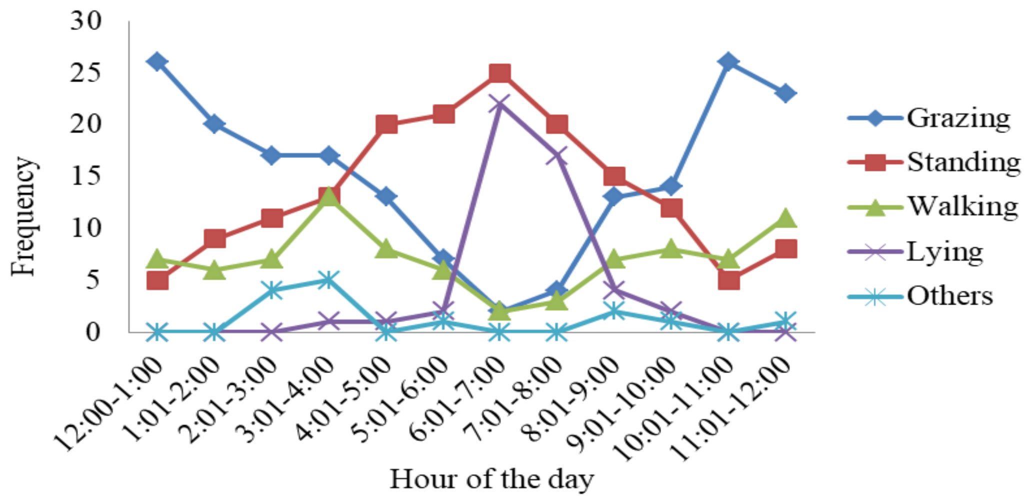

Figure 2. Diurnal activity pattern of SHB in the dry season in hour of the day.

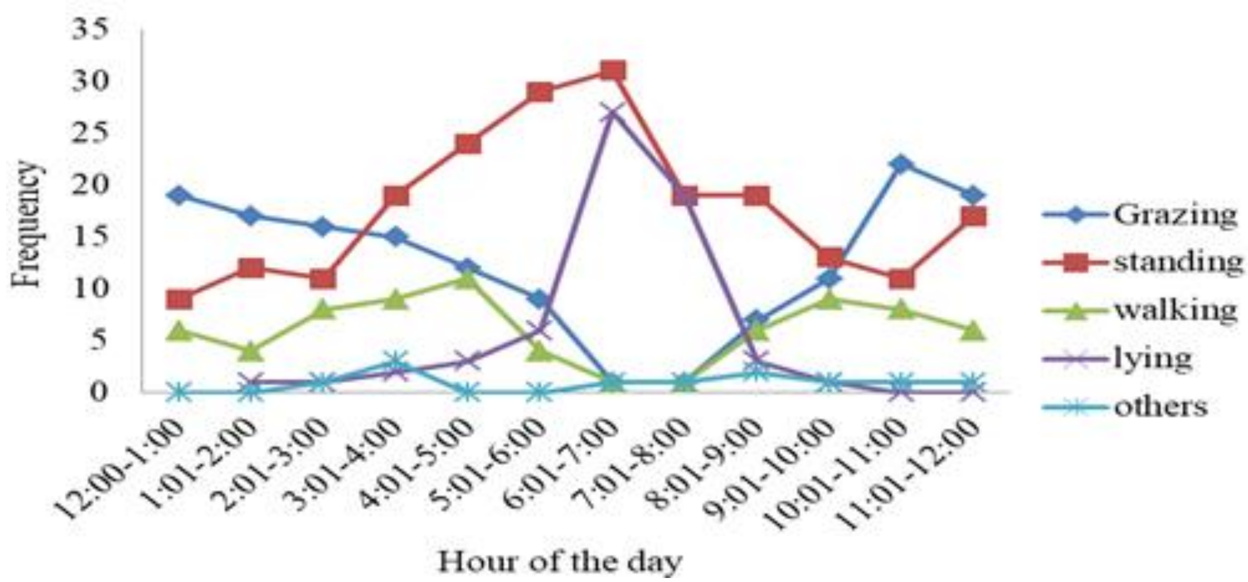

Figure 3. Diurnal activity pattern of SHB during the wet season in hour of the day.

Significant differences were also revealed among age/sex groups ($\chi2$= 17.0, = P< 0.05) for feeding activities ($\chi2$= 13.091, df = 3, P < 0.05) between seasons and among age/sex groups ($\chi2$= 259.440, df = 3, P < 0.05) for other daily activities (Figure 4).

Social behavior

Among a total of 951 observations made for social behavior study of SHB, 43.5% were for mixed type group, 38.9% were for adult male-adult female and 17.5% were for adult female with young social group type. We found significant differences in the total observation between types of social groups (X^2 = 109.52, df = 2, P < 0.05). The frequency of occurrence between seasons also showed significant differences (X^2 = 22.722, df = 1, P < 0.05). Comparison of the frequency of occurrence for each type of social group showed no significant difference between seasons for mixed type group (X^2 = 1.1691, df = 1, P > 0.05), adult male-adult female (X^2 = 0.0108, df = 1, P>0.05) Table 2.

Table 3 presents comparison of the occurrence frequencies of the social interactions within mixed type social group. Comparison of occurrence frequencies of social behavior between mixed type social group did not

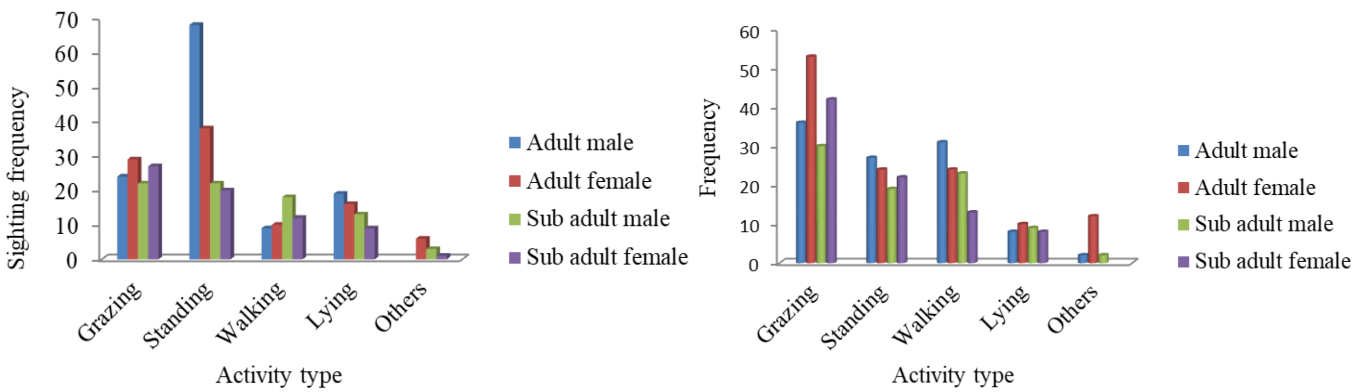

Figure 4. Diurnal activity pattern among age/sex groups of SHB in wet and dry season in maze National Park.

Table 2. Comparison for different social activities within a group.

S/N	Type of social group	Number of group	Frequency of occurrences		Total observation	Percentage	
			Wet	Dry		Wet	Dry
1	Mixed type group	26	218	196	414	52.65	47.34
2	Adult male-adult female	12	184	186	370	49.72	50.27
3	Adult female with young	7	-	167	167	-	100
	Total	45	402	549	951	100	100

Table 3. Comparison of occurrence frequencies of social interaction within mixed type social group of SHB.

S/N	Member of mixed type social group	Occurrence frequency of social behavior							
		Agonistic	(%)	Vigilance	(%)	Intraspecific	(%)	Territoriality	(%)
1	Territorial male	36	33.64	24	27.58	11	11.45	31	44.28
2	Bachelor male	10	9.34	9	10.34	18	18.75	19	27.14
3	Female with young	41	38.31	32	36.78	14	14.58	3	4.28
4	Adult female	15	14	19	21.83	12	12.5	1	1.43
5	Sub adult male	3	2.8	2	2.3	26	26	16	22.86
6	Sub adult female	2	1.87	1	1.14	15	15.62	-	-
	Total	107	100	87	100	96	100	70	100

show significant differences (X^2 = 6.566, df = 3, P > 0.05). Comparison of occurrence frequencies of social groups within each mixed type social group showed significant differences for territorial male (X^2 = 13.8, df = 3, P < 0.05), sub adult male (X^2 = 33.426, df = 3, P < 0.05), female with young (X^2 = 39.3, df = 3, P < 0.05), adult female (X^2 = 15.2, df = 3, P < 0.05), and sub adult female (X^2 = 33.1, df = 3, P < 0.05), but not for Bachelor male (X^2= 5.86, df = 3, P > 0.05). Comparison of each social behavior between mixed type social groups depicted significant difference for agnostic behavior (X^2 = 78.89, df = 5, P < 0.05), vigilance behavior (X^2 = 54.17, df = 5, P < 0.05), and territoriality (X^2 = 66.11, df = 5, P < 0.05), but did not depict significant variations for intraspecific competition (X^2 = 9.38, df = 5, P > 0.05).

Table 4 shows the occurrence frequency of social behavior between adult-male to adult-female group size pair. Comparison of the total occurrence frequency of social behavior between adult-male to adult-female group size pair did not reveal significant differences (X^2 = 4.30, df = 3, P > 0.05). On the other hand, comparison of occurrence frequency of each social behavior between the different group size pair revealed significant variation

Table 4. Occurrence frequency of different social behavior between adult-male to adult female group size pair.

S/N	Adult-male to adult-female group size pair	Occurrence frequency of social behavior							
		Agonistic	%	Vigilance	%	Intraspecific	%	Territoriality	%
1	One to one	34	53.9	27	38	3	3.6	4	6.6
2	Two to three	18	28.6	18	25.4	17	20.5	13	21.3
3	Three to five	7	11.1	15	21.1	28	33.7	19	31.2
4	Five to eight	4	6.4	11	15.5	35	42.2	25	41
	Total	63	100	71	100	83	100	61	100

for agonistic behavior (X^2 = 35.09, df = 3, P< = 0.05), Vigilance behavior (X^2 = 7.817, df = 3, P < 0.05), intraspecific competition (X^2 = 28.18, df = 3, P < 0.05) and territoriality (X^2 = 15.79, df = 3, P < 0.05). Likewise, comparison of the occurrence frequency of social behaviors within each pair showed significance variation for one to one (X^2 = 44.35, df = 3, P < 0.05), three to five (X^2 = 13.26, df = 3, P < 0.05) and five to eight (X^2 = 30.97, df = 3, P < 0.05), but did not show significant variation for two to three group size pair (X^2 = 1.03, df = 3, P > 0.05).

DISCUSSION

This study revealed significant difference in the observed frequencies for standing between wet and dry seasons. This could be due to sufficient amount and availability of quality forage during the wet season that results in spending more time in standing than in dry season when grazing took much time while searching for quality forage through day time (Vymyslicka et al., 2010).

In this study SHB showed two feeding peak hours for both wet and dry season in the day time (Figures 2 and 3). These were early morning (12:00-2:00 h) and late afternoon (10:00-12:00 h). Whereas standing and lying were recorded for one peak time of the day (6:00h-8:00 h) in both seasons. Similar patterns were reported for Nech Sar National Park (Vymyslicka et al., 2010) and Senkelle SHB Sanctuary (Lewis and Wilson, 1979; Berhanu and Yirga, 2004). High feeding peaks in the early morning and late afternoon for Swayne's hartebeest might be due to low disturbances by human activities and low ambient temperatures (Cain et al., 2006). The same results were stated by Aberham et al. (2016) for ungulates of African buffalo in Chebera Churchura National Park.

Among age/sex groups of Swayne's hartebeest, adult females were seen more frequent while feeding than adult male. On the other hand, adult males were observed more frequently in standing than other age/sex groups. This was in line with other studies for mammals that females need to forage more time to satisfy their nutritional requirement, makes differed activity patterns between males and females (Neuhaus and Ruckstuhl, 2004). It was stated that foraging time is positively correlated with body size in African herbivores (du Toit and Yetman, 2005). Long time spent in standing of male Swayne's hartebeest might be due to its involvement in territoriality and vigilance next to females with young. Activities those are categorized under other activities are mostly revealed for adult females in dry season. These might be due to calving of Swayne's Hartebeest in dry season that involves nursing, licking and grooming.

Different studies proposed and suggested four factors that influence ungulate's activity patterns. These are seasonal variation in forage quantity and quality (Moncorps et al., 1997); time of the day and seasonality in temperature variations (Shi et al., 2003); livestock movements and human activity (Schaller, 1998); and biological process occurring in 24 hour intervals (Maher, 1991).

In this study, females with young showed highest vigilant behavior of occurrence with frequency rate of 36.78% and territorial male was the second vigilant member with average occurrence rate of 27.58% in which long time invested looking for predation or any disturbing events happening around (human and non-human disturbances). Hunter and Skinner (1998) reported the same trend for other antelopes of Wildebeest and Impala in South Africa. Territories were maintained by territorial males in mixed social group type and defend against occupation by other adult males. The result was consistent with Berger and Hilton-Barber (2004). Researchers reported that, animals on the edge of herds or out of their social group spent more time to vigilance than those in the central location of the group in South Africa (Bednekoff and Ritter, 1994; Burger and Gochfield, 1994). From this finding, it can be said that the vigilance behavior of the Swayne's Hartebeest was negatively correlated with the size of its social group. This showed that as the social group size increase, the rate of occurrence for vigilance behavior decrease. This was in line with studies by Sonja and James (2009) on ungulates of Impala. On the other hand, as the size of social group increased, the intraspecific behavior also increased. For instance; for already defined social group of male to female pair type the occurrence rate for intraspecific behavior, for smallest group size two was 3.6% and in large group size of 13 was 42.19%. In addition, when comparing the social behavior of SHB within the same group, the territorial male to all others, there were statistically significant variation except for adult male and sub adult female, while female with young has no significance variation except with adult male. Adult male showed significance variation only with bachelor male and sub adult male while sub adult male has no significance difference with bachelor male and sub adult female but no variation with others and sub adult female has no significant variation with all members in group.

Conclusion

Standing in the wet and grazing in the dry season were the major activities of SHB in the study area. Observation frequency for standing showed significant difference across the seasons. The observation frequency for diurnal activity within each season showed significant differences. Significant differences were revealed among age/sex groups for activities between seasons. Mixed type group, adult male-adult female, adult female with young social group types were identified in the present study. We found significant differences in the total observation frequency between types of social groups. Within each mixed type social group, we found significant differences for territorial male, sub adult male, female with young, adult female, and sub adult female. Each social behavior between mixed type social groups depicted significant difference for agnostic behavior, vigilance behavior, and territoriality. Occurrence frequency of each social behavior between the different group size pair revealed significant variation for agonistic behavior, vigilance behavior, intraspecific competition and territoriality. Occurrence frequency of social behaviors within each pair showed significance variation for one to one, three to five and five to eight group size pair. The findings of this study could provide useful information for effective conservation of Swayne's Hartebeest in particularly in the studied area and can also be applied to other protected areas and other large herbivores as the SHB's general behavioral patterns overlap with those of other large herbivores.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Aberham M, Mundanthra B, Gurja B (2016). Diurnal activity budget of African buffalo (*Syncerus caffer* (Sparrman, 1779) in Chebera Churchura National Park, Ethiopia. African Journal of Ecology 56:436-444.

Abiot H (2013). Effect of habitat disturbance on the population of Swayne's Hartebeest (*Alcelaphus buselaphus Swaynei*) in Senkelle Swayne's Hartebeest Sanctuary. MSc. Thesis School of Wildlife Management and Ecotourism Studies, Wondo Genet College of Forestry and Natural Resources, Hawassa, Ethiopia.

Almaz T (2009). Sustaining the Allideghi grassland of Ethiopia: Influences of Pastoralism and Vegetation change. PhD Dissertation, Utah State University, Utah, USA.

Altman J (1974). Observational study of Behavior. Sampling methods. Behavior 43:227-269.

Bednekoff PA and Ritter R (1994). Vigilance in the Nxai Pan Springbok. Antidorcas marsupialis. Behaviour 129: 1–11.

Befekadu R (2005). Population status of Swayne's Hartebeest in Ethiopia. Fifth Annual Sahleo-Saharan interest group Meeting report, Souss, Tunisia, Pp.10-15.

Befekadu R, Afework B (2006). Population status and structure of Swayne's Hartebeest (*Alcelaphus buselaphus swaynei*) in Maze National Park, Ethiopia. International Journal of Ecology and Environmental Science 32:259-264.

Berger LR, Hilton-Barber B (2004). Field Guide to the Cradle of Human kind Sterkfontein, Swartkrans, Kromdraai and Environs World Heritage Site (2nd eds.). Struik Publishers, South Africa, Cape Town, Pp.163.

Berhanu G, Yirga S (2004). Seasonal Home Range of Swayne's Hartebeest (*Alcelaphus buselaphus Swaynei*) in Senkele Swayne's Hartebeest Sanctuary. SINET: Ethiopian Journal of Science 27(2):121-126.

Burger J, Gochfield M (1994). Vigilance in African mammals: differences among mothers, other females and males. Behaviour 131:153-169.

Cain JW Iii Krausman PR, Rosenstock SS, Turne, JC (2006). Mechanisms of thermoregulation and water balance in desert ungulates. Wildlife Society Bulletin 34:570-581.

Chu HJ, Jiang ZG, Ge Y, Jiang F, Tao YS, Wang C (2009). Population densities and number of khulan & goitred gazelle in Mt. Kalamaili Ungulate Nature Reserve. Biodiversity Science 17:414-422.

Du Toit JT, Yetman AC (2005). Effects of body size on the diurnal activity budgets of African browsing ruminants. Oecologia 143:317-325.

East R (1999). African Antelope Database 1998. IUCN/SSC Antelope specialist Group. IUCN, Gland, Switzerland, P.434.

EWCA (2012). Maze National Park (MzNP). Retrieved from http://www.ewca.gov.et/en/node/ on December, 2019.

IUCN (2013). International Union for Conservation of Nature and Natural resources; IUCN SSC Antelope Specialist Group *Alcelaphus buselaphus swaynei*. IUCN Red List of Threatened Species. (Available at http://www.iucnredlist.org). Accessed on November, 2018.

Jarman PJ (1974). The social organisation of antelope in relation to their ecology. Behaviour 48:215-267.

Kingdon J (2015). The Kingdon Field Guide to African Mammals. London: Academic Press.

Kingdon J (1997). The Kingdon Field Guide to African Mammals. London: Academic Press, pp. 1-464.

Kurauwone MV, Justice M, Beven U, Olga K, Simon C, Tawanda T (2013). Activity Budgets of Impala (*Aepyceros melampus*) in closed environments: the Mukuvisi Woodland experience, Zimbabwe. International Journal of Biodiversity, pp. 1-8.

Lewis J, Wilson R (1979). The ecology of Swayne's hartebeest. Biological Conservation 15(1):1-12.

Lin J, XU, WX, Yang WK, Xia CJ, Liu W (2012). Habitat suitability assessment of *Equus hemionus hemionus* in Kalamaili Mountain

Nature Reserve. Biodiversity Science 20:411-419.
Liu W, Yang WK, Xu WX (2008). Food habits of the Khulan (*Equus hemionus*) in autumn. Acta theriologica Sinica 28:33-36.
Maher CR (1991). Activity budgets and mating system of male pronghorn antelope at Sheldon National Wildlife Refuge, Nevada. Journal of Mammalogy 72:739-744.
Moncorps S, Bousses P, Reales D, Chapuis J (1997). Diurnal time budget of the moulfon (*Ovis musimon*) on the Kerguelen archipelago: influence of food resources, age, and sex. Canadian Journal of Zoology 75:1828-1834.
Neuhaus P, Ruckstuhl KE (2004). Can the activity budget hypothesis explain sexual segregation in desert bighorn sheep? Behavior 141:513-520.
Norris D, Michalski F, Peres CA (2010). Habitat patch size modulates terrestrial mammal activity patterns in Amazonian forest fragments. Journal of Mammalogy 91(3):551-560.
Ruckstuhi KE, Neuhaus P (2009). Activity budgets and sociality in a monomorphic ungulate: the African Oryx (*Oryx gazelle*). Canadian Journal of Zoology 87:165-174.
Schaller GB (1998). Wildlife of the Tibetan Steppe. University of Chicago Press, Chicago.
Shibru S, Vancampenhout K, Deckers J, Leirs H (2020). Human Pressure Threaten *Swayne's Hartebeest* to Point of Local Extinction from the Savannah Plains of Nech Sar National Park, South Rift Valley, Ethiopia. Journal of Biodiversity and Endangered Species 8(1):8. DOI: 10.24105/2332-2543.2020.8.239
Shi JB, Dunber RIM, Buckland D, Miller D (2003). Daytime activity budgets of feral goats (*Capra hircus*) on the Isle of Rum: Influence of season, age, and sex. Canadian Journal of Zoology 81:803-815.
Simon S (2016). Responses of Vegetation, Small mammals and Large herbivores to human induced pressures in the Savannah Plains of Nech Sar National Park, South Ethiopia Rift Valley. PhD Dissertation, University of Antwerp, Belgium.
Siraj M, Zhang K, Sebsebe D, Zerihun W (2016). Floristic composition and plant community types in Maze National Park, Southwest Ethiopia. Applied Ecology and Environmental Research 15(1):245-262.
Sonja MS, James WC (2009). Foraging efficiency and vigilance behaviour of impala: the influence of herd size and neighbor density. African Journal of Ecology 47(1):109-118.
Vasey N (2005). Activity budgets and activity rhythms in red ruffed lemurs (*Vareci arubra*) on the Masoala Peninsula, Madagascar: seasonality and reproductive energetic. American Journal of Primatology 66:23-44.
Vymyslicka P, Hejcmanova P, Antoninova M, Stejskalova M, Svitalek, J (2010). Daily activity pattern of the endangered Swayne's Hartebeest (Alcelaphus buselaphus swaynei Sclater, 1892) in the Nechisar National Park, Ethiopia. African Journal of Ecology 49:246-249.
Wondimagegnehu T, Afework B (2011). Current Population Status of the Endangered Endemic Subspecies of Swayne's Hartebeest (*Alcelaphus buselaphus swaynei*) in Maze National Park, Ethiopia. SINET: Ethiopian Journal of Science 34(1):39-48.
Wondimagegnehu T, Afework B (2015). Diurnal activity pattern of Oribi (*Ourebia ourebi*) in Maze National Park, Ethiopia. International Journal of Ecology and Eco solution 2(3):31-35.
Wondimagegnehu T, Afework B (2013). Population status of Oribi (*Ourebia Ourebi Zimmermann*, 1783) in Maze National Park, Southern Ethiopia. Bangladesh. Journal of Zoology 41(2):145-151.
Xia CJ, Yang WK, Blank D, Qiao JF, Liu W (2011). Diurnal time budget of goitred gazelles (*Gazella subgutturosa*) in Xinjiang, China. Acta theirologica Sinica 30:144 -150.
Yerushalmi S, Green RM (2009). Evidence for the adaptive significance of circadian rhythms. Ecological Letter 12:970-981.
Yosef M, Addisu A, Girma M (2015). Social organization in the mountain nyala (*Tragelaphus buxtoni*) population in the Bale Mountains National Park, Ethiopia. International Journal of Biodiversity and Conservation 7(2):103-111.
Yosef M, Girma M, Aramede F, Kefyalew S, Mezemir G (2012). Status of the Swayne's Hartebeest (*Alcelaphus buselaphus swaynei*) meta-population under land cover changes in Ethiopian Protected Areas. International Journal of Biodiversity and Conservation 4(12):416-426.

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Contribution of spring and summer hydrodynamic conditions in the eutrophication process at Lake Taihu, China

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Contribution of different hydrodynamic conditions caused nutrients released and algal blooms growth and deteriorates water quality. Important factors related to climate variation, such as water temperature, precipitation, wind, solar radiation, and human activities can influence trophic conditions in the water column. A field survey was conducted at Meiliang Bay during spring and summer seasons and in diverse hydrodynamic conditions. The study aimed to investigate the variation of wave shear stress generated by strong wind and vessels. The measurement results showed that the shear stress increased in direction with increasing wind speed and significant wave heights. Wave shear stress τ has a maximum value = 0.2 Nm^2 during weak wind 1.5-2.5 m/s and significant wave height = 0.20 m while, it has a maximum value = 0.8 Nm^2 with strong wind range from 4.5 to 10 m/s corresponding with the significant wave height which has maximum value = 0.65 m in 2014. Also, wave shear stress τ has maximum value = 0.25 Nm^2 with maximum significant wave height = 0.6 m during passages vessels in 2016. It ranges from -0.8 to 0.8 Nm^2 with maximum wave amplitude value U = 0.4 m/s passages heavy ship in 2018. The results indicated that the bottom layer has a major impact, with strong winds and vessels' induced waves. Furthermore, the shear stress generated by those forces impacted directly on the boundary of the lake and caused sediment resuspension leading to release nitrogen. The outcomes of this paper give a clear idea about the processes happening in the lake.

Key words: Vessels, hydrodynamic, waves, shear stress, Meiliang Bay, Lake Taihu.

INTRODUCTION

Climate change can cause increasing temperatures and evaporation while decreasing water obtainability. In addition, climate change can increase surface runoff causing floods, and may also result in deteriorated water quality. Sensitive factors for climate variation, for example, water temperature, precipitation, wind, solar radiation and human activities can also influence trophic conditions in water pole (Nazari-Sharabian et al., 2018). Differences in hydrodynamics among lakes have been related with variances in morphological geometries and the neighbouring topographies in addition to hydro-meteorological and geochemical influences (Sharip et al., 2018). Shallow lakes are characterised by intermittent resuspension of sediments which happens when the bottom shear stress exceeds the critical shear stress (Li et al., 2017b). Li et al. (2017a) studied the impact of wind field-induced flow velocity at the Eastern Bay of Lake Taihu and found that wind field is a significant factor causing resuspension of sediments and nutrients. Waves and currents generated shear stresses are the active forces at the deep water that influence sediment distribution, micro-topography, and habitat. Bottom shear stresses and its forcing processes mobility events were different spatially and temporally in the Middle Atlantic (Dalyander et al., 2013). Chao et al. (2008) developed a three-dimensional numerical model for simulating cohesive sediment transport in water bodies where wind-induced currents and waves are important and the results showed that the sediment is resuspended by the actions of wind waves and by shear stress generated and transported by wind-driven flow. Linares et al. (2018) indicated that the oscillations on bottom shear stress in freshwater estuaries in the Great Lakes are induced meteorologically and can increase it by an order of magnitude in comparison with river - dominated flow conditions. Pang et al. (2006) showed that lake current had relatively significant effects on the sediment solids concentrations (SSC) at littoral zone of Lake Taihu, while SSCs at the central area of the Lake was mainly influenced by waves. Waves are the most important factor for controlling sediment resuspension processes. Their effects are more noticeable in the shoreline zone than the middle zone due to the waves interacting directly with the shoreline (Qin, 2004; Gabel et al., 2017). The wave's interactions affect sediment surface, biota, cause resuspension, erosion, transport of particles, the release of nutrients, methane reallocation and stress on zoobenthos affecting their diversity, abrasion of biofilms from stones, and the spread of aquatic macrophytes (Luettich et al., 1990; Hawley, 2000, Eriksson et al., 2004; Bussmann, 2005; Peters, 2005; Scheifhacken, 2006). Pollution of Lake Taihu is resulting from anthropogenic development in the Lake Taihu Basin. Lake Taihu has knowledgeable several ecological problems meanwhile the1960s, mainly eutrophication and cyanobacterial blooms (Qin et al., 2007; Paerl et al., 2011; Jiang et al., 2018).

Anthropogenic nutrient over-enrichment, coupled with rising temperatures and an increasing frequency of extreme hydrologic events are accelerating eutrophication and encouraging algal blooms. These consequently affect water supplies, fisheries, recreation, tourism, and property values (Paerl et al., 2011; Ma et al., 2019). The watershed nutrient management struggles to control algae blooms in huge quantities and cover the lake by reducing P inputs. But the N loading has also increased, supporting blooms of non-N2 fixers, and changing lake nutrient resources and cycling characteristics (Qin, 2004; Qin et al., 2007; Paerl et al., 2011). Water quality parameters associated with limitation factors change according to the real state and sensitivities of water parameters (Jiang et al., 2018). Trophic level index (TLI) and water quality index (WQI) methods are used in the lake to determine the eutrophication levels and the status of water quality (Wang et al., 2019). Anthropogenic activities affect the ecological stability of Lake. Studying water quality parameters is very important for solving the problems in the ecosystem. Nutrients and pollutants are transmitted and accumulate in Meiliang Bay. The obejectives of this study are therefore to: 1) to study the variation of wave shear stress according to the inducer, and 2) to assess the water quality by hierarchical cluster in spring and summer seasons.

MATERIALS AND METHODS

Description of study site

Field observations were recorded in Meiliang Bay, which is located at (31°25′7.41″N, 120°12′46.90″E; Figure 1) in three periods (April, 2014; May, 2016, and July, 2018) in the summer seasons with different hydrodynamic conditions. Meiliang Bay is a semi-enclosed bay with a surface area of 129.3 km^2, 1.9 m average depth and is located northern part of Lake Taihu (Liu et al., 2014; Gao et al. 2017; Li et al. 2017b). It is extremely eutrophic, as indicated by cyanobacteria blooms during summer leading to severe water quality problems (Gao et al., 2017; Li et al., 2017b). Meiliang Bay has average annual wind speed 4.5 m/s , with dominant summer wind from the southeast and dominant winter wind from the northwest (Wu et al., 2013; Gao et al., 2017; Li et al., 2017b).

Field observation pattern instruments

The instrument's patterns were used in three field observations as shown in Table 1. According to the Chinese standard methodology for lake eutrophication surveys (Jin, 1990).

This method is corresponding to the American standard methods (APHA, 1998), for water quality parameters (James et al., 2009).

Water quality sampling

Water quality samples were transported to Taihu Laboratory Lake Ecosystem Research, Chinese Academy of Sciences (TLLER) for filtration to obtain suspended particulate matter (SPM) substance by

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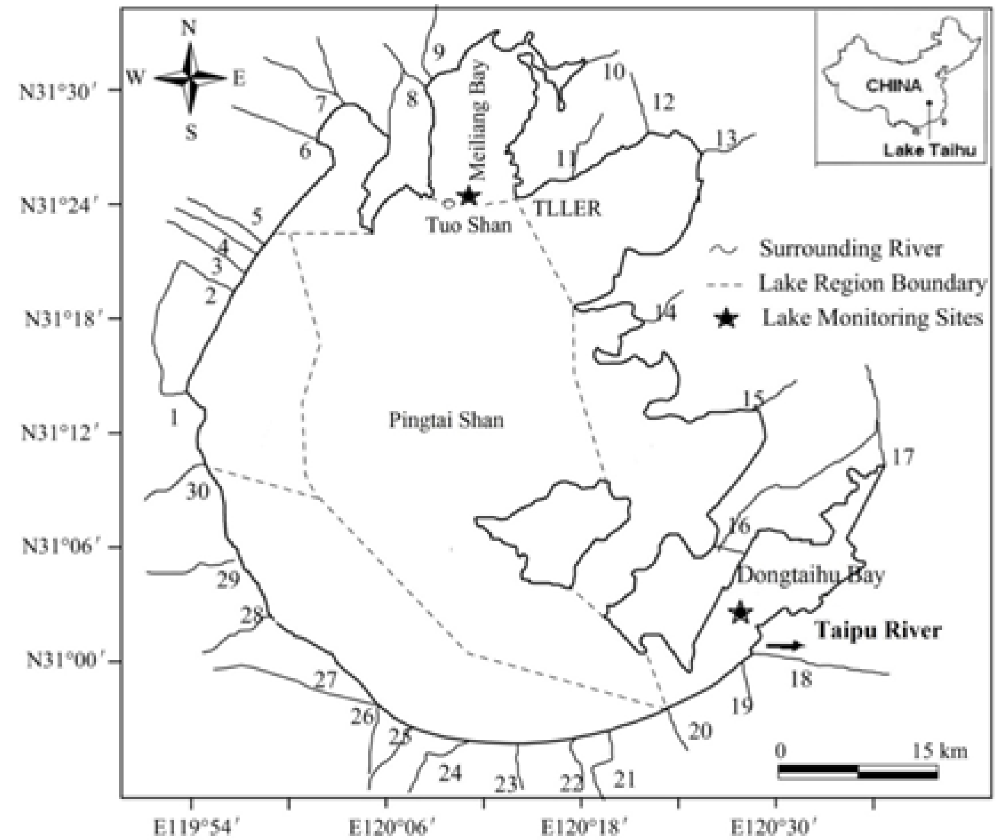

Figure 1. Location of Study area with descriptions of sampling sites of Lake Taihu.

Table 1. Instruments pattern were used in Meiliang Bay.

Detailed parameters of A. Meteorological data		Instruments	Position of instruments
A.1 wind field	Wind speed	PH-Handheld weather stations 5 min	5 m above the water surface
		TLLER weather stations, 1 h	20 m above the sea level
	Wind direction	TLLER weather stations, 1 h	20 m above the sea level
	Wave (wave height H、period T)	RBRduo T.D wave, 5 min	1.77 m above the bottom
1			
B.2 Conventional physical and chemical indicators	The concentration of suspended sediment (SS)	OBS-3A, 3 min	0.95 m below the water surface; 2.65 m under the water surface
	Water temperature (WT) Dissolved oxygen (DO) mg/L pH; conductivity	YSI 6600, YSI ProPlus10 min	2.3, 0.5 m below the water surface
	TN; NH_3^+-N; NO_3—N; NO_2^--N; DTN; TP; PO_4^{3-}; DTP& Chl-a B.4 Algae concentration.	3 h	20cm below the water surface; 10cm above the bottom

filtering only 250 ml of water through cellulose acetate membranes (0.45 µm), then the analyses including total nitrogen (TN), total dissolved nitrogen (TDN), dissolved inorganic nitrogen (DIN; ammonium (NH_4^+) + (NO_3^-) + (NO_2)), total phosphorus (TP), total dissolved phosphorus (TDP) and Phosphate (PO_4) were performed. Other parameters, including pH, water temperature (T), dissolved oxygen (DO), total dissolved solids (TDS) and electrical conductivity (EC) were obtained by using a multi-parameter instrument EXO2 sonde Yellow Springs Instrument (YSI) 6600 and YSI ProPlus. As well as, Synchronous, high-frequency measurements of wind, currents, waves, and Sediment resuspension concentrations (SSCs) were carried out in this study.

The observation tools included an RBR duo T.D wave tide gauge, PH-II Handheld weather stations, a PHWD wind direction sensor, and a bottom-mounted holder equipped with an Acoustic Doppler current profiler (ADP Argonaut-XR), Acoustic Doppler Velocimeter (ADV Ocean, Son Tek Inc.), and Optical Backscatter Sensor (OBS) turbidity meter. The wind parameters were measured using PH-II Handheld weather stations and a PHWD wind direction sensor fixed above the surface of the lake.

Wave data collection

Wave parameters were analysed following the general wave data Equation 1:

$$W_s = \left(\frac{dH^2}{2\pi}\right) tanh \frac{2\pi h}{w_s} \quad (1)$$

Wave parameters were analysed following the general wave data equation (1):
W_s is a reference to the significant wavelength, H is the significant wave period, and h is the depth points we observed. The maximum orbital velocity of a wave near the bottom layer u_w (m/s) can be expressed as Equation 2 following the method by Madsen (1976) and Whitehouse (2000)

$$O_w = \frac{\pi E_s}{L_s \, sin\left(\frac{2\pi e}{Ps}\right)} \quad (2)$$

Where E_s means the effective wave height (meters), L_s the wavelength (m), P_s is wave period, and e is the depth points in the meter.

Shear stress collection

Shear stress created by waves was calculated by the following Equation 3 (Grant and Madsen 1979):

$$\tau w = 0.5 \rho f_w O_w^2 \quad (3)$$

The abbreviation τ_w is shear stress (N/m^2), ρ indicated to the density of water (kg/m^3), O_w the maximum wave orbital velocity near the bed (calculated by Equation 2), and the wave f_w friction coefficient related to the lake bottom roughness and Reynolds number. The f_w calculated as follows (Jiang et al., 2000; Li et al., 2017b; Shih et al., 2017).

General hydrophysiology

The spatial and temporal variation of the water surface quality was evaluated by using a Multivariable method during different hydrodynamic effects. The Multivariate hierarchical cluster analysis (HCA) agreements the use of a mathematical explanation of the relationship to group several measures into the same section or between the diverse sections. Considering the temporal and spatial variations in Lake water quality and determining the factors that affect water quality can assist researchers in establishing significance for sustainable water management (Chen and Lu, 2014). Samples categorised according to their parameters. All the selected variables Temperature (Temp)°C, Dissolved oxygen (DO)mg/L, Salinity (SAL), pH, Chlorophyll-a(Chl-a) µg/L, Turbidity (Turbid) NTU were utilised in this statistical analysis. The results of all samples were statistically analysed by software Origin pro-2018.

RESULTS AND DISCUSSION

In Lake Taihu, It is known that the wave height increased when the wave period is increased. While wave shear stress has no significant by the wave period (Ding et al., 2018). Data from near bottom of the lake by using high-frequency instruments expose that the shear stress has different critical means values in spring and summer seasons in the same site according to the inducers of waves. The measurement results showed that the shear stress increased in direction with increasing wind speed (m/s) and significant wave height (m) (Figure 2). Also, the data analysis shows that different hydrodynamic results express the influence that happened during generated wave shear stress by different forces in the eutrophic shallow Lake in China. Wave shear stress τ has maximum value = 0.2 (Nm^2) during weak wind 1.5-2.5 m/s and significant wave height = 0.20 (m) while wave shear stress τ has maximum value = 0.8(Nm^2) with strong wind range between 4.5 to 11 (m/s) corresponding with the significant wave height which has maximum value = 0.65 (m) in 2014. Also, wave shear stress τ has maximum value = 0.25 (Nm^2) with maximum significant wave height = 0.6 (m) during passages high-speed vessels in 2016. Wave shear stress τ has a maximum value range from - 0.8 to 0.8 Nm^2 with maximum wave amplitude value U = 0.4 m/s during blowing water by heavy ship in 2018 (Figure 3).

Waves under strong wind forcing have action on the boundary of water and stimulated sediment resuspension, while the critical shear stresses caused by waves and currents have the same degree with weak wind forcing (Qin, 2004; Wei et al., 2019). Zheng et al. (2015) explore the variations of the current speed, wave parameters and sediment resuspension under different wind speeds in Lake Taihu and found that there were exponential distributions between the mean wind speed and wave parameters and between the mean wind speed and current speed.

The scholars found that with increasing surface wind, a consistent increase in the concentration and particle size of the Suspended Particulate Matter (SPM) in the water column. The disturbance of the water column can lead to sediment disturbance and nutrients released larger than steady conditions. The resuspension process has a significant correlation with the release of nutrients from sediment. Waves are the main reason for sediment resuspension generated by shear stresses in the central part of the shallow lake and Meiliang bay (Asmaa, 2019).

For a few days field observation, by using Yellow Springs Instrument (YSI), (Table 2) shows that the comparisons of means physical parameters were confirmed the trophic state in Lake Taihu during three

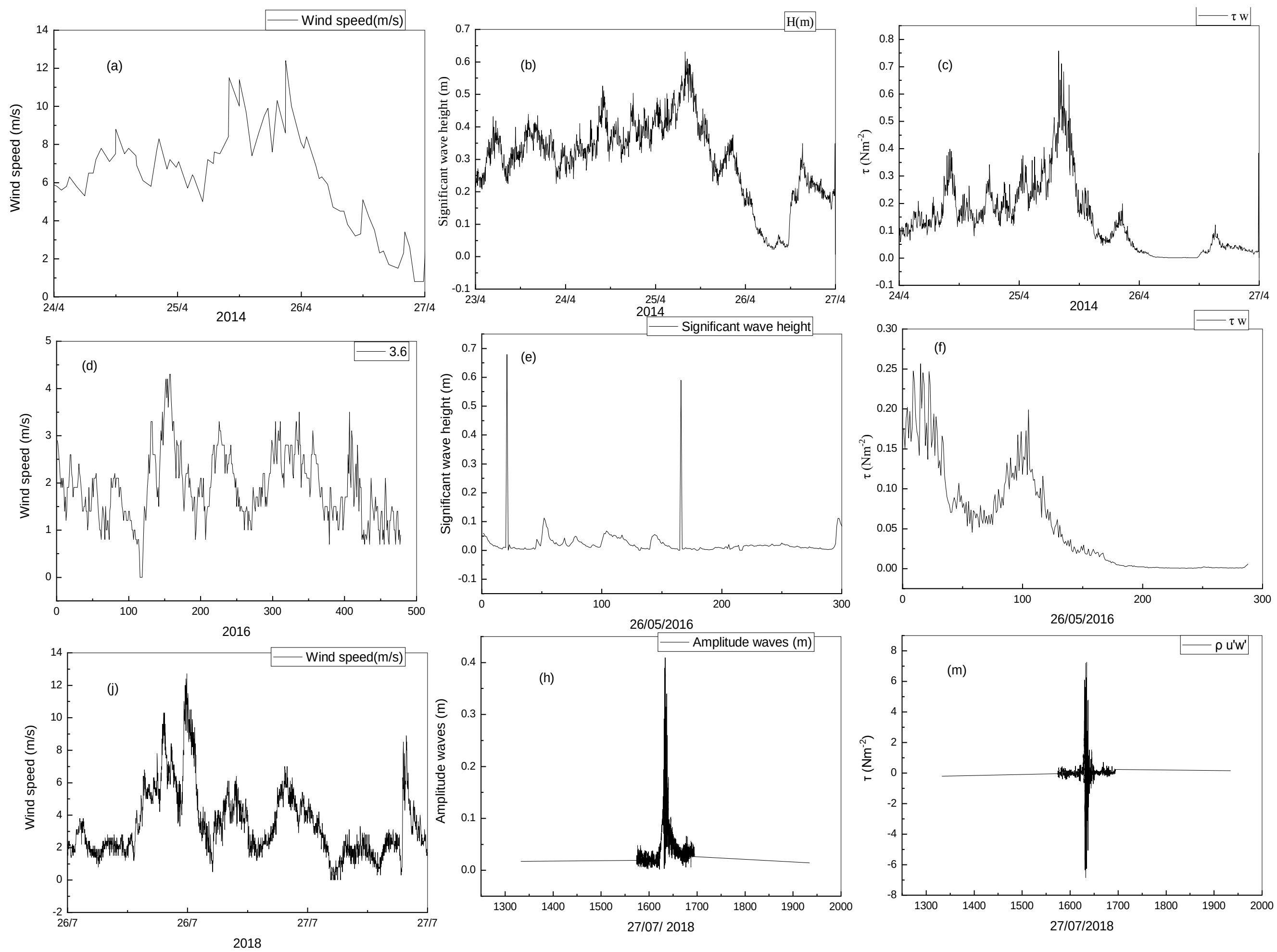

Figure 2. Different hydrodynamic conditions showing wind speed (m/s); significant wave height (m); wave shear stress (N/m^2) in April 2014; May 2016 and July, 2018.

summer seasons under different hydrodynamic conditions. The means of Total dissolved solids (TDS), Dissolved Oxygen (DO)/mg/L, Salinity (SAL), Chlorophyll-a (Chl-a) ug/L, Turbidity (NTU) and Blue-green algae BGA-PC 1 (µg/L) are gathered with Multivariate analysis. From the table, the means comparisons of physical parameters show that the highest mean values were in 2014 and the lowest mean values were in 2018.

Euclidean distance was used in this analysis and categorize the water samples. Euclidean distance estimates if the samples can be grouped into statistically different hydrochemical groups that could be important in the physical background. The figure shows the groups, which were categorized in the water samples in the seasons.

In the diagram of Hierarchical Cluster Analysis, there was only one cluster appear in the three field observations and the most representative observation and the Least representative Observation was summarized in Table 3. The dendrogram tree of water quality parameters for 40 samples selected for analysis has descriptive in Table 4. In April, 2014, the means of water quality parameters were of the temperatur was 16°C the dissolved oxygen was 23.01 mg/dL, salinity was 0.33 PPT, pH was 9.15, Turbidity was 60.545(NTU), and Chllorophyl was 4.95 µg/L. While, in May, 2016 the means of water quality parameters were of temperature (°C) was 19.6, the dissolved oxygen was 7.65 mg/dL, Salinity was 0.25 PPT, pH was 8.5, Turbidity was 37.32 NTU, and Chllorophyl was 5.68 µg/L. Also, in July, 2018 the means of water quality parameters were of temperature (°C) was 33.56, the dissolved oxygen was 10.55 mg/dL, Salinity was 0.24 PPT, pH was 10.26, Turbidity was 19.96 NTU, and Chllorophyl was 3.81 ug/L.

Figure 4 shows that the means of nutrients: total phosphorus (TP), total dissolved nitrogen and phosphatase have similar values while total Nitrogen (TN), total dissolved nitrogen (TDN), Ammonia (NH_4) and Phosphate (PO_4) have the maximum means values and more sensitive for resuspension in the water with the

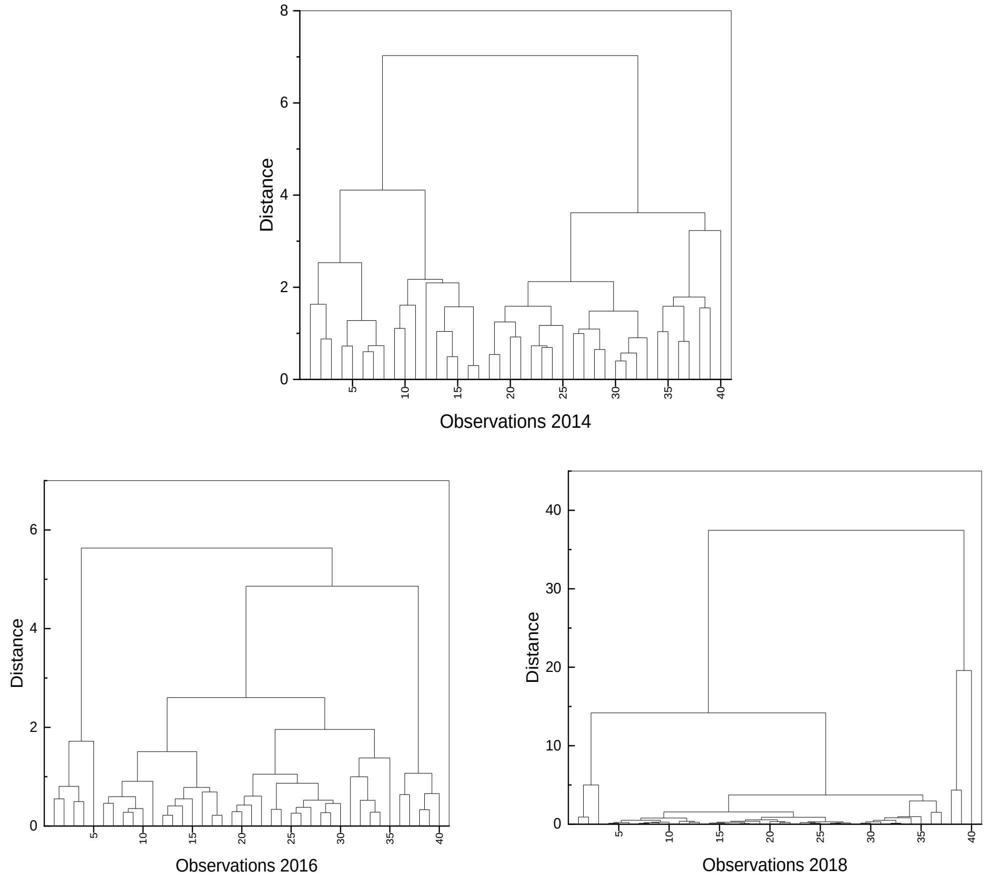

Figure 3. Diagram of hierarchical cluster analysis for water quality physical parameters during spring and summer seasons.

Table 2. Descriptive statistics of physical parameters of water quality in the spring and summer seasons.

Parameter	N.analysis	Mean	SD	Sum	Minimum	Medium	Maximum
TDS1/ 2014	4	0.46	1.29	1.85	0.457	0.465	0.47
TDS2/2016	4	0.34	0.006	1.37	0.340	0.34	0.34
TDS2/2018	Na	Na	Na	Na	Na	Na	Na
DO1/2014	4	8.76	0.091	35.07	8.676	8.75	8.89
DO2/2016	4	8.05	1.96	32.22	5.247	8.58	9.79
DO3/2018	4	10.21	0.005	40.86	10.21	10.215	10.22
Sal1/ 2014	4	0.35	0.005	1.40	0.35	0.35	0.36
Sal2/ 2016	4	0.25	0.004	1.02	0.25	0.25	0.26
Sal3/2018	4	0.24	0	0.96	0.24	0.24	0.24
Chllo-a1/2014	4	13.33	2.25	53.34	11.27	12.93	16.21
Chlo-a 2/2016	4	5.067	0.78	20.27	3.96	5.25	5.79
Chlo-a 3/2018	4	4.05	0.08	16.22	4	4.02	4.18
Turbidity 1	4	120.8	32.10	483.49	93.93	111.04	167.48
Turbidity 2	4	32.64	4.17	130.58	28.29	32.1	38.09
Turbidity 3	4	16.05	1.61	64.21	14.64	15.73	18.12
BGA-PC 1 µg/L	4	3961.8	1801.1	15847.4	1837.05	3905.10	6200.2
BGA-PC 2 µg/L	4	8126.3	7207.4	32505.4	2034.63	5972.8	18525.049
BGA-PC 3 µg/L	4	0.46	1.290	1.85963	0.457	0.465	0.47

Table 3. Most representative observation and the least representative observation.

Field observations time	Cluster	Most representative observation	Least representative observation
April, 2014	1	17	1
May, 2016	1	13	3
July, 2018	1	9	21

Table 4. Descriptive statistics of dendrogram of water quality parameters in 2014, 2016, and 2018 seasons.

Parameter	N analysis	Mean	S. deviation	Sum	Min.	Med.	Max.
2014							
Temp °C	40	16.99	0.119	679.9	16.8	17	17.2
DO/mg/L	40	23.01	3.861	920.4	15.22	23.7	30.35
SAL	40	0.33	0	13.2	0.33	0.33	0.33
pH	40	9.151	0.007	366.0	9.13	9.15	9.16
Turbidity	40	60.545	1.183	2421	58.5	60.3	63.8
Chl ug/L	40	4.95	0.695	198	3.5	5.05	6
2016							
Temp	40	19.6	0.047	786.67	19.61	19.65	19.82
ODO	40	7.65	0.263	305.97	7.26	7.615	8.16
SAL	40	0.25	0.003	10.05	0.25	0.25	0.26
pH	40	8.49	0.093	339.66	8.4	8.465	8.76
Turbidity	40	37.32	2.88	1492.8	31.1	37.3	42.7
Chl ug/L	40	5.68	0.407	227.25	4.84	5.71	6.56
2018							
Temp	40	33.56	0.026	1342.411	33.534	33.55	33.604
ODO	40	10.55	0.018	422.01	10.53	10.54	10.58
SAL	40	0.24	1.69	9.6	0.24	0.24	0.24
pH	40	10.26	0.064	410.41	10.17	10.26	10.38
Turbidity	40	19.96	11.15	798.47	13.32	15.89	67.66
Chl ug/L	40	3.810	0.098	152.43	3.64	3.81	4

strong wind and vessels conditions. Eutrophication changed in the equilibrium of the aquatic ecosystem and lead to the damage of the water ecosystem and the steady decline of its functions. Consequently, the impact on water quality characteristics appears worse in the transparency of the water. Therefore, the sunlight penetrates the water body and photosynthesis plants under the water layers will be decreasing totally. Water eutrophication caused the supersaturation of nutrients which means lack of dissolved oxygen in the water and this is very dangerous to aquatic animals. Also, Algae produces toxins and increases organic matter; the organic matter in the water produces harmful gases, which are toxic for the fish and seashell (Qin et al. 2007, Yang et al. 2008, Qin 2009, Wang and Wang 2009). Scholar's investigations found that the algae produced toxins, such as Cyanotoxins, were detected in the Yangtze River, in addition to many reservoirs and lakes of Yellow River valleys, apart from Dianchi Lake, Lake Taihu and Lake Chaohu (Ye et al. 2007, Yang et al. 2008).

The major influencing factors on water eutrophication include nutrient enrichment, hydrodynamics, environmental factors such as temperature, salinity, carbon dioxide, element balance, etc., and microbial and biodiversity. Waves and currents play an important role in sediment resuspension and internal nutrient release in large, shallow lakes. The turbidity started to increase at wind speeds of approximately 4 m/s and significantly increased when wind speeds exceeded 6 m/s. Wave-generated shear stress contributed more than 95% to sediment resuspension and that only in weak wind conditions (<4 m/s) and the shear stresses generated by currents and waves contributed equally. Other scholars found similar results by Ding et al. (2018), Jalil et al. (2019), and Asmaa

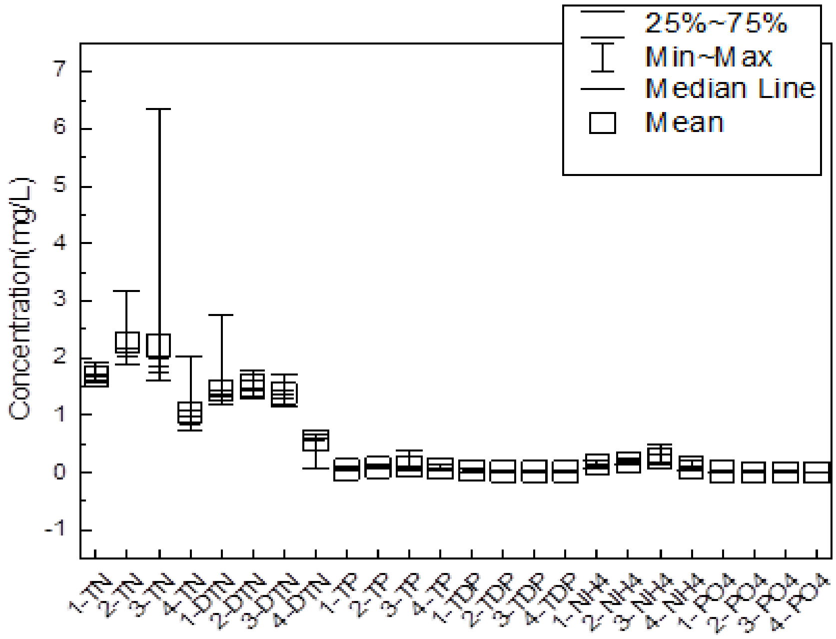

Figure 4. Box plot of the compression of concentration nutrients during suspension processes in fourth Hydrodynamic conditions in Meiliang Bay: 1- weak wind in 2014, 2- strong wind in 2014; 3- Vessels in 2016 and 4- Weak wind in 2018.

(2019).

Most of the previous sediment dynamics observations have been done in rivers and open channels where sediment resuspension is mainly caused by current-induced shear stress (Wang et al., 2014). However, it has been shown that wind-induced wave contributes significantly to the sediment resuspension process in shallow lakes, ponds, and nearshore of the lakes. Wave-generated shear stress contributed more than 70% to sediment resuspension in shallow lakes (Sheng, 1979; Wang et al., 2014). Understanding the mechanisms of water eutrophication is important and will help with the prevention of water eutrophication. Water eutrophication in lakes, reservoirs, estuaries, and rivers is prevalent around the world, specifically in developing countries such as China (Yang et al., 2008; Qin, 2009).

The results of the compressions method evaluate the spatial and temporal variation of the water surface quality of Meiliang Bay. The statistical analysis of all the selected variables Temperature (Temp)°C, Dissolved oxygen (DO)/mg/L, Salinity (SAL), pH, Chlorophyll-a (Chl-a) µg/L and Turbidity (Turbid) NTU are confirmed the trophic state (Table 2) and categorises statistically two different hydrochemical groups that could be important in the physical background. The compressions method provided similar results that corresponded with the lake's real trophic cases. Strong evidence that the regression relationship between chlorophyll-a, dissolved oxygen with P-value = 0.00, and pH levels in Meiliang bay are significantly time-dependent and correlated when algal growth increased the dissolved oxygen decreased in the seasons. Hypoxia is the result of low Dissolved oxygen content (≤2 mg/L) in shallow lakes and it lies at the variable depth of water profile causing eutrophication in shallow lakes (Zhou et al., 2013). This Bay is facing severe water quality and algal bloom problems (Zhu et al., 2013; Liu et al., 2014) which is directly related to the wind-induced vertical mixing of nutrients and reduced amount of dissolved oxygen causing increased hypoxia. Our finding is similar to the study found by Khan and Ansari (2005) which demonstrated that the pH and dissolved oxygen affecting water eutrophication and both factors are very important.

Also, increased the maximum means values of total Nitrogen (TN), total dissolved nitrogen (TDN), Ammonia (NH_4) and Phosphate (PO_4) with strong wind and vessels this indicated that during different hydrodynamic conditions the most nutrient released from the bottom layer in the lake by those forces is nitrogen and sensitive for resuspension in the water. Furthermore, the results revealed that nitrogen is the critical limiting factor to algal growth and eutrophication in Lake Taihu, this finding corresponds to the studies found by Alongi et al. (2003), Paerl et al. (2011). Moreover, Cheng and Li (2006) shown that the eutrophication or red tide happens when N concentration in water reaches 300 µg/L and P concentration reaches 20 µg/L. The trophic mean state in Meiliang Bay in the three summer seasons nearby the same but in 2014 is the strongest than 2016 and a noticeable decline in 2018. This result may be because of climate changed or the heavy rain during the field observation period.

Conclusion

The present study studied the compressions between different hydrodynamics conditions. Filed observations were in summer seasons at various hydrodynamic forces in Meiliang Bay Lake Taihu. The results indicated that the bottom layer has a significant impact on strong winds and vessel waves. Furthermore, when the shear stress generated by those forces, it impacted directly on the boundary of the lake and caused sediment resuspension leading to release nitrogen. The worst water quality was in summer season in 2014 and 2016, and then entirely decline in 2018. These results may be due to Typhon or heavy rain during the collection of data. The new method of hierarchical cluster analyses and variance was used to assess the water quality in different hydrodynamic conditions. The outcomes of this paper give a clear idea about the processes happening in the lake and which force is more effective on the boundary and released nutrients that encourage algal blooms in these seasons.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

American Public Health Association (APHA). (1998). Standard methods for the examination of water and wastewater. 20th ed. American Public Health Association, Washington, DC.

Alongi DM, Chong VC, Dixon P, Sasekumar A, Tirendi F (2003). The influence of fish cage aquaculture on pelagic carbon flow and water chemistry in tidally dominated mangrove estuaries of peninsular Malaysia. Marine Environmental Research 55: 313-333.

Asmaa Q (2019). Waves-waves collide induced by different wind directions caused high exchanged in the water level at the open area Shallow Lake, China African Journal of Environmental Science and Technology 13(2):91-103.

Bussmann I (2005). Methane release through resuspension of littoral sediment. Biogeochemistry 74:283-302.

Chao X, Jia Y, Shields FD, Wang SSY, Cooper CM (2008). Three-dimensional numerical modeling of cohesive sediment transport and wind wave impact in a shallow oxbow lake. Advances in water resources 31:1004-1014.

Chen J, Lu J (2014). Effects of land use, topography and socio-economic factors on river water quality in a mountainous watershed with intensive agricultural production in East china. PloS one 9:e102714-e102714.

Cheng X, Li S (2006). An analysis on the evolvement processes of lake eutrophication and their characteristics of the typical lakes in the middle and lower reaches of Yangtze River. Chinese Science Bulletin 51:1603-1613.

Dalyander PS, Butman B, Sherwood CR, Signell RP, Wilkin JL (2013). Characterizing wave- and current- induced bottom shear stress: U.S. middle Atlantic continental shelf. Continental Shelf Research 52:73-86.

Ding Y, Sun L, Qin B, Wu T, Shen X, Wang Y (2018). Characteristics of sediment resuspension in Lake Taihu, China: A wave flume study. Journal of Hydrology 561:702-710.

Eriksson BK, Sandström A, Isæus M, Schreiber H, Karås P (2004). Effects of boating activities on aquatic vegetation in the Stockholm archipelago, Baltic Sea. Estuarine, Coastal and Shelf Science 61:339-349.

Gabel F, Lorenz S, Stoll S (2017). Effects of ship-induced waves on aquatic ecosystems. Science of The Total Environment 601-602:926-939.

Gao X, Li Y, Tang C, Acharya K, Du W, Wang J, Luo L, Li H, Dai S, Yu Z (2017). Using ADV for suspended sediment concentration and settling velocity measurements in large shallow lakes. Environmental Science and Pollution Research 24:2675-2684.

Grant WD, Madsen OS (1979). Combined wave and current interaction with a rough bottom. Journal of Geophysical Research: Oceans 84:1797-1808.

Hawley N (2000). Sediment resuspension near the Keweenaw Peninsula, Lake Superior during the fall and winter 1990-1991. Journal of Great Lakes Research 26:495-505.

Jalil A, Li YP, Zhang K, Gao XM, Wang WC, Khan HOS, Pan BZ, Ali S, Acharya K (2019). Wind-induced hydrodynamic changes impact on sediment resuspension for large, shallow Lake Taihu, China. International Journal of Sediment Research 34:205-215.

James RT, HK, Zhu GW, Qin BQ (2009). Comparative analysis of nutrients, chlorophyll and transparency in two large shallow lakes (Lake Taihu, PR China and Lake Okeechobee, USA). Hydrobiologia 627:211-231.

Jiang L, Li Y, Zhao X, Tillotson MR, Wang W, Zhang S, Sarpong L, Asmaa Q, Pan B (2018). Parameter uncertainty and sensitivity analysis of water quality model in Lake Taihu, China. Ecological Modelling 375:1-12.

Jiang W, Pohlmann T, Sündermann J, Feng S (2000). A modelling study of SPM transport in the Bohai Sea. Journal of Marine Systems 24:175-200.

Jin XTQ (editors) (1990). The standard methods for observation and analysis in lake eutrophication. 2nd ed. Beijing (China). Chinese Environmental Science Press 240 p. Chinese.

Khan F, Ansari A (2005). Eutrophication: An Ecological Vision. Botanical Review 71:449-482.

Li Y, Jalil A, Du W, Gao X, Wang J, Luo L, Li H, Dai S, Hashim S, Yu Z, Acharya K (2017a). Wind induced reverse flow and vertical profile characteristics in a semi-enclosed bay of large shallow Lake Taihu, China. Ecological Engineering 102:224-233.

Li Y, Tang C, Wang J, Acharya K, Du W, Gao X, Luo L, Li H, Dai S, Mercy J, Yu Z, Pan B (2017b). Effect of wave-current interactions on sediment resuspension in large shallow Lake Taihu, China. Environmental Science and Pollution Research 24:4029-4039.

Linares A, Wu CH, Anderson EJ, Chu PY (2018). Role of Meteorologically Induced Water Level Oscillations on Bottom Shear Stress in Freshwater Estuaries in the Great Lakes. Journal of Geophysical Research-Oceans 123:4970-4987.

Liu J, Wang P, Wang C, Qian J, Hon J, Hu B (2014). The macrobenthic community and its relationship to the contents of heavy metals in the surface sediments of Taihu Lake, China. Fresenius Environmental Bulletin 23:1697-1707.

Luettich RA, Harleman DR, Somlyody L (1990). Dynamic behavior of suspended sediment concentrations in a shallow lake perturbed by episodic wind events. Limnology and Oceanography 35:1050-1067.

Ma J, Wang P, Ren L, Wang X, Paerl HW (2019). Using alkaline phosphatase activity as a supplemental index to optimize predicting algal blooms in phosphorus-deficient lakes: A case study of Lake Taihu, China. Ecological Indicators 103:698-712.

Madsen O (1976). Wave climate of the continental margin: elements of its mathematical description. Marine Sediment Transport in Environmental Management pp. 65-87.

Nazari-Sharabian M, Ahmad S, Karakouzian M (2018). Climate Change and Eutrophication: A Short Review. Engineering, Technology and Applied Science Research 8:3668-3672.

Paerl HW, Xu H, McCarthy MJ, Zhu G, Qin B, Li Y, Gardner WS (2011). Controlling harmful cyanobacterial blooms in a hyper-eutrophic lake (Lake Taihu, China): The need for a dual nutrient (N & P) management strategy. Water Research 45:1973-1983.

Pang Y, Li Y, Luo L (2006). Study on the simulation of transparency of Lake Taihu under different hydrodynamic conditions. Science in China

Series D 49:162-175.
Peters L (2005). Periphyton as a Habitat for Meiofauna: a case of a neglected community.
Qin B (2009). Lake eutrophication: Control countermeasures and recycling exploitation. Ecological Engineering 35:1569-1573.
Qin B, Xu P, Wu Q, Luo L, Zhang Y (2007). Environmental issues of Lake Taihu, China. Hydrobiologia 194:3-14.
Qin BHW, GAO G, LUO L, ZHANG J (2004). Dynamics of sediment resus- pension and the conceptual schema of nutrient release in the large shallow Lake Taihu, China. Chinese Science Bulletin 49: 54-64.
Scheifhacken N (2006). Life at turbulent sites: benthic communities in lake littorals interacting with abiotic and biotic constraints; field and mesocosm investigations.
Sharip Z, Shah SA, Jamin A, Jusoh J (2018). Assessing the Hydrodynamic Pattern in Different Lakes of Malaysia. Applications in Water Systems Management and Modeling, Daniela Malcangio, IntechOpen.
Sheng YP, Lick W (1979). The transport and resuspension of sediments in a shallow lake. Journal of Geophysical Research 84 (C4) 1809.
Shih W, Diplas P, Celik AO, Dancey C (2017). Accounting for the role of turbulent flow on particle dislodgement via a coupled quadrant analysis of velocity and pressure sequences. Advances in water resources 101:37-48.
Wang A, Ye X, Du X, Zheng B (2014). Observations of cohesive sediment behaviors in the muddy area of the northern Taiwan Strait, China. Continental Shelf Research 90:60-69.
Wang H, Wang H (2009). Mitigation of lake eutrophication: Loosen nitrogen control and focus on phosphorus abatement. Progress in Natural Science 19:1445-1451.
Wang J, Fu Z, Qiao H, Liu F (2019). Assessment of eutrophication and water quality in the estuarine area of Lake Wuli, Lake Taihu, China. Science of The Total Environment 650:1392-1402.
Wei J, Li YP, Weng SL, Huang DJ, Du W, M X, Gao WC, Wang JW, Wang SS, Zhang M, Jepkirui A, Nwankwegu S, Norgbey E, Asmaa Q (2019). Determination of threshold parameter in quadrant splitting for identifying coherent motions in Lake Taihu, China. Journal of Soils and Sediments 19:1017-1028.
Whitehouse R (2000). Dynamics of Estuarine Muds: A Manual for Practical Applications. Thomas Telford.
Wu T-F, Qin B-Q, Zhu G-W, Zhu M-Y, Wei L, Luan C-M (2013). Modeling of turbidity dynamics caused by wind-induced waves and current in the Taihu Lake. International Journal of Sediment Research 28:139-148.
Yang X-E, Wu X, Hao H-l, He Z-l (2008). Mechanisms and assessment of water eutrophication. Journal of Zhejiang University. Science. B 9:197-209.
Ye C, Xu Q, Kong H, Shen Z, Yan C (2007). Eutrophication conditions and ecological status in typical bays of Lake Taihu in China. Environmental Monitoring and Assessment 135:217-225.
Zheng S-S, Wang P-F, Wang C, Hou J (2015). Sediment resuspension under action of wind in Taihu Lake, China. International Journal of Sediment Research 30:48-62.
Zhou Y, Obenour DR, Scavia D, Johengen TH, Michalak AM (2013). Spatial and temporal trends in Lake Erie hypoxia, 1987–2007. Environmental science & technology 47:899-905.
Zhu M, Zhu G, Li W, Zhang Y, Zhao L, Gu Z (2013). Estimation of the algal-available phosphorus pool in sediments of a large, shallow eutrophic lake (Taihu, China) using profiled SMT fractional analysis. Environmental pollution 173:216-223.

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