A Study of Bushfires in a Ghanaian Coastal Wetland. I. Impact on Small Mammals

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Abstract

The study was undertaken at the Muni-Pomadze wetlands near Winneba in the Central Region of Ghana. The main objective of the study was to investigate the impact of bushfires on the small mammal community of this coastal wetland, since this has long-term negative implications for the biodiversity, ecotourism potential and the socio-economic well-being of the people of the area. The methodology involved the monitoring of the relative abundance and diversity of the small mammal community on burnt and unburnt habitats of the area using live-trapping. There were 268 captures of four rodent and one insectivore species, notably *Tatera kempi* (Kemp's gerbil), *Lemniscomys striatus* (spotted zebra mouse), *L. barbarus* (striped zebra mouse), *Mastomys erythroleucus* (multimammate mouse) and *Crocidura crossei* (white-toothed shrew). Kemp's gerbils were the most dominant species captured (87%), followed by spotted zebra mice (7.0%). Multimammate mice and the white-toothed shrew were captured on only the unburnt plots, while the others occurred on both plots. There was significantly higher relative abundance and species diversity on the unburnt than the burnt plots, and sexual activity was also generally higher on the unburnt plots. Breeding activity of the rodents was at its highest towards the begining of the rains in May/June. The results indicated a general degradation of the wetland habitat as a result of rampant bushfires. The relative abundance, diversity and biomass of the small mammals populations were also negatively affected. It is, therefore, recommended that reforestation, as well as public education and awareness programmes should be initiated in the area. Local participation in biodiversity conservation initiatives should also be enhanced.

Introduction

The Muni-Pomadze wetlands, located near Winneba in the Central Region of Ghana, is one of the five internationally-recognized coastal wetlands (Ramsar sites) in Ghana. This is because of its importance as a habitat for resident and migratory water birds (waders, terns, etc.) (Ntiamoa-Baidu & Gordon, 1991). Its importance also stems from its use as the traditional hunting grounds of the local Effutu people during their annual "Aboakyer" Festival, which is of immense socio-economic benefit both locally and nationally (Wilson, 1963; Wyllie, 1968). Unlike the other four internationally-recognized coastal wetlands, the Muni-Pomadze wetland appears to be especially vulnerable to bushfires, because of its significantly more extensive (98%) dry land coverage (Amatekpor, 1994). The widespread practice of deliberate setting of bushfires by the local people, especially during the dry season, could also be a factor. The area also represents one of the high risk areas for bushfires in the Central Region (Gboloo, 1998). Unfortunately, such unsustainable human use and the apparent neglect of the wetland have resulted in its degradation over the years, with the town of Winneba no longer "situated among trees" as Dickson (1969) put it. The current situation, if allowed to persist, will result in the loss of rich biodiversity from the wetland, with its attendant adverse effect on its eco-tourism potential.

Bushfires have been defined as "fires set to bush with an intended purpose, but which get out of control, spread quickly and devastate non-target areas" (Akpene, 2001). Bushfires can be caused naturally through lightning and ignition of combustible material by rolling rocks, deliberately through arson, agricultural or construction land clearing, or accidentally through careless use (cooking, cigarette butts, etc.). Bushfires are inevitable in dry ecosystems (e.g. tropical savannas), but it is often the human-caused bushfires, estimated to constitute 98% of all the bushfires recorded in Ghana, which cause more damage to the environment (Gboloo, 1998). Bushfires are considered to be one of the leading causes of deforestation in West Africa (Korem, 1985).

Before the 1970s, bushfires had been less frequent and severe in Ghana, but have become more rampant in recent times. This is largely due to undesirable human activities and, to a lesser extent, changes in climatic and environmental conditions (e.g. the severe Sahelian drought and strong harmattan winds). The current situation, if allowed to persist, poses very real threats to biodiversity conservation in Ghana (Swaine *et al.*, 1997; Gboloo, 1998). For example, there were 847 recorded bushfires in Ghana in 1982 (Environmental Protection Council, 1986), resulting in the loss of about 50% of vegetation cover and the destruction of about 35% (154,000 metric tons) of standing crop and stored cereals (Ampadu-Adjei & Atsiatorme, 1988; Gboloo, 1998).

The assessment of the environmental quality of an area involves the use of certain plant and animal species as bio-indicators, because of certain peculiar characteristics they possess. The presence, absence or relative abundance of such bio-indicators forms the basis of an assessment of environmental health (level of environmental degradation) (Martin & Coughtrey, 1982). The rapid turnover and high reproductive capacity of small mammals, coupled with their sensitivity to environmental degradation (Decher, 1987), make them important bio-indicators. The effect of bushfires on small mammal populations could be either direct (killing), or indirect (exposure to intense predation through destruction of habitat, nesting materials and food sources) (Delany, 1964). Both situations pose problems for biodiversity conservation, since small mammals play important ecological roles (predators, seed dispersers and prey species) in the ecosystem food web.

The main objectives of this study were to (i) investigate the effect of bushfires on the abundance and diversity of the small rodent species inhabiting the Muni-Pomadze wetland, and (ii) assess the level of degradation of the wetland. Based on the hypothesis that the abundance, diversity, and reproductive activity of the rodents will be affected by bushfires, it was predicted that significant differences in the above parameters will occur between burnt and unburnt ("natural") habitats in the study area. The ultimate objective was to provide useful scientific data for the development of more effective management strategies for the wetland, especially the conservation of its biodiversity and the improvement of its ecotourism potential, as well as the improvement of the socio-economic well-being of the local people.

Materials and methods

Study area

The Muni-Pomadze Ramsar Site (5° 19' - 5° 37' N, 0° 37' - 0° 41' W) encompasses over 90 km^2 of the Muni Lagoon watershed located near Winneba in the Central Region (Fig. 1), about 56 km west of Accra. The wetland is bounded on the north by the Yenku A Forest Reserve established in 1937 (Hawthorne & Abu-Juam, 1995), on the south by the Atlantic Ocean, on the west by the Mankwaafa, Brounye and Boaku rivers, and on the east by the Ayensu river and Pratu stream (Fig. 2).

The wetland falls within the coastal savanna vegetation zone of Ghana, with a bimodal rainfall distribution and a low mean annual rainfall of about 854 mm. The major rainy season occurs from March/April to July/August with a peak in June, while the minor rainy season runs from September to November. The major dry season runs from December to March, and the minor dry season from August to September. Mean annual temperature ranges from 24 °C in August to 29 °C in March with a relative humidity (RH) range of 75-80%. The vegetation is Southern Marginal Forest, consisting mainly of grassland and islands of thicket and savanna trees (Hall & Swaine, 1981) dominated by *Andropogon gayanus, Heteropogon contor-tus, Panicum maximum* and *Sporobolus pyra-midalis.* About 40% of the area was converted into *Eucalyptus,* neem *(Azadirachta indica)* and teak plantations when forest reserves (Yenku Block A and Yenku Block B) were established in the area.

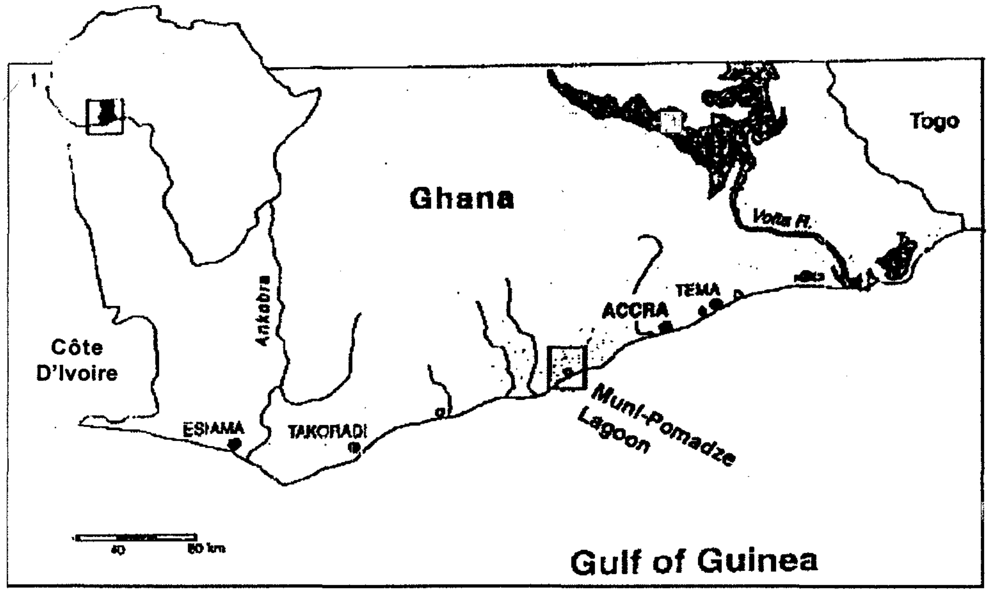

Fig. 1: Map of Southern Ghana Showing the Study Area: Muni-Pomadze Wetlands

Farming and arti-sanal fishing (marine and lagoon) are the main human activities in the wetland, the main cultivated crops being maize and cassava. There are other human activities like hunting, sand winning, charcoal making, crafts, salt and clay mining, alcohol distillation, quarrying and trading (Dadson, 1984). There are 11 human settlements in the wetland, the largest being Winneba with a population of 27,000 (Grimble *et al.,* 1998).

Plot demarcation and vegetation burning

Two main sampling plots were

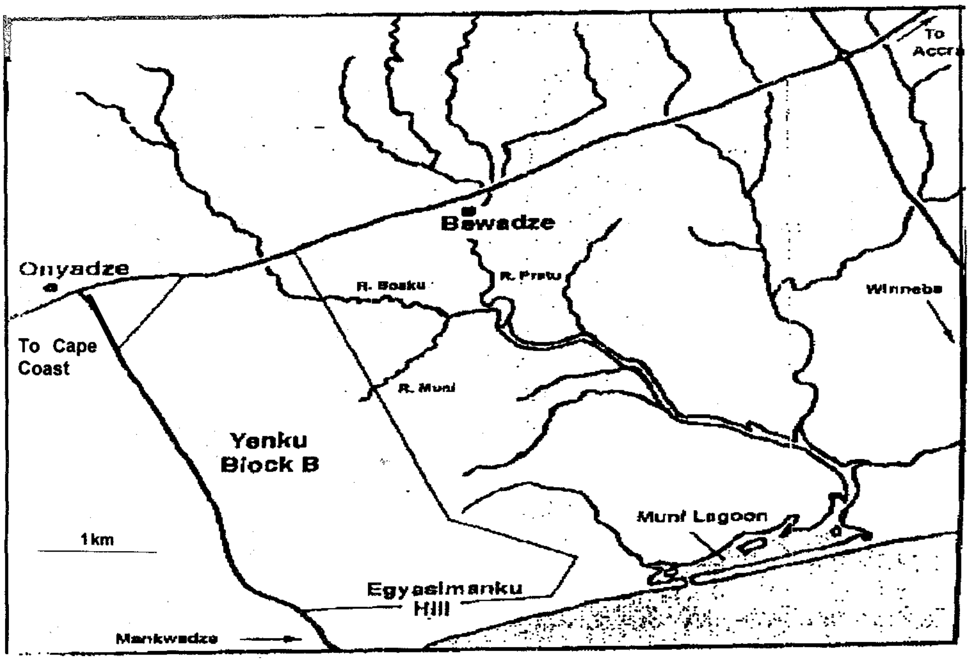

Fig. 2: Map of the southern part of the Muni-Pomadze Ramsar Site surrounding the Muni lagoon.

demarcated: (i) undisturbed or natural (unburnt) habitat, and (ii) disturbed (burnt) habitat. The undisturbed area represented a natural state, unaffected by human activities (e.g. burning, cultivation, fuelwood gathering, etc.) that characterized the burnt habitat, which was subjected to controlled burning with the help of District Fire Officers of the National Fire Service. Fire barriers were created to ensure that the fire did not spread to non-target areas.

Small mammal trapping techniques

Four plots, each measuring 25 m × 25 m were randomly demarcated on the study area along the northern margin of the Egyasimanku Hills (Fig. 2). Two of the plots located about 500 m apart were demarcated on the burnt area, while the other two located also 500 m apart were located in the undisturbed (unburnt) area. On each of the four plots, 25 Sherman live traps (Sherman Trap Co., Kentucky, USA) measuring 7.6 m × 3.5 m × 23 m were set in a rectangular array at trap-stations with inter-trap distances of 10 m and each trap-line measuring 50 m. Trap-stations were permanently marked with red flagging tape for easy identification. One side of each grid was lettered A to E, while the other side perpendicular to it was numbered 1 to 5, giving each trap-station an alphanumeric code or unique identification number (e.g. A1, A3, B2, C3, E4, etc.). The traps were set late in the evening, between 3.00 p.m. and 5.00 p.m. and baited with fresh mixture of groundnut paste and corn meal. Each trap was checked twice daily, early in the morning and late afternoon, when they were reset and re-baited. There were three consecutive nights (4 days) of trapping every month for 6 months on each plot, making a total of 300 trap-nights (one trap-night = one trap set for one night) per trapping period, and a total of 1,800 trap-nights for the 6-month study.

Captured animals were shaken gently from the trap into a meshed cloth bag, identified, sexed (using the anal-genital distance, which is longer in males), aged (assigned to three broad age-classes: juvenile, sub-adult and adult), weighed, examined for reproductive condition (abdominal or scrotal testes in males; enlarged nipples, perforate vaginas and pregnancy in females), and released at the point of capture. The above information, including the trap-station number, was recorded on field data sheets, the main assumption being that the more abundant species will be encountered more frequently than the less abundant ones. Key references for small mammal identification were Delany & Happold (1987), Kingdon (1997) and the University of Ghana Zoology Museum. The small mammal field handling techniques followed Wilson *et al.* (1997).

Analysis of data

The relative abundance (R.A.) (number of individuals of a particular species per 100 trap-nights) of the captured species in the various habitats was estimated as follows (one trap-night = one trap set for one night):

$$RA = \frac{\text{Number of individuals captured} \times 100}{\text{Number of trap-nights (TN)}}$$

Species diversity was estimated using Shannon-Wiener Index (Magurran, 1988) as follows:

$$H' = -\sum_{i=1}^{s} p^i \ln p^i$$

where H' = species diversity; s = number of species; p^i = proportion of i^{th} species in the sample.

The fresh biomass of each species of rodents was obtained by computing the mean weight of all adult rodents captured in a particular habitat. Statistical analysis involved the use of two-way analysis of variance (ANOVA), t-tests and chi-square at 5% level of significance (Fisher & Yates, 1963) using the computer programme, Statistical Package for Social Studies (SPSS) for Windows (Student's version) to compute frequencies and percentages, and Minitab for Windows to test for significance.

Results

Relative abundance and diversity of small mammals

There were 268 captures of five species of small mammals in 1,800 trap-nights, giving a high overall trapping success of 14.9%. There were four species of rodents (*Tatera kempi*–Kemp's gerbil, *Lemniscomys striatus* – zebra mouse, *L. barbarus*– zebra mouse and *Mastomys erythroleucus*– multimammate mouse), and one insectivore species, *Crocidura crossei* (white-toothed shrew). *T. kempi* was the most numerous species, making up about 87% of total captures (Table 1). The least abundant species was *M. erythroleucus* (1.5%). Only one individual, *C. crossei,* was captured during the study. Trapping success in the unburnt plot (19%) was higher than that in the burnt plot (10.7%), based on the assumption that all the species of rodents had an equal chance of being trapped, and the rodents were evenly-distributed on the plots. As expected, *T. kempi* were only captured in the mornings, while the zebra mice *(L. striatus and L. barbarus)*, being crepuscular and diurnal, were captured both in the mornings and evenings. Species diversity of the rodent community in the unburnt plot (0.58) was greater than in the burnt plot (0.39). All five species were captured in the unburnt plot, but only three of the species *(T. kempi, L. striatus, L. barbarus)* were captured in the burnt plot (Table 1).

Small mammal population dynamics

There were no captures in the burnt vegetation immediately after burning, and the captures were generally low until April/May. Monthly fluctuations in the total capture of all the rodent species appeared to be dependent on fluctuations in numbers of the commonest species, *T. kempi*. Monthly total captures of all the rodent species trapped in the unburnt plot were generally higher than in the burnt vegetation. In both burnt and unburnt plots, the number of rodent captures continued to increase from April to the end of sampling in July, but the increase was steeper in the burnt vegetation (Table 2). The relative abundance of *T. kempi* increased after April in the unburnt plot, while that of *L. striatus* and *L. barbarus* decreased during the same period. In the burnt plot, the relative abundance of *T. kempi* increased sharply after March until June. Zebra mice were absent in the burnt

TABLE 1

Relative abundance and species diversity of small mammals at Muni-Pomadze Ramsar Site

Species	*Burnt plot*			*Unburnt plot*		
	No. of captures	*% Total*	*Relative abundance*	*No. of captures*	*% Total*	*Relative abundance*
Tatera kempi	87	89.7	9.7	146	85.4	16.2
Lemniscomys striatus	7	7.2	7.0	12	7.0	1.3
Lemniscomys barbarus	3	0.3	4.7	8	4.7	0.9
Mastomys erythroleucus	0	0	2.3	4	2.3	0.4
Crocidura crossei	0	0	0.6	1	0.6	0.1
Total	97	100		171	100	
Number of species (S)	3			5		
Species diversity (H')	0.39			0.58		

TABLE 2

Monthly changes captures of three common rodent species at Muni-Pomadze Ramsar Site

Species	*Total captures per month*												
	Unburnt plot						*Burnt plot*						*Total*
	F	*M*	*A*	*M*	*J*	*J*	*F*	*M*	*A*	*M*	*J*	*J*	
Tatera kempi	15	19	24	27	37	24	10	10	14	17	18	18	**233**
Lemniscomys striatus	3	3	2	2	2	0	0	0	1	1	2	3	**19**
Lemnicomys barbarus	3	3	1	1	0	0	0	0	0	0	1	2	**11**
Total	21	24	27	30	39	24	10	10	15	18	21	23	
Grand total			166 (63.1%)						97 (36.9%)				263

plot between February and April. *L. striatus* occurred earlier in April, while *L. barbarus* were captured only after the beginning of the rains in May. Generally, more captures were recorded after rainy days than drier days.

Fresh biomass of small mammals

The fresh biomass of the rodent species in the unburnt plot was higher than that of the burnt plot, and the fresh body weight of all the species varied during the study. The weight of *T. kempi* varied between 40 and 150 g, while that of *L. barbarus* varied between 20-50 g. Males were generally heavier than females. There was no significant difference in the biomass of *T. kempi* between burnt and unburnt plots (Tab $t_{0.05}$ = 1.654; Cal $t_{0.05}$ = -0.01; p-value = 0.99). There were, however, significant differences in the biomass of *L. striatus* (Tab $t_{0.05}$ = 1.654; Cal $t_{0.05}$ = - 2.39; p-value = 0.016) and that of *L. barbarus* (Tab $t_{0.05}$ = 1.654; Cal $t_{0.05}$ = - 3.15; p-value = 0.026) between the burnt and unburnt plots(Table 3).

Age structure

Table 4 summarises the numbers of juveniles, sub-adults and adults of the three commonest rodents captured during the study. Adult *T. kempi* were recorded on both burnt and unburnt plots. In the unburnt plots, however, adult *L. striatus* and *L. barbarus* were absent from the captures only toward the end of the study. The total number of different species of adult rodents captured in the unburnt plots was higher than in the burnt plots. Both plots had juveniles of *T. kempi* (3.4% and 2.7% of total captures in burnt and unburnt plots, respectively), but no juveniles of *L. striatus* and *L. barbarus*. Sub-adults of *L. striatus* and *L. barbarus* were only absent in the burnt plot.

Reproductive characteristics of the rodent community

Throughout the study, there were no lactating females of the four rodent species on the burnt plot, which also recorded more females with imperforate than perforate

TABLE 3

Fresh biomass of mature adult rodents at Muni-Pomadze Ramsar Site

	Mean weight of captured adult (grams)	
Species	Unburnt plot	Burnt plot
Tatera kempi	69.9	70.0
Lemniscomys striatus	30.0	33.6
Lemniscomys barbarus	30.0	40.3
Mastomys erythroleucus	-	50.0

Table 4

Numbers of captured rodents of different age-groups in burnt and unburnt plots (percentages in brackets)

	Unburnt plot			Burnt plot		
Species	Adult	Sub-adult	Juvenile	Adult	Sub-adult	Juvenile
Tatera kempi	121 (89)	21 (81)	4 (100)	71 (88)	13 (100)	3 (100)
Lemniscomys striatus	9 (7)	3 (11)	0 (0)	7 (8)	0 (0)	0 (0)
Lemniscomys barbarus	6 (4)	2 (8)	0 (0)	3 (4)	0 (0)	0 (0)
Total	136 (81.9)	26 (15.7)	4 (2.4)	81 (83.5)	13 (13.4)	3 (3.1)

vaginas, suggesting reduced breeding activity. The females with imperforate vaginas were both adults and sub-adults. There were, however, lactating females on the unburnt plot. Some individuals of *T. kempi* and *L. barbarus* captured in the burnt plots were either pregnant or had perforated vaginas, an indication of sexual activity. All *L. barbarus* females captured in the same plot were imperforate. The study also indicated that there were more sexually active females (perforated vaginas, lactating, pregnant) in the burnt than unburnt plots (Table 4). Pregnant *T. kempi* individuals were captured on the unburnt plot throughout the study except in February, while on the burnt plot pregnant individuals were captured only during June/July at the peak of the rains. The only pregnant *L. striatus* was captured in May. Both of the two female *M. erythroleucus* captured were sexually active. There were generally higher numbers of males of *T. kempi* and *L. barbarus* with scrotal testes (indication of sexual activity) in the unburnt plot than in burnt plot (Table 5). In the unburnt plot, however, all the males of the four species captured showed some signs of sexual activity, although *M. erythroleucus* had the highest.

Discussion

The high relative abundance of the nocturnal *T. kempi* could be attributed to the lack of competition from the diurnal and crepuscular zebra mice. The occurrence of *M. erythroleucus* at the end of the sampling period in July could be the result of increased farming activities in June, the main farming season. Happold (1974) reported a similar association between *Mastomys* and cultivation in Nigeria, where the species probably invaded the plots from neighbouring maize and cassava farms. Decher & Bahian (1999) also found that *M. erythroleucus* is not an old forest species, but rather invades young secondary forest from neighbouring farmland. The higher captures during the rainy season were probably due to increased ground cover and food availability (insects, worms, etc.). Happold & Happold (1991) also reported lower abundance of rodents in the dry season than in the rainy season, while Green & Taylor (1975) attributed the depletion of rodent numbers to the removal of ground cover.

The diversity of terrestrial small mammal fauna depends on the nature of the habitat (Ryan & Attuquayefio, 2000), with more stable ecosystems (e.g. tropical rain forest)

Table 5

Reproductive characteristics of rodents at Muni-Pomadze Ramsar Site (total numbers in brackets)

Species	**Percentage of sexually-active individuals*			
	Females		*Males*	
	Unburnt plot	*Burnt plot*	*Unburnt plot*	*Burnt plot*
Tatera kempi	51.4	37.8	76.4	52.4
Lemniscomys striatus	75.0	25.0	83.3	66.7
Lemniscomys barbarus	50.0	0	75.0	0
Mastomys erythroleucus	100	0	100	0

* Female sexual activity: Pregnancy, enlarged nipples (lactating), perforated vaginas
* Male sexual activity: Scrotal or enlarged testes

having higher species diversity than seasonally- or periodically-perturbed ones. The low diversity of small mammal species in the study area could indicate a low community stability, in turn a probable result of frequent disturbances due to undesirable human activities (e.g. bushfires, fuelwood harvesting, farming, hunting, etc.). The higher species diversity in the unburnt plot may be attributed to the availability of better living conditions (e.g. shelter, food and nesting materials) for the small mammals. Nel & Rautenbach (1975) observed that the distribution of rodents in a particular habitat is influenced by the amount of cover and structure of the substrate. The results obtained in this study suggest a greater influence of amount of cover, since the substrate was similar in both burnt and unburn plots. Being more luxuriant, the unburnt plot probably provided better refuge for nesting and foraging on insects and seeds, which are important sources of food for rodents, especially during the dry season (Happold & Happold, 1991).

One of the immediate effects of bushfires in the study area was the attraction of large numbers of predators of small mammals to the area, likely because of easier prey detection. Many predatory birds (e.g. hawks) were observed whenever there was burning of vegetation. Lawrence (1966) suggested that the lack of cover during the immediate post-burnt periods forced surviving prey species to forage in undesirable places lacking adequate cover. The absence of breeding females in the burnt plots may be due to the low quality and quantity of food, and the lack of cover and nesting material after burning, since the vulnerable juvenile rodents need to be adequately protected from predators.

The number of captures of breeding females in the burnt plots increased after the rains from April/May to July, when a new flush of grass and other plants appeared in the burnt plots and probably attracted insects after the rains, encouraging the invasion of adults. A similar phenomenon was reported by Happold (1974) in Nigeria, while Neal (1968) suggested that breeding in savanna rodents could be related to rainfall, which increases insect populations, and provides adequate protein-rich diets for pregnant and lactating females. Even in the unburnt plots, sexually-active individuals were more abundant during the rains, suggesting that both the nutritive value and abundance of food are important during the breeding season. With the onset of rains, previously dry food became more tender and succulent, providing nutritive food for both pregnant and/or lactating rodents and their offspring. According to Rose-Innes (1971) bushfires cause the release of "sprouting promoter substances" which increase ground cover, enabling the rodents to move about more freely in search of food. Increased ground cover also probably encouraged the immigration of adult rodents from dry season refugia with low grass cover.

From the results of this study, it is recommended that the inhabitants of the study area should be educated on both the beneficial and detrimental impacts of bushfires on biodiversity conservation, and, therefore, their judicious use. Volunteer fire squads could also be formed to fight bushfires whenever they occur. There is also the need to translate anti-bushfire laws (e.g. PNDC L. 229) to the predominantly illiterate inhabitants of the study area, in addition to ensuring the strict enforcement of such laws (Gboloo, 1998). Reafforestation programmes with full local participation (traditional rulers, opinion leaders, local envirомnental NGOs, etc.) are also recommended. The above recommendations should form part of a management plan which should be evolved for the wetland.

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