Preliminary Report 2015/2016

The impact of the Mauritius fruit bat (*Pteropus niger*) on commercial fruit farms: possible mitigation methods and GPS tracking of bats

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Introduction

The Mauritian fruit bat (*Pteropus niger*) is a medium-sized Old World fruit bat with an average weight of adult female of 473g (Nyhagen *et al*., 2005). It is endemic to the Mascarene Islands and was once found throughout the archipelago. The bat is however now found only on the island of Mauritius because of habitat destruction and hunting (Cheke and Dahl, 1981).

Mauritius has retained only less than 1% of its good quality native vegetation cover and lost 46% of its native vertebrate fauna (Safford, 2001). Remaining wildlife is strongly associated with native vegetation, which is invaded by exotic species. At least 47 species are highly invasive and cause native habitat degradation. Additionally, numerous exotic animal species cause destruction to native plants, their fruits or seeds, and also spread invasive plant species (Safford, 2001).

Bats were the only mammals to naturally colonise the Mascarenes and as a consequence it is likely that the Mauritius fruit bat, as the only extant frugivorous mammal, plays an important role in the regeneration of the islands' native flora. A study on the foraging ecology of this bat recorded 22 food plant species in the diet (of which 32% were endemic). It suggested that these bats are important seed dispersers for several endemic/native plant species and are probably also involved in the pollination of some of them (Nyhagen, 2001, Nyhagen *et al*., 2005). For example the endemic forest canopy tree bois de natte (*Labourdonnaisia glauca)* shows adaptations to, and possibly a dependence on, seed dispersal by bats as these are the only native vertebrates feeding on this tree. There is a paucity of data on the habitat use and movement patterns of *P. niger*, so the ecosystem function of this species has not been adequately assessed.

The population of these bats had increased during the last decade and there are increasing claims that it is doing considerable damage to the commercial fruit crops and in particular to the litchi and mango crops. At present, the species is viewed as a common pest, having been implicated in crop damage by fruit farmers and back yard fruit growers. Fruit growers have been lobbying the Mauritian Government since 2002 (D. Sarjua, in litt. to Ministry of Agriculture, 18 Dec. 2002, copied to MWF) to remove *P. niger* from the protected species list so that the species may be legally controlled in orchards. In 2015 this lobbying was successful, a cull was implemented and the official number of bats killed was 30,938, although the reliability of this estimate is questionable.

The Impact of Bats on Fruit Farms and Mitigation Methods

Between October 2015 and February 2016 work was carried on at litchi and mango orchards to assess the damage that Mauritius fruit bats (*Pteropus niger*) and other animals cause to the fruit plantations. Additionally, longan trees were assessed along road sides in the Moka area. Netting of litchi trees was implemented to evaluate whether netting can serve as a non-lethal solution to protect fruit crops and avoid harm to the bats.

The main species feeding on fruiting trees were birds: red-whiskered bulbul (*Pycnonotus jocosus*), common myna (*Acridotheres tristis*), and the ring-necked parakeet (*Psittacula krameri*). Mammals feeding on fruit included the crab-eating macaque (*Macaca fascicularis*), black rats (*Rattus rattus*) and the Mauritian fruit bat (*Pteropus niger*).

Study site

The work took place in six litchi orchards (Fig.1), these were: Calebasses, Medine, Constance, Belle Vue Maurel, Reduit and Savanna and at one Mango orchard in Labourdonnais. The longan trees were assessed in St. Pierre village (Moka).

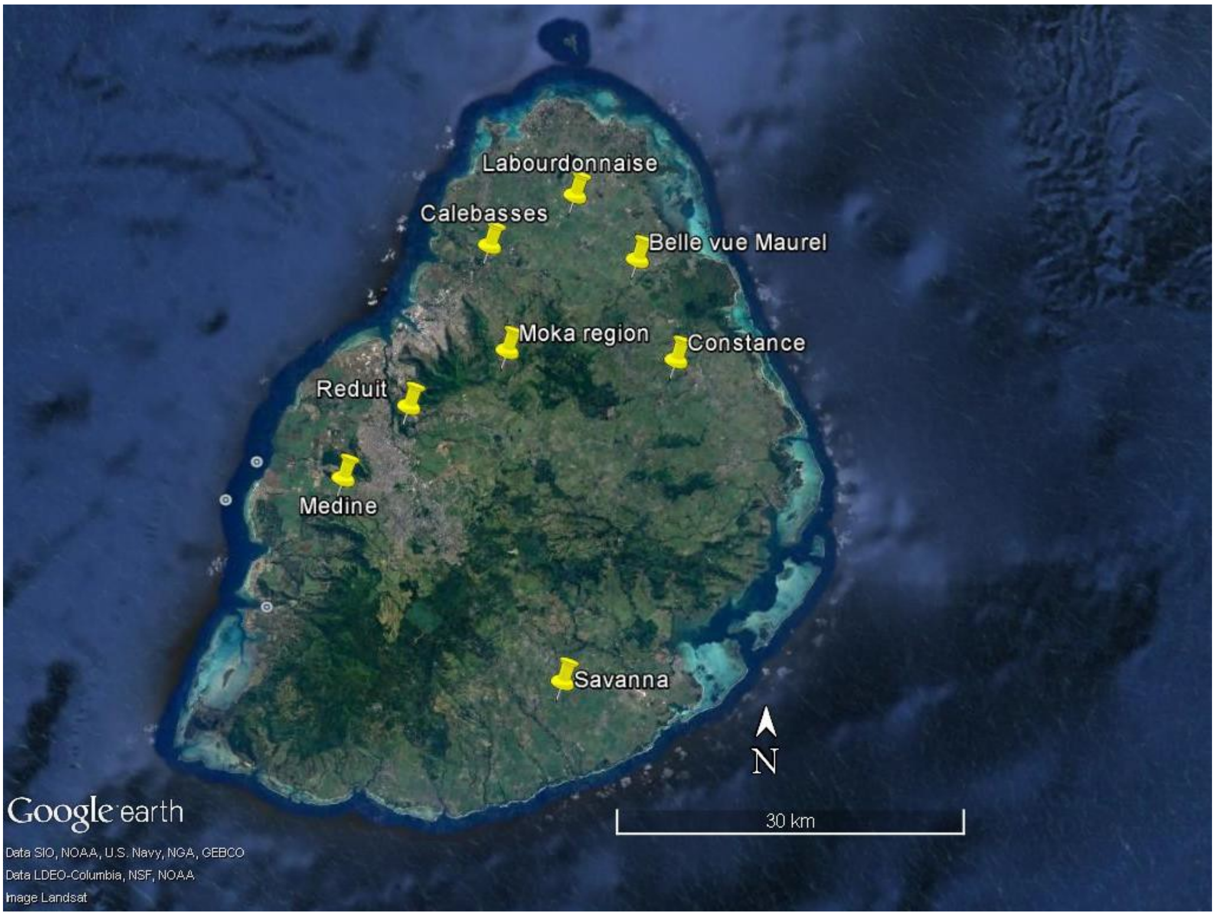

Fig. 1 Distribution of assessed orchards in Mauritius.

Methodology

Fruit assessment

In each orchard trees were classified as 'big' i.e. over 6m high and 'small' i.e. below 6m high. Ten of each tree size of litchi trees were then randomly chosen and the number of fruits on each tree assessed by counting the total number of panicles on the tree, and taking the average number of fruits per panicle from 20 randomly selected panicles. The total number of panicles was then multiplied by the average number of fruits per panicle. The same method was applied to longan trees, while mango fruits (due to their larger size and more conspicuous nature) were counted individually at each assessed tree.

Selected litchi trees were visited on a daily basis and the number of fruits on the ground under the trees was assessed and counted. The damage done to the fruits were divided into 'bat damaged' (when canine marks were visible on the fruit or seed found), 'bird damaged' (when the seed was smooth or the fruit had obvious holes with no visible canine punctures), 'fungus infected' (when fruits had obvious breaks in the skin and showed discoloration), 'rat damaged' (when marks of incisors were visible on the fruits or seed), as 'natural fall' (when intact, undamaged fruits where found on the ground) and as 'monkey damaged' (when the seed was crushed). The same methods were applied to mango trees.

Due to accessibility problems with longan trees and their position near to roads, detailed counting of fallen fruits was not possible, therefore the number of empty panicles was counted three times a week and classed with both bat and bird damage combined.

Netting

In Calebasses orchard three large trees were netted using an anti-bird net (nylon made net with a mesh of around 3x3cm) placed over a frame made of PVC pipes. The pipes were manipulated over the tree in a shape of a tent in a way to lift the net above the tree canopy ('with frame' netting). Another three trees were netted using the bird net placed directly over the tree canopy ('no frame' netting). The damage to the netted trees was assessed in the same way as un-netted trees. Medine orchard had trees already netted with bird netting placed directly over the tree canopy.

Results

Litchi orchard

In general the litchi trees over 6m tall produced between 2000 to 5000 fruits while trees under 6m tall between 1500 to 4000 fruits. Bell Vue Maurel was an exception as trees under 6m tall produced on between 400 to 900 fruits.

Calebasses

On average the bat damage (Fig.2.) accounted for 9.42% (± 11.1 SD) of fruit (368 fruits) on the big trees and 0.08% (± 0.11 SD) (3) on small trees; birds were responsible for around 3.23% (± 4.21 SD)

(125) of damage on big and 1.46% (± 1.75 SD) (59) of damage on small trees; rat damage was 0.08% (± 0.13 SD)(3) on big and 0.05% (± 0.11 SD) (2) on small trees; 3.02% (± 1.77 SD) (118) on big and 1.72% (± 3.27 SD) (70) of fruit loss on small trees was due to fungal disease; 5.69% (± 5.89 SD) (222) of fruit on big, and 3.95% (± 3.15 SD) (161) on small trees fell due to wind or other abiotic causes. In total 21.43% (± 3.49 SD) (835) of fruits were damaged on big trees and 7.26% (± 1.6 SD) (296) on small trees.

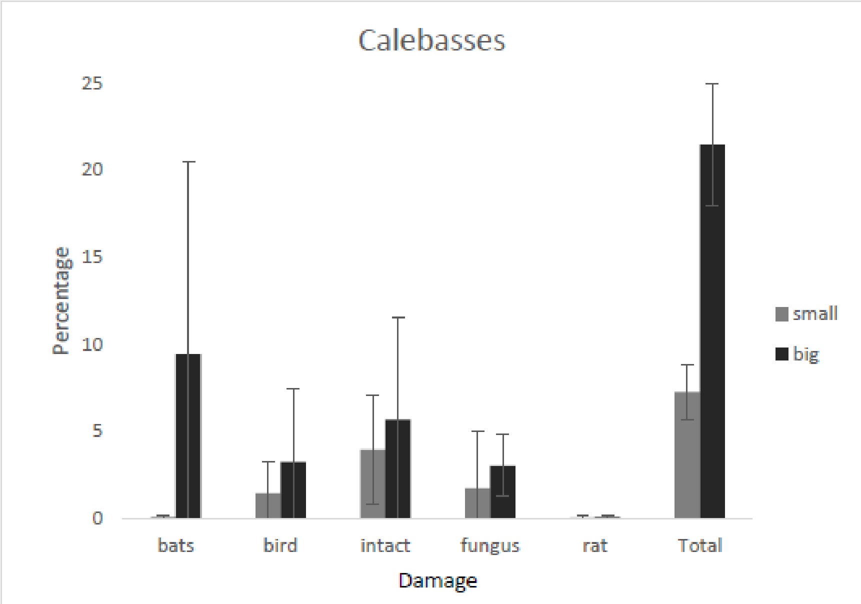

Fig.2 Average damage to litchi fruits on big (N=10) and small (N=10) trees in Calebasses orchard. Bars represent standard deviation.

On trees netted on the frame (N=3) (Fig.3) bats accounted for 0.48% (± 0.76 SD) (18 fruits) of damage; birds for 3.53% (± 0.43 SD) (151); fallen intact fruits comprised 2.86% (± 1.71 SD) (117) of loss; fungal disease for 0.86% (± 0.36 SD) (35) and rats for 0.03% (± 0.05 SD) (5). The total damage was of 7.76% (± 2.52 SD) (327) for trees netted with frames vs. 21.43% (± 3.49 SD) (838) on unprotected trees.

On trees netted with no frame (N=3) (Fig.2) bats accounted for 0.70% (± 0.47 SD) (25 fruits) of damage; birds for 3.80% (± 1.55 SD) (145); intact fruits comprised 5.47% (± 2.72 SD) of fruit loss (218); fungal disease for 2.80% (± 1.16 SD) (114) and rats for 0.04% (± 0.04 SD) (2). The total damage was of 12.81% (± 5.31 SD) (505) on netted trees with no frame vs. 21.43% (± 3.49 SD) (838) on unprotected tree.

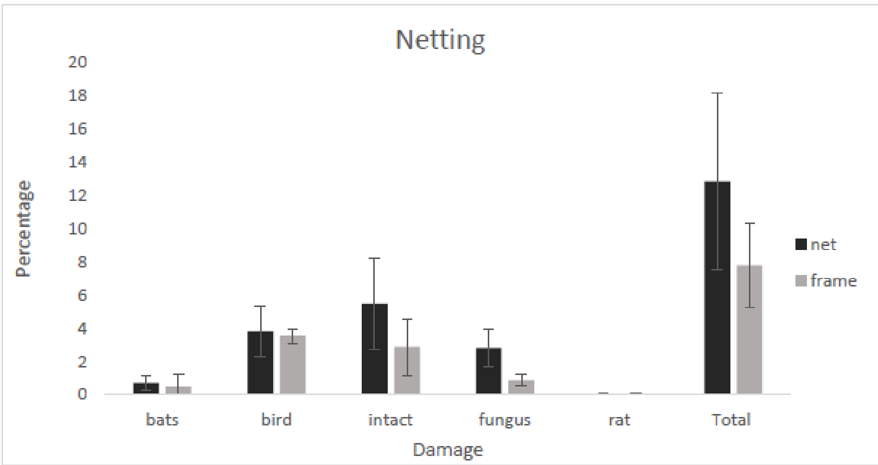

Fig.3 Average damage of litchi fruits on big trees netted directly over the canopy (N=3) and on the frame (N=3) in Calebasses orchard. Bars represent standard deviation.

Medine
In Medine orchard (Fig.4.) only big trees were found of which 10 netted and un-netted trees were assessed. The nets were placed directly over the tree canopy, i.e. without frames.

On average 52.78% (± 39.51 SD) (1694 fruits) were damaged by bats; 8.29% (± 8.11 SD) (266) by birds; 6.20% (± 4.34 SD) (199) were found intact on the ground; 1.75% (± 1.81 SD) (56) fell after damage by fungal disease and 0.60% (± 1.09 SD) (19) were damaged by rats. The total damage accounted for 69.62% (± 21.95 SD) of fruits (2235). For netted trees the damage caused by bats decreased to 12.35% (± 10.30 SD) (497). Birds accounted for 11.54% (± 8.55 SD) of damage (464); fallen fruits comprised 7.42% (± 5.73 SD) of lost fruit (299); fungal damage 2.95% (± 2.65 SD) (199) and rats 0.75% (± 0.41 SD) (30). The total damage was of 35.02% (± 5.12 SD) (1410) on trees netted over the canopy vs. 69.62% (± 21.95 SD) (2235) on un-netted trees.

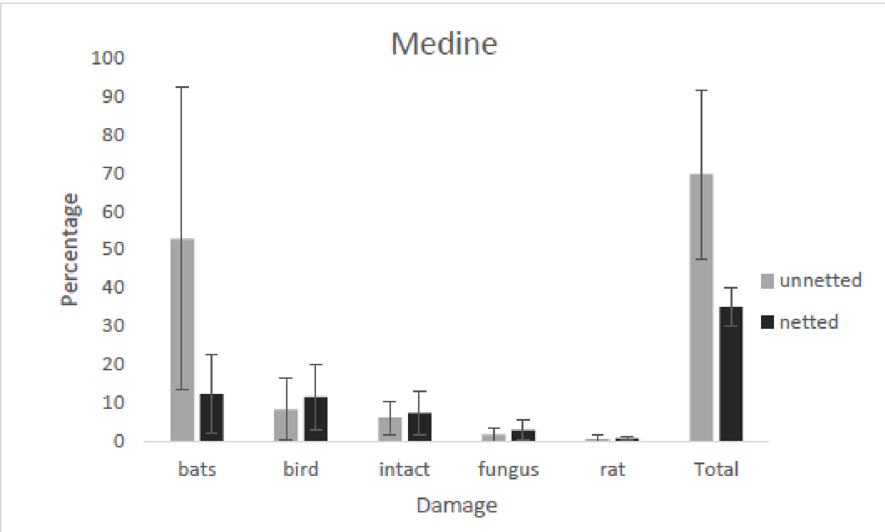

Fig.4 Average damage of litchi fruits on big un-netted (N=10) and trees netted directly over the canopy (N=10) in Medine orchard. Bars represent standard deviation.

Belle Vue Maurel
Only small trees were found in this orchard (Fig.5.) none of which were netted. On average 6.73% (±5.99 SD) (28 fruits) were damaged by bats; 6.48% (± 5.48 SD) (27) by birds; 4.62% (± 2.74 SD) (19) were found intact on the ground; 1.97% (± 1.44 SD) (8) had fungal disease and 0.48% (± 0.21 SD) (2) were damaged by rats. The total damage accounted for 20.29% (± 2.76 SD) (85).

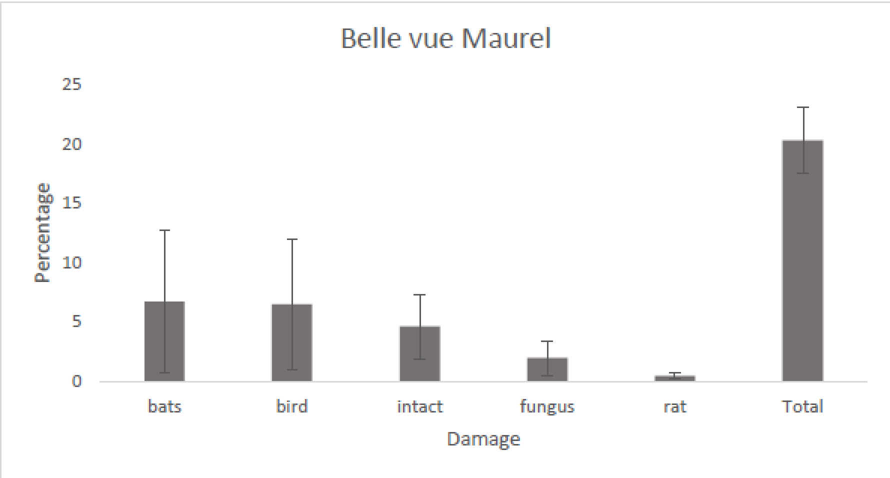

Fig.5 Average damage of litchi fruits on small trees (N=10) in Belle Vue Maurel orchard. Bars represent standard deviation.

Constance

The average damage (Fig.6.) to un-netted trees caused by bats was 15.02% (± 8.71 SD) (359 fruits) on big trees and 5.33% (± 6.81 SD) (82) on small trees; 6.66% (± 2.16 SD) (159) of loss on big and 12.17% (± 12.09 SD) (187) on small trees was caused by birds; 9.83% (± 2.15 SD) (235) on big and 10.26% (±10.46 SD) (158) of fruits on small trees were found intact on the ground; 4.53% (± 1.90 SD) (108) of fruits on big and 4.36% (± 6.40 SD) (67) on small trees had fungal diseases; 0.15% (± 0.12 SD) (3) on big and 0% of fruits on small trees were eaten by rats. The total damage was on average was 36.19% (± 5.60 SD) (866) on big trees and 32.12% (± 3.78 SD) (494) on small trees.

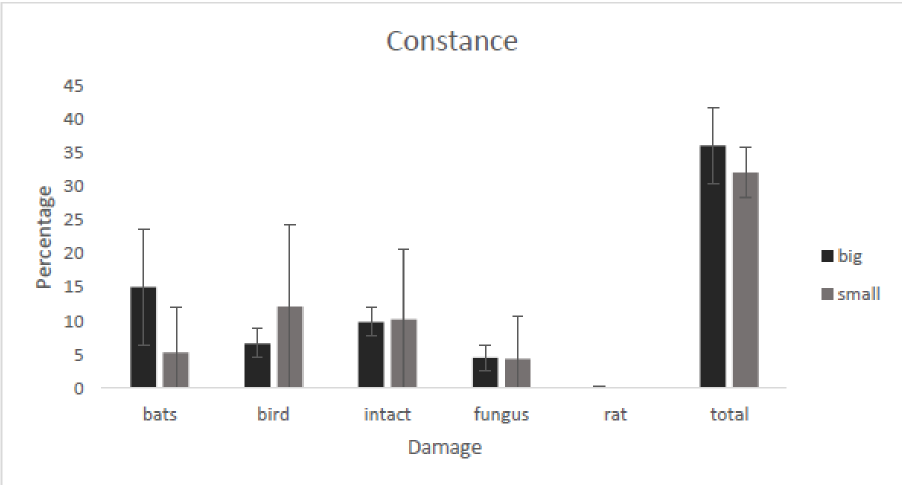

Fig.6 Average damage of litchi fruits on big (N=10) and small (N=10) un-netted trees in Constance orchard. Bars represent standard deviation

Reduit

A pattern of 100% damage was seen on all of 20 small and four big trees present in the non- commercial Reduit orchard. With the limited time available on the project, one small and one big tree were investigated to provide as indication of damage (Fig.7.).

Bats accounted for 69.86% (3370 fruits) of damage on big and 56.82% (1458) of damage on small trees; 13.04% (629) of loss on big and 28.18% (723) on small tree was caused by birds; 9.16% (442) on big and 5.07% (130) of loss on small were intact fruits found on the ground; 0.54% (26) on big and 1.05% (27) on small tree had fungal disease; 0.29% (14) of fruit on big and 1.79% (46) of fruit on small trees were damaged by rats and 7.11% (343) on big and 7.09% (182) on small trees showed evidence of monkey damage. The total fruit loss of 100% on both the big (4824) and small (2566) tree was found.

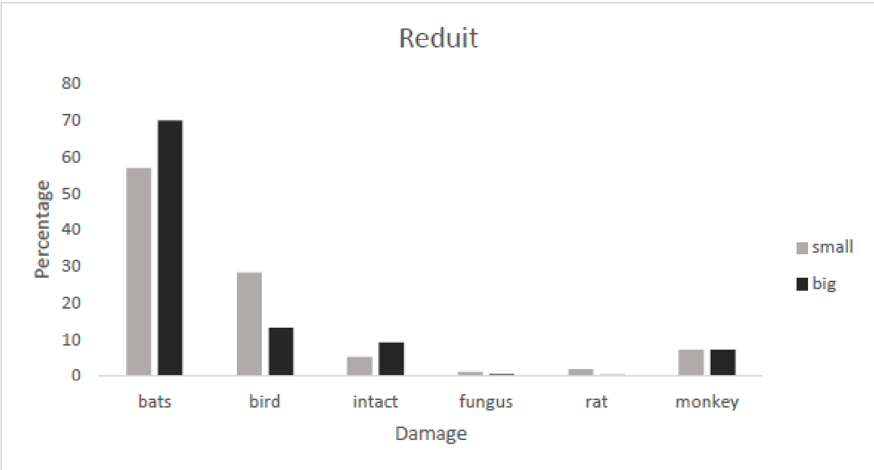

Fig.7 Damage done to a big (N=1) and a small (N=1) tree at Reduit orchard.

Savannah

General damage of around 20% based on the count of empty panicles left on the trees (N=20) was estimated. The differentiation between the different frugivores was not possible because the orchard was assessed at the end of the fruiting season and there were no leftover fruits remaining on the ground to allow detailed counting.

Total damage at litchi plantations in Mauritius

Across the four orchards (Savannah and Reduit orchard excluded) (Fig.8 and Tab.1), on average bats were responsible for 25.74% (± 23.59 SD) of damage to big and 4.05% (± 3.51 SD) of damage to small trees; birds for 6.06% (± 2.58 SD) on big and 6.71% (± 5.36 SD) on small trees; fallen fruits for 7.24% (±2.26 SD) on big and 6.28% (± 3.46 SD) on small trees; fungal disease for 3.10% (± 1.39 SD) on big and 2.68% (± 1.46 SD) on small trees and rats for 0.28% (± 0.28 SD) on big and 0.26% (± 0.30 SD) on small trees.

Table 1. Average damage caused by different culprits across four litchi orchards.

Litchi Orchard			**Couse of damage**			
Big Trees	**Bats**	**Bird**	**Intact Fruits**	**Fungus**	**Rat**	**Total**
Calebasses	9.42	3.23	5.69	3.02	0.08	**21.43**
Medine	52.78	8.29	6.20	1.75	0.60	**69.62**
Constance	15.02	6.66	9.83	4.53	0.15	**36.19**
Mean	25.74	6.06	7.24	3.10	0.28	**42.41**
SD	23.59	2.58	2.26	1.39	0.28	**10.02**
Small Trees	**Bats**	**Bird**	**Intact Fruits**	**Fungus**	**Rat**	**Total**
Calebasses	0.08	1.46	3.95	1.72	0.05	**7.26**
Belle Vue Maurel	6.73	6.48	4.62	1.97	0.48	**20.29**
Constance	5.33	12.17	10.26	4.36	0.00	**32.12**
Mean	4.05	6.71	6.28	2.68	0.26	**19.98**
SD	3.51	5.36	3.46	1.46	0.30	**2.66**
Netted big trees	**Bats**	**Bird**	**Intact Fruits**	**Fungus**	**Rat**	**Total**
Medine (without frame)	12.35	11.54	7.42	2.95	0.75	**35.02**
SD	10.30	8.55	5.73	2.65	0.41	**5.12**
Calebasses (on frame)	0.48	3.53	2.86	0.86	0.03	**7.76**
SD	0.76	0.43	1.71	0.36	0.05	**1.55**
Calebasses (without frame)	0.70	3.80	5.47	2.80	0.04	**12.81**
SD	0.47	1.55	2.72	1.16	0.04	**2.23**

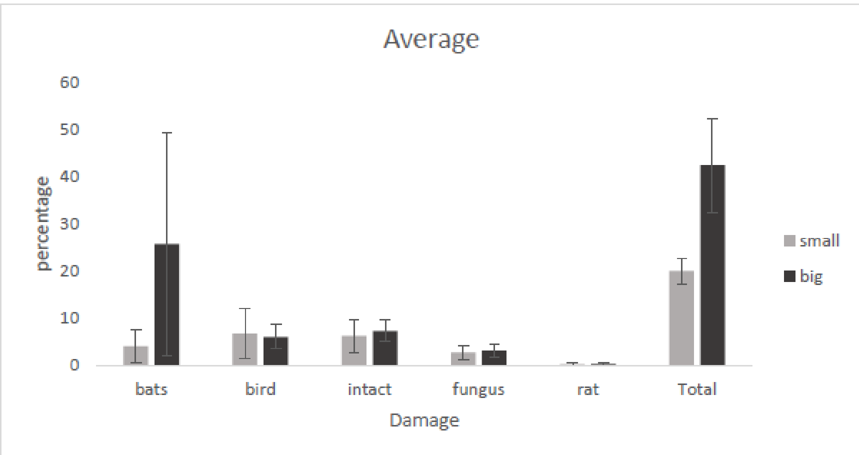

Fig.8 Average damage of litchi fruits done to small and big trees across all of the assessed orchards (N=4). Bars represent standard deviation

Mango orchard

There was a big variation in fruit production between mango trees. A big tree (over 6m tall) produced between 200 and 6000 fruits while small tree (below 6m tall) between 200 and 700 fruits. None of the trees were netted. From those (Fig.9) on average on small trees the total damage was 72.86% (± 20.34 SD) (398) from which 47.78% (± 16.80 SD) (266) was done by birds; 24.79% (± 10.79 SD) (130) of fruit loss was due to natural fall (over-ripe fruits) and only 2.81% (± 0.28 SD) (18) of damage was due to bats. On big trees average damage was 65.33% (±16.38 SD) (902) from which 31.33% (± 11.67 SD) (410) were damaged by bats; 12.50% (± 5.30 SD) (165) were damaged by birds and 21.49% (± 10.22 SD) (327) of damaged was due to the natural fall of fruits.

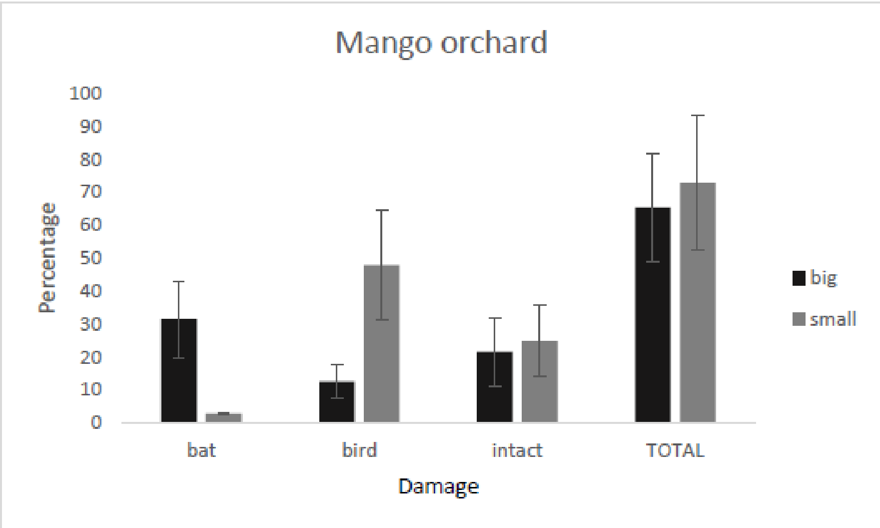

Fig.9 Average damage to mango fruits on big (N=10) and small (N=10) trees in Labourdonnais orchard. Bars represent standard deviation

Longan trees

On average longan trees (N=10) produced 3239 fruits from which 32.77% (± 30.27 SD) (1064) were damaged by either birds or bats. It was not possible to distinguish between the causes of damage due to the fact that longan trees were usually in backyards or on the side of the road, which made it impossible to assess the cause of damage.

Conclusion

The data show that damage done by bats and other animals varies considerably from orchard to orchard. However, smaller trees (<6m) experience less damage caused by bats compared to large trees (>6m). This suggests that pruning of the trees is essential and may minimize the impact bats have on fruit crops. However in places like Medine and Constance the damage caused by bats is pronounced and those orchards suffer a big loss.

Birds are responsible to much more damage than bats on smaller trees and that is seen across all the orchards (mango and litchi). Other culprits like rats have very small to none influence on the fruits. It could be due to the fact that rats will feed on fruits which are already down on the ground. Fungal infection on litchi fruits is common in Mauritius, however in all of the orchards fungicide was used to spray the fruits against the infection.

The netting proved to be successful in minimizing the damage caused by bats.

Netted trees had reduced damage by over 70% in Medine to almost 100% in Calebasses compared with un-netted trees. The total damage on netted trees was reduced by over 60% in Calebasses and over 50% in Medine compared with un-netted trees. It is therefore essential to net the trees. Nonetheless, bats are responsible for majority of the damage on fruit trees and it is essential to test other mitigation methods which will be more practical in application since netting is time and labour demanding, thus not well accepted by farmers in Mauritius. It is especially very unpractical to net large trees in backyards which often more than 10m tall.

Additionally, it is important to monitor the orchards for more seasons in the years ahead, as the damage will vary in respect to the amount of fruits present in the orchard and in nearby forests. Years when natural food is scarce may force the animals to feed more extensively on commercial fruits, while during times of fruit abundance in the forest and orchard the damage may be less pronounced.

GPS tracking of the Mauritian fruit bat

The movement of the bats was assessed using GPS/GSM tags donated by Microwave Telemetry between December 2014 and September 2016. The tags were solar powered and produced fixes during the night from between 20min to 3h depending on the battery charge. The tag was attached using a leather collar around bat's neck with a tag positioned between the shoulders. In total 12 bats were tagged. Most of them produced several months of data with one individual reaching almost a year of monitored movement.

Results and Conclusion

The data are still being analysed due to its complexity and large scale. However, a clear pattern of seasonal movement of bats is seen while looking at the Google Earth map (Fig. 10).

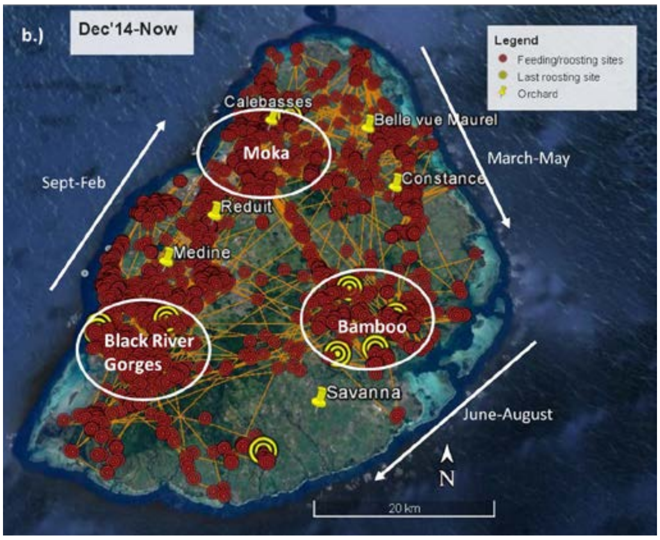

Fig.10 Movement of 12 tagged bats between December 2014 and August 2016. Highlighted three main mountain ranges in Mauritius and seasonal movement of the bats around the island.

The bats are moving seasonally, in accordance to food availability. At the start of the commercial fruiting season which is around September-October the bats are starting to disperse from south-east towards the west, north and north-east of the island where majority of fruit plantations are present due to a favourable warm climate. At the end of the fruiting season around March-April bats are moving from the north towards south-east and the Bamboo mountain chain which, due to the south- eastern wind trend tends to produce fruits before sites in the Black River Gorges. The movement of bats towards the south-east also coincides with the flowering of traveller's palms (*Ravenala madagascariensis*), introduced from Madagascar, and which flower around April. The south-east of Mauritius is highly invaded by the palm and provides rich nectar and pollen resources for the bats which may trigger the movement towards that area. Around June the bats often move the south-west and stay around Black River Gorges, feeding on a variety of native and introduced plants, while around September they once again start dispersing towards the north of the island.

Further analysis will reveal more about the movement pattern of the bats, their home ranges and food preferences along with most commonly consumed plant species recorded during the ground truthing of the bats' feeding sites.

Acknowledgements

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