# Tooth condition, body mass index and management options for edentulous black flying-foxes (*Pteropus alecto* Gould) in the Townsville district, north Queensland, Australia

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## Abstract

*Objective*

We investigated the relationship between a body mass index and tooth conditions in the black flying-fox to provide guidance on management of edentulous flying-foxes by bat carers and veterinarians.

*Methods*

Flying-foxes brought into care through injury were weighed, their forearms measured and the state of their teeth evaluated. Measurements were subjected to Chi-square, ANOVA, t-tests and regressions to tease out any relationship between body mass index and condition of canines and molar teeth, as well as in relation to gender and season.

*Results*

There is no statistically significant relationship between the state of a bats dentition and its body mass index.

*Conclusions*

The black flying fox (*Pteropus alecto*) in Townsville appears to experience a rapid decline in dental condition through time. Despite this, there is little indication that loss of teeth results in a decline in body mass index. We attribute the lack of effect of tooth loss on body condition to the dominance of floral foods in the diet of *P. alecto* in Townsville and a lesser importance of hard fruit that require an intact dentition for consumption. Edentulousness on its own is not sufficient reason to euthanise black flying foxes in Townsville and similar relatively dry localities where blossom dominates flying fox diet.

**Key words**

Body condition; *black flying-fox*; diet; toothlessness; euthanasia

## Introduction

The black flying fox (*Pteropus alecto* Gould) is the most commonly encountered pteropid bat in the Townsville district. North Queensland Wildlife Care Inc. receives approximately 180 individuals of this species each year. A number are edentulous, or have severely reduced dentition and although the *Code of Practice - Care of sick, injured or orphaned protected animals in Queensland* recommends euthanasia for such individuals, opinions differ as to whether such a course of action is supported by evidence. In this paper we examine the relationship between dental state and the body mass of black flying foxes submitted to North Queensland Wildlife Care between August 2008 and February 2012 with a view to determining whether or not bats with worn or absent teeth are at nutritional disadvantage and therefore unsuitable for rehabilitation and release.

## Methods

*Ethics*

Animals measured for this study were acquired and held under rehabilitation permits issued by the Department of Environment and Heritage Protection (formerly the Department of Environment and Resource Management). Ethics approval was granted by the James Cook University Animal Ethics Committee (approval number A1959). No animals were specifically collected for the study. All interventions were carried out for therapeutic purposes under veterinary advice.

*Study locality*

Townsville (latitude 19.25˚S, longitude 146.77˚E) is located in north Queensland, approximately 1500 km north of Brisbane. The climate is seasonally dry tropical, and as a result there are strong temporal controls on the availability of plant-based foods. The most important flying fox camp, comprising a permanent presence of approximately 500-1000 animals (Parsons pers. obs.) lies on the right bank of the Ross River. The resident population of black flying foxes is periodically supplemented by huge numbers of little red flying foxes (*Pteropus scapulatus*) which move into the region co-incident with massed flowering of *Melaleuca leucadendra, Corymbia* spp. and other myrtaceous trees.

Vegetation within foraging range of this camp, and subsidiary sites in the city and to the immediate north of the city, is dominated by sclerophyllous forest and woodland in which *Eucalyptus* spp. and *Corymbia* spp. are the most prominent floristic elements. Riparian forests on the freshwater reaches of rivers and streams are dominated by *Melaleuca leucadendra*. Sheltered coastlines and intertidal reaches of rivers support extensive mangrove communities. Coastal plains to the north support a mixed flora rich in *Melaleuca viridiflora* and *Grevillea* spp. as well as *Eucalyptus* and *Corymbia*.

Native fruit is seasonally available to flying foxes from localized patches of coastal vine thicket and vine thicket patches occupying sheltered slopes on adjoining hills. Some urban plantings include figs and other fruit bearing native trees. Exotic fruit, especially mangoes, bananas, pawpaw and introduced palms are also available on a seasonal basis in suburban gardens. The leaves of the mangrove

*Avicennia eucalyptifolia* and some leguminous trees, such as the introduced rain tree (*Samanea saman*), are also eaten (Luly, pers. obs).

*Study animals*

Flying foxes measured in this study were brought into care as a result of injury and were released or euthanised according to the terms of the Department of Environment and Heritage Protection wildlife rehabilitation permit WIRP03212510. All animals received were screened and selected according to strict criteria intended to minimise confounding influences exerted by underlying disease and dehydration / starvation attendant upon an extended period of debility. Decision rules were:

1. Animals were adult black flying foxes. Juvenile and first-year bats, as determined by forearm measurement (forearm < 140 mm), weight (weight < 500 gm) and subjective assessment were excluded from the study population.
2. Animals selected for the study were patently injured, not ill.
3. Animals selected had a reliable history that demonstrated a short time interval (less than 24 hours) between injury, discovery and rescue.

*Outcome measures*

Bats were weighed on receipt. Forearm measurements (made in millimeters with a vernier caliper) and assessments of tooth condition were made after the animal had been stabilised or euthanised. Measurements and assessment of tooth condition were made by Luly to ensure consistency. Animals deemed not to meet the selection criteria were entered into the rehabilitation program or euthanised as appropriate to their circumstances.

For the purposes of this study, canine and molar teeth were scored separately. Each set of teeth was scored as follows:

Score 1 All teeth sharp and white
Score 2 Teeth discoloured but sharp and unworn;
Score 3 Teeth white or discoloured but occlusal surfaces blunted and showing clear signs of wear;
Score 4 Canines distinctly shortened; molars worn flat;
Score 5 Teeth worn to stubs or animal edentulous.

Body condition was represented as a body mass index calculated as a ratio of forearm length (mm) to body weight (gm). The index used was that of Pinson[1]. In practice, the index generates a "preferred" weight by subtracting 100 from the forearm measurement and multiplying the result by 10. Thus for a forearm measurement of 155 mm the "preferred" weight would be 550gm. The preferred weight was used to calculate a percentage deviation from that figure. Where the weight of a bat is 15% below the preferred weight, the bat is considered to be malnourished[2]. Where weight is 20% below the

"preferred" weight, the bat is considered to be starving[1]. A subjective assessment of the condition of each bat included in the study cohort was also made, based on palpation of the thorax and upper back. The dependent weight related variables were:

(1) Ratio of weight to forearm length (mm);

(2) Percent weight of the preferred weight;

(3) Malnourishment (yes, no).

*Statistical analyses*

Categorical data were presented using absolute and relative frequencies. Numerical data were approximate normal distributed and described using mean values and standard deviations (SD) and range. Bivariate statistical tests were conducted investigating the associations between season, gender, and condition of teeth on the three dependent variables, separately, using exact Chi-square tests for trend, one-way ANOVA, unpaired t-tests, and Fisher's exact test.

Multi-variable linear regression analyses were conducted for the dependent variables (1) ratio of weight to forearm and (2) percent weight of the preferred weight; while logistic regression analysis was conducted for the dependent variable malnourished (yes or no). In preparation for the analyses, all independent characteristics were dummy coded. Independent variables were: Season when animal was found (categorised as winter/spring (June to November) versus summer/autumn (December to May); Gender; Condition of canines; and Condition of molars.

Multivariable models are the results of stepwise backward and forward procedures. Results are presented as regression coefficients (linear regression) and odds-ratios (logistic regression) and 95% confidence intervals (95%-CI). During the analysis a level of significance of 0.05 was assumed. Statistical analysis was conducted using SPSS version 21 (IBM SPSS, Chicago, Illinois).

## Results

Forty seven individual *P. alecto* fitted the selection criteria and were included in the study. The majority of these animals (N=30) were recovered from fruit netting or barbed wire fences. Nine were found with assorted injuries, including fractures, tears in the wing membrane and bilateral detachment of the retina. Five bats had been caught by dogs whilst foraging close to the ground. Three had been electrocuted. Of the 47 animals included in this analysis 25 (53.2%) were male and about half (51.1%) were found during the summer/autumn season (Table 1). The mean of the percent of weight of the preferred weight was 95% (SD 16%) with 13 (27.7%) animals identified as being malnourished. The vast majority of bats investigated had noticeable dental wear. The modal score for canine teeth was 2 (N=20) whilst the modal score for molars was 4 (N= 25).

Bivariate analysis showed that the mean ratio of weight to forearm was statistically significantly higher in animals found during the summer/autumn season (4.04; SD = 0.75) compared to the winter/spring season (3.57, SD = 0.62; p=0.025). Similarly, the mean of the percent of weight of the preferred weight

was higher in the animals found during summer/autumn (100%; SD = 16%) compared to the winter/spring animals (89%; SD = 14%; p=0.017). Of the 23 animals found during winter/spring, 9 (39.1%) were malnourished compared to 4 of 24 (16.7%) animals found during the summer/autumn season (p=0.111).

The bivariate analysis showed further that male animals were on average in much better condition than females. The mean ratio of weight to forearm was statistically significantly higher in male animals (4.20; SD = 0.62) compared to females (3.36, SD = 0.55; p<0.001). Similarly, the mean of the percent of weight of the preferred weight was higher in males (103%; SD = 15%) compared to females (85%; SD = 12%; p<0.001). Of the 22 female animals 11 (50.0%) were malnourished compared to 2 of 25 (8.0%) male animals (p=0.002).

The associations between the three weight-related outcome measures and the condition of the teeth were not statistically significant (Table 2). The observed associations were counter-intuitive, showing slightly higher mean ratios of weight to forearm (p=0.182), higher mean percent weight of preferred weight (p=0.401) and fewer malnourished animals (p=0.140) as the condition of the molars deteriorated.

Results of multivariable analyses confirmed that gender of the animal had an independent effect on weight related outcome measures. Male bats were statistically significantly more likely to have larger weight to forearm ratios (regression coefficient 0.84; 95%-CI 0.49 to 1.18; p<0.001) and they were more likely to have larger percent of weight of the preferred weight (regression coefficient 0.17; 95%-CI 0.09 to 0.25; p<0.001) compared to females. Female bats were 11.5 times more likely (95%-CI 2.2 to 61.0; p=0.004) to be malnourished compared to males.

When multivariable models were adjusted for season and gender, neither the condition of the canine nor the condition of the molar teeth showed any statistically significant effects on weight related outcome measures (Figures 1, 2, 3 and 4).

## Discussion

The preliminary data presented here suggest that there was little relationship between tooth condition and nutritional status in the years for which data were available. There are intriguing differences between results for molars and canines and between sexes which require more detailed analysis using a more comprehensive data set. The results are, however, consistent with dietary preferences shown by *P. alecto* in the Townsville district.

Dietary studies carried out by Parsons (unpublished data) indicated that *P. alecto* depends heavily on nectar flowers from eucalypts and paperbarks, a conclusion which makes sense in that the landscape around the city is dominated by tropical savannas and the rainforest / vine thicket vegetation which yields the majority of fleshy fruit is scarce. Introduced plants such as palms, mangoes and paw paws

are eaten, but these taxa do not appear in meaningful quantities in scat analyses (Parsons, unpublished data). This contrasts strongly with the spectacled flying fox (*P. conspicillatus*) where figs are a prominent element in scats and numerous other fruit, native and introduced, also occur[3]. Data from Townsville suggest that for much of the year, *P. alecto* diets are similar to those recorded for the pollen and nectar specialised little red flying fox (*Pteropus scapulatus*). The grey-headed flying fox (*Pteropus poliocephalus*) diet resembles that of *P. alecto* in Townsville in being opportunistic in use of fruit foods[4] but in relying heavily on nectar and pollen for much of the year[5].

Inter-seasonal and gender-based differences in body condition noted are consistent with seasonal differences in food availability and breeding biology. Flowering of eucalypts is sporadic and major flowering events do not occur every year. Flowering of *Melaleuca* spp. occurs in the early dry season (*M. fluvialtilis* and *M. leucadendra*) and just before the wet season (*M. leucadendra)* whilst availability of mangoes and other exotic fruit peaks in the early wet season, usually in early to mid-December. The wet season peak in fruiting and flowering broadly coincides with peak lactation demand in female *P. alecto*.

Most of the dry season in the Townsville district is nutritionally challenging for flying foxes which must commute significant distances to locate widely scattered trees in fruit or in flower. At that time of year, females are in an advanced state of pregnancy, adding to their energetic requirements as compared to males. Later in the year, females carry large dependent young while foraging in addition to demands imposed by lactation. Males are spared this requirement and it is unsurprising that their body condition is consistently better than that of females.

The ubiquity of tooth wear in adult *P. alecto* in Townsville suggests that although they depend on nectar and pollen for a significant part of the year, abrasive materials, such as leaves and bark, must also be eaten. The difficulty of determining the age of flying foxes means it is difficult to estimate rates of tooth wear, however the presence of discoloration and wear on the teeth of many first-year individuals implies that wear begins early. Flying foxes have the potential to live long lives in the wild[6] however data for *P. poliocephalus*[7] and *P. conspicillatus*[6] suggest that lifespans in the wild are often cut short due to shooting, misadventure or, in the case of *P. conspicillatus*, tick envenomation[8]. The substantial tooth wear noted illustrated by our data suggests that estimates of age based on tooth wear are attractive, but are unlikely to be useful.

## Conclusions

Codes of Practice regulate the care and rehabilitation of wildlife in most States. The codes seek to ensure that cruelty to animals is avoided, suffering is minimised and the success rates of rehabilitation and release are maximised. All codes contain provisions that stipulate conditions under which animals (in this case, flying foxes) are to be euthanised. Our results suggest that although there is an intuitive requirement for flying foxes to have intact dentition to prosper in the wild, in the Townsville district, and probably also in other areas in which savanna or woodland is the dominant vegetation type,

reliance on floral resources likely buffers edentulous bats against dietary stress arising from inability to eat hard fruit. Euthanasia of edentulous bats, or bats with reduced dentition is not warranted in the absence of other considerations. We believe these conclusions are likely to apply to other nectar focused flying fox species, such as grey-headed flying foxes (*P. poliocephalus*) and little red flying foxes (*P. scapulatus*).

## Limitations

The strict decision rules applied to the sample cohort means that the sample size was small. Data collection continues and we expect to be able to analyse a larger data set in future.

There are indications that body mass index is a relatively weak indicator of nutritional status[2] but until a better usable index can be developed it will have to suffice.

Tropical cyclone Yasi, which made landfall on the 3 February 2011, affected the landscapes around, and to the north of, Townsville during the data collection period. Food supplies for frugivorous birds and bats were severely affected and may have had an as yet unquantified effect on the regional scale nutritional status of flying foxes from February 2011 until vegetation had substantially recovered late in 2011.

There is a need to extend sampling outside the Townsville region and to other flying fox species in order to identify the extent to which conclusions reached here have wider applicability.

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