Journal of Tropical Ecology (2011) **27**:433–435. Copyright © Cambridge University Press 2011
doi:10.1017/S0266467411000071

SHORT COMMUNICATION

Successful germination of seeds following passage through orang-utan guts

Nynne H. Nielsen*,†, Magnus W. Jacobsen*,†, Laura L. L. B. Graham‡, Helen C. Morrogh-Bernard†, Laura J. D'Arcy†,§ and Mark E. Harrison†,#,[1]

* Biological Institute, University of Copenhagen, Universitetsparken 15, 2100 Copenhagen, Denmark
† Orang-utan Tropical Peatland Project, Centre for the International Cooperation in Tropical Peatlands, Universitas Palangka Raya, Jl. Yos Sudarso, Palangka Raya 73112, Central Kalimantan, Indonesia
‡ Geography Department, University of Leicester, University Road, Leicester LE1 7RH, UK
§ Zoological Society of London, Regent's Park, London NW1 4RY, UK
# Wildlife Research Group, The Anatomy School, University of Cambridge, Downing Street, Cambridge CB2 3DY, UK
(*Accepted 21 January 2011*)

Key Words: Ape, Borneo, Indonesia, peat-swamp forest, *Pongo*, Sabangau, seed dispersal, seed germination

Orang-utans (*Pongo* spp.) are primarily frugivorous (Morrogh-Bernard *et al.* 2009) and are often regarded as important seed dispersers (Corlett 1998). In Tanjung Puting, Borneo, Galdikas (1982) found intact seeds in 94% of faecal samples, with a median 111 seeds per defecation; and in Ketambe, Sumatra, Rijksen (1978) found seeds in 44% of faecal samples. Furthermore, orang-utans have large day ranges (e.g. mean = 968 m, range = 280–2834 m across adults in Sabangau; Harrison 2009) and slow passage rates of digesta through the gut (Caton *et al.* 1999), and, hence, may disperse seeds far from parent trees. Many seeds are also spat out or discarded at distances up to 75 m from parent trees (Galdikas 1982).

Until now, however, a critical piece of evidence has been missing from claims regarding the importance of orang-utans as seed dispersers: that showing successful germination of seeds following passage through the gut. In apes, this has been demonstrated for the chimpanzee (*Pan troglodytes troglodytes*) and gorilla (*Gorilla gorilla gorilla*) by Poulsen *et al.* (2001), who report that germination was achieved for the seeds of 8/10 and 4/4 defecated species, respectively. Similar results are reported elsewhere for the chimpanzee (Wrangham *et al.* 1994, but see Gross-Camp & Kaplin 2005), bonobo (*Pan paniscus*, Idani 1986) and Bornean hybrid gibbon (*Hylobates muelleri* × *albibarbis*) (McConkey 2000). We therefore initiated a short-term study on the orang-utan, in which we hypothesized that, following passage through the orang-utan gut: (1) seeds would remain viable; (2) germination success would increase (or at least not decrease); and (3) length of time to germination would decrease (or at least not increase) relative to control seeds collected by the authors, which were of the same ripeness stage as those ingested by the orang-utans.

This research was conducted on a population of wild Bornean orang-utan (*Pongo pygmaeus wurmbii* Tiedemann), as part of the OuTrop-CIMTROP multi-disciplinary research project in the Natural Laboratory of Peat-Swamp Forest, Sabangau, Central Kalimantan, Indonesia. Data on diet composition of habituated individuals through focal-animal follows have been collected at this site since 2003, using standard protocols (Harrison 2009). The data presented in this paper were collected during a 6-wk period in October and November 2008. Germination trial methods match closely those used by previous ape researchers (McConkey 2000, Poulsen *et al.* 2001).

Three different categories of seeds were collected: (1) excreted, in which faeces excreted during daily follows were collected, carried to camp and washed through a sieve, before extracting any seeds present; (2) seeds spat out by orang-utans while feeding, which were cleaned with tissue paper to remove remaining pulp; and (3) control seeds, obtained directly from fruits of equal ripeness as those eaten by the orang-utans from either

[1] Corresponding author. Email: harrison_me@hotmail.com.

the parent tree or another tree. Although seeds from four species (Ebenaceae: *Diospyros bantamensis* Valeton, Elaeocarpceae: *Elaeocarpus mastersii* King, Gnetaceae: *Gnetum* sp. and Tetrameristaceae: *Tetramerista glabra* Miq.), plus unidentified *Ficus* spp. (Moraceae) were collected, adequate sample size and comparable control samples were only obtained for *E. mastersii* (minimum 36 seeds for each category-substrate combination), which is both spat out and swallowed frequently. Results for the other species are available upon request.

All seeds present were identified, numbered and laid out on germination trays using two substrates: (1) peat soil or (2) tissue paper. *Elaeocarpus mastersii* (seed size: $10 \times 4 \times 4$ mm) was tested on both peat and tissue paper to determine the most suitable treatment for achieving germination. All planting was conducted in controlled conditions in the Sabangau Seedling Nursery. Seed trays were moved every 24 h to expose them to equal amounts of light and shade in different parts of the nursery. Seeds were kept moist and checked for germination (i.e. emergence of the radicle) daily until germination occurred.

A total 28 faecal samples were collected from eight orang-utans, of which 20 (71.4%) contained at least one intact seed. Orang-utans were observed feeding on fruits of 11 different species during the study period, but only the aforementioned four species and figs were found in the faeces. The mean (± SD) number of seeds per faecal sample was 123 ± 188 including figs, and 110 ± 168 excluding figs; the mean number of species per sample was 1.10 ± 0.96 (range = 0–4).

Germination was achieved in at least one category (excreted, spat-out or control seeds) for three of the five taxa studied (*D. bantamensis*, *E. mastersii* and *Ficus* spp.), all of which exhibited germination of excreted seeds. For *E. mastersii*, significant differences in germination success were found between categories using both the peat (control 86.1% seeds germinated, spat out 97.6% and excreted 25.6%; Kruskal–Wallis, $H = 86.1$, $df = 2$, $P < 0.001$) and tissue substrates (control 86.0%, spat out 98.0% and excreted 48.0%; $H = 38.1$, $df = 2$, $P < 0.001$). A Dunn's post hoc test ($\alpha = 0.05$) revealed that, for both the peat and tissue paper substrates, germination success was lower for excreted seeds than for spat-out or control seeds.

Significant differences in length of time until germination between categories existed for *E. mastersii*, on both the peat (mean control = 21.0 d, spat out = 18.2 d and excreted = 14.1 d; $H = 33.4$, $df = 2$, $P < 0.001$) and tissue (control = 22.7 d, spat out = 20.0 d and excreted = 18.9 d; $H = 10.4$, $df = 2$, $P = 0.006$) substrates. Dunn's post hoc tests revealed that excreted and spat-out seeds germinated faster than controls when grown on tissue, and that all three categories differed when grown on peat.

Our results demonstrate that seeds can remain viable following passage through an orang-utan gut, supporting our first hypothesis. This provides the first confirmation of the defecation of viable seeds by orang-utans, matching findings for other ape species (McConkey 2000, Poulsen *et al.* 2001, Wrangham *et al.* 1994). It is unknown how many species orang-utans disperse in Sabangau, but orang-utans at this site are known to consume fruits of at least 118 species (Harrison 2009) and, hence, the total number of dispersed species is likely to be high. Combined with observations of consistent prevalence of intact seeds in orang-utan faeces (Galdikas 1982, Rijksen 1978, this study), the large number of species ingested (Russon *et al.* 2009), large day range (Harrison 2009), slow digesta passage rates (Caton *et al.* 1999) and ability of orang-utans to handle even the largest fruits that other frugivores cannot manipulate (Corlett 2009), this supports the belief that orang-utans are important seed dispersers in Bornean and Sumatran rain forests (Corlett 1998, Galdikas 1982).

ACKNOWLEDGEMENTS

CIMTROP and LIPI for permissions; Hotelejer Anders Månsson og Hustrus Legat, Frimodt-Heineke Fonden, the U.S. Fish and Wildlife Service Great Apes Survival Fund, the Rufford Foundation and the Orang-utan Tropical Peatland Project for funding; and Simon Husson and Susan Cheyne for support. We are grateful to Eben, Udin, Thomas, Twentinolosa, Santiano, Yudhi Kuswanto, Ambut, Ramadhan, Simone Ottene, Sophie Curtis, Sonya Gadhia and Karen Jeffers for help with data collection.

LITERATURE CITED

CATON, J. M., HUME, I. D., HILL, D. M. & HARPER, P. 1999. Digesta retention in the gastro-intestinal tract of the orangutan (*Pongo pygmaeus*). *Primates* 40:551–558.

CORLETT, R. T. 1998. Frugivory and seed dispersal by vertebrates in the Oriental (Indomalayan) Region. *Biological Reviews of the Cambridge Philosophical Society* 73:413–448.

CORLETT, R. T. 2009. *The ecology of tropical East Asia*. Oxford University Press, Oxford. 272 pp.

GALDIKAS, B. M. F. 1982. Orangutans as seed dispersers at Tanjung Puting, Central Kalimantan: implications for conservation. Pp. 285–298 in de Boer, L. E. M. (ed.). *The orangutan: its biology and conservation*. Dr W. Junk Publishers, The Hague.

GROSS-CAMP, N. & KAPLIN, B. A. 2005. Chimpanzee (*Pan troglodytes*) seed dispersal in an Afromontane forest: microhabitat influences on the postdispersal fate of large seeds. *Biotropica* 37:641–649.

HARRISON, M. E. 2009. *Orang-utan feeding behaviour in Sabangau, Central Kalimantan*. Ph.D. thesis, University of Cambridge, UK.

IDANI, G. 1986. Seed dispersal by pygmy chimpanzees (*Pan paniscus*): a preliminary report. *Primates* 27:441–447.

MCCONKEY, K. R. 2000. Primary seed shadow generated by gibbons in the rainforests of Barito Ulu, Central Borneo. *American Journal of Primatology* 52:13–29.

MORROGH-BERNARD, H. C., HUSSON, S. J., KNOTT, C. D., WICH, S. A., VAN SCHAIK, C. P., VAN NOORDWIJK, M. A., LACKMAN-ANCRENAZ, I., MARSHALL, A. J., KANAMORI, T., KUZE, N. & SAKONG, R. B. 2009. Orangutan activity budgets and diet: a comparison between species, populations and habitats. Pp. 119–133 in Wich, S. A., Utami Atmoko, S. S., Mitra Setia, T. & van Schaik, C. P. (eds.). *Orangutans: geographic variation in behavioral ecology and conservation.* Oxford University Press, Oxford.

POULSEN, J. R., CLARK, C. J. & SMITH, T. B. 2001. Seed dispersal by a diurnal primate community in the Dja Reserve, Cameroon. *Journal of Tropical Ecology* 17:787–808.

RIJKSEN, H. D. 1978. *A field study on Sumatran orangutans (Pongo pygmaeus abelii Lesson 1827): ecology, behavior and conservation*. Veenman and Zonen, Wageningen. 421 pp.

RUSSON, A. E., WICH, S. A., ANCRENAZ, M., KANAMORI, T., KNOTT, C. D., KUZE, N., MORROGH-BERNARD, H. C., PRATJE, P., RAMLEE, H., RODMAN, P. S., SAWANG, A., SIDIYASA, K., SINGLETON, I. & VAN SCHAIK, C. P. 2009. Geographic variations in orangutan diets. Pp. 135–155 in Wich, S. A., Utami Atmoko, S. S., Mitra Setia, T. & van Schaik, C. P. (eds.). *Orangutans: geographic variation in behavioral ecology and conservation*. Oxford University Press, Oxford.

WRANGHAM, R. W., CHAPMAN, C. A. & CHAPMAN, L. J. 1994. Seed dispersal by forest chimpanzees in Uganda. *Journal of Tropical Ecology* 10:355–368.