Population study of *Rafflesia lobata* in the northern section of the central Panay Island mountain ranges, Philippines.

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Introduction

Panay Island is a triangular-shaped and sixth largest island in the Republic of the Philippines. It has two remaining forested regions: the north-west Panay peninsula mountain ranges which is a protected area since 2002; and the central Panay mountain ranges that extend from the north down to the south of the island along the western sea coast. Sibalom National Park in the southern region is the only protected area in the central mountain ranges. The width of its primary forest area varies from approximately 10 km up to 20 km wide along its length. The highest point is Mt. Madya-as which is 6,822 ft and located in Culasi municipality province of Antique. The mountain range in the peninsula is composed of remnant lowland rainforest to montane rainforest in the middle elevation and mossy forest in the elevation above 900 meters. In the central mountain ranges the lowland rainforests are non-existent along its perimeter but still present along the valleys deep in the forested areas. Along the perimeter is where montane forest abruptly start due to converted land use by the upland people. In some section, the montane forest starts from 500 meter in elevation, but some sections are as high as 800 meters. Mossy forest occurs from 900 meters above sea level. The central mountain ranges are approximately 10 times larger than the peninsula mountain ranges. Due to this larger size, many of the threatened species like Writhered-Billed Hornbill (*Aceros waldeni*), Visayan Tarictic Hornbill (*Penelopines panini*), Mabitang monitor lizard (*Varanus mabitang*) and Philippine Spotted Deer (*Cervus alfredi*) are quite common in the northern section of the central mountain ranges and quite rare, if not locally extinct, in the peninsula mountain ranges. These threatened species amongst non-threatened species of the greater Negros-Panay are 50% endemic (Heaney *et al.* 1998; DENR-PAWCZMS).

Rafflesia R. Brown (Rafflesiaceae) is a genus of parasitic plants found from the Kra Isthmus of Thailand through West Malesia (Meijer 1997, Nais 2001). In Sibalom NP is where *Rafflesia speciosa* was first discovered by the local community and described in 2002 by Barcelona and Fernando (2000). This discovery was a historic event because the last *Rafflesia* species described in the country was

Rafflesia schadenbergiana Goeppert in 1885. The location of this species in the field of Mindanao Island has become unknown since its discovery and was only known again when in 6th June 2007 fresh blooms were withnessed and photographedd: (Julie Barcelona pers. comm.). The first Philippine *Rafflesia* is *R. manillana* Teschemacher 1844. *R. speciosa* discovery was a turning point in the Philippine *Rafflesia* because in the last few years more new species has been described: *R. mira* by Fernando and Ong in 2005; *R. magnifica* by Madulid, Tandang and Agoo in 2005; *R. baletei* by Barcelona *et al.* in 2006; and the most unusual *Rafflesia* species due to the lobate diaphragm is the *R. lobata* by Galang and Madulid in 2006. No single country or landmass where 5 species of *Rafflesia* discovered and described in less than 5 years! R. banahaw by Barcelona *el al.* is the most recently described Philippine Rafflesia.Apparently there is a potentially third Rafflesia species in Mindanao Island (Julie Barcelona pers. comm.) There are a few more species currently being described in 2007 (Julie Barcelona pers. comm.). This could mean that the Philippines will out-number the landmass of Borneo which has 8 *Rafflesia* species and makes the country the global center of *Rafflesia* i.e. the highest species concentration per area.

Rafflesia lobata Galang and Madulid (2006) is one of the most recently described species and the most unusual. In fact, during the early stages of the author's discovery and description of *R. lobata* Mr Barkman commented "it is the most exciting discovery since *R. arnoldii*!"(Todd Barkman *pers. comm.*). It is unusual because the diaphragm is lobate, unlike all the *Rafflesia* species. Its lobe numbers is variable (2-5), the 5 and 4 lobed forms have outcurved diaphragm. Currently, 12 *R. lobata* sites are known compared to two in 2005 and six in 2006. All these *Rafflesia* sites are in the northern section of the central mountain ranges. Bud and flower data were collected in 2005 and 2007 which are used for this report. Due to the urgent need to collect holotype specimen and images of *R. lobata* and illness during the fieldwork, the author could not collect valuable bud and flower data in 2006. Inevitably new population of *R. lobata* are found. In fact, a new population has been found in Iloilo province which is in the southern most section of the central mountain ranges (Julie Barcelona *pers. comm.*).

Method

In 2005 all the buds and flowers were tagged in Mt. Igtuog and Mt. Sakpaw sites. Bud and flower location along the host species, bud diameter, flower diameter, gender and approximate age were collected and recorded.

In 2007 the same data collection technique were used in all 12 known *Rafflesia* sites. Namely Mt Sakpaw, Mt Igtuog, Ma-adyos, Nauling, Mt. Usigan, Kamantikun River 1, Kamantikun River 2, Mt Panakuyan 1, 2, 3 and 4.

A standard caliper ruler was used to measure bud and flower diameter. Tape measure were used to measure the bud/flower location on the vine from the ground level straight down from the bud/flower.

Bud health status was identified by visual inspection followed by touching and squeezing. Relatively soft and almost black buds are symptoms of diseased. Healthy buds are visually shinny and hard to touch. Bud diameter is measured along the widest point. When buds are still fully enclosed by cupula, the cupula is included in the measurements. The removal of cupula of very young buds (less than 20 mm) to measure the exact bud diameter would mean certain death to the buds.

Flower diameter is measured on the widest natural fold of the perigone lobes. The fieldwork periods in April-May 2007 were chosen because this was the optimal flowering season to maximize flower data. Flower gender was identified by visually identifying the presence or absence of anthers underneath the disk of all the flowers. Unknown gender means the flower age has reached a point where it is severely decomposed and the presence or absence of anthers is not possible.

Data were collected and collated for analysis.

Results

In 2005, there were 82 data points collected and in 2007 there were 359 data points. The large difference between 2005 and 2007 was due to 10 more *Rafflesia* sites in 2007.

Figure 1: Bud location and status (2005 + 2007)

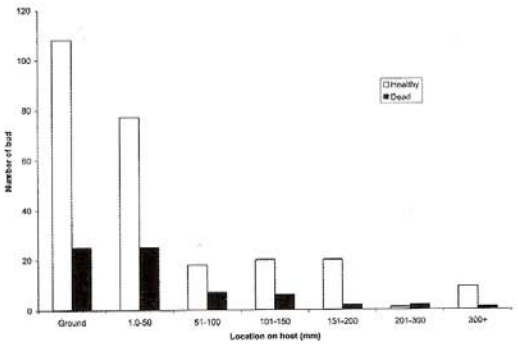


Figure 1 shows 441 data points (combined years) of bud vine location and health status. More than 50% of the buds were located less than half a meter to the ground. Bud death rate is constantly moderate and it only exceeds healthy bud number when it is located between 2 and 3 meters high.

Figure 2: Bud size and status in 2005

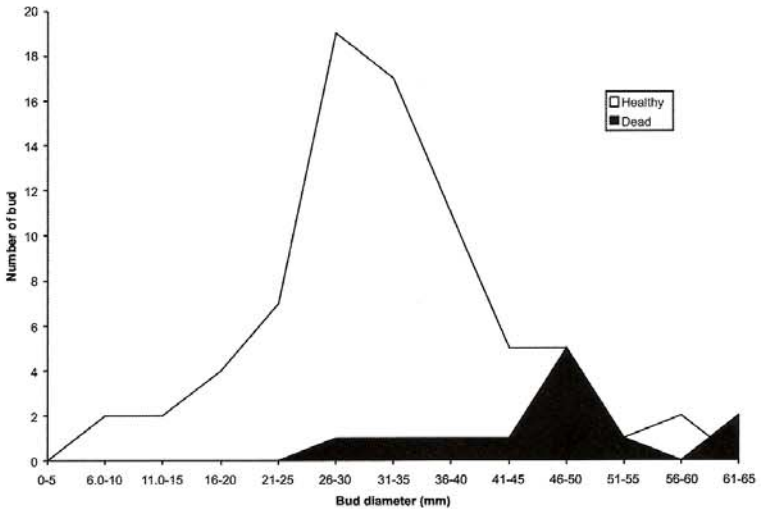
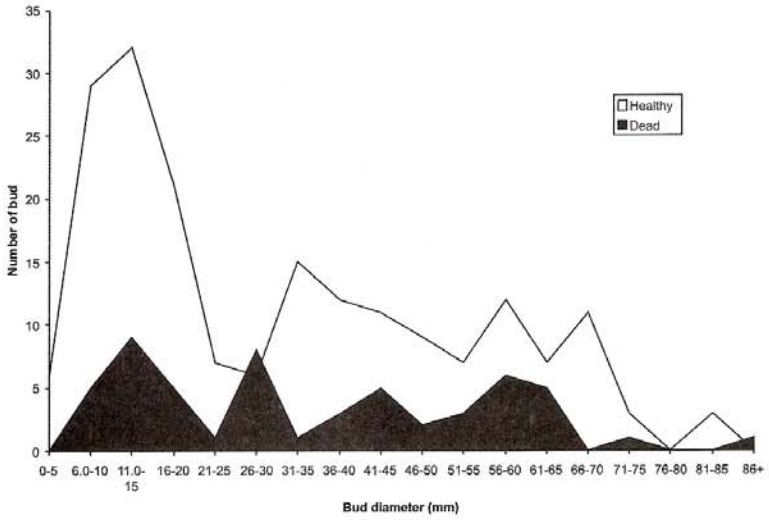


Figure 2 shows the bud diameter and status in 2005 data-set. Large number of buds were at the size between 20 to 40 mm. Many of these buds bloomed in summer 2006. Bud deaths start to occur from 20 mm diameter onwards.

Figure 3: Bud size and status in 2007



This is quite interesting as Figure 3 shows continuous bud death from at an early stage of less than 5 mm diameter up to the blooming stage. (Discuss have shown that this might be more realistic dataset because the 2005 dataset have not included many buds below 10 mm because of lack of skills in identifying them during the very early stage of discovery of *R. lobata*)

Figure 4: Bud population in 2005

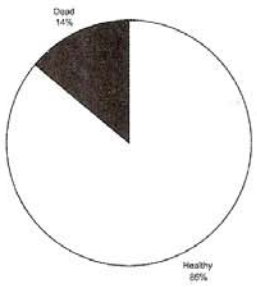
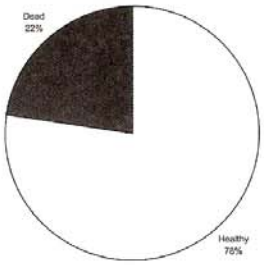


Figure 5: Bud population in 2007



Figures 4 and 5 showthe bud populations in 2005 and 2007. The death rate has gone up from 14% to 22%. This is expected as the data points have increased from 82 in 2005 and 359 in 2007. Due to the larger data points in 2007, it would be statistically favourable to lean on the 2007 percentages as the more clear reflection of the death rate of *R. lobata*.

Figure 6: Flower size and gender 2007

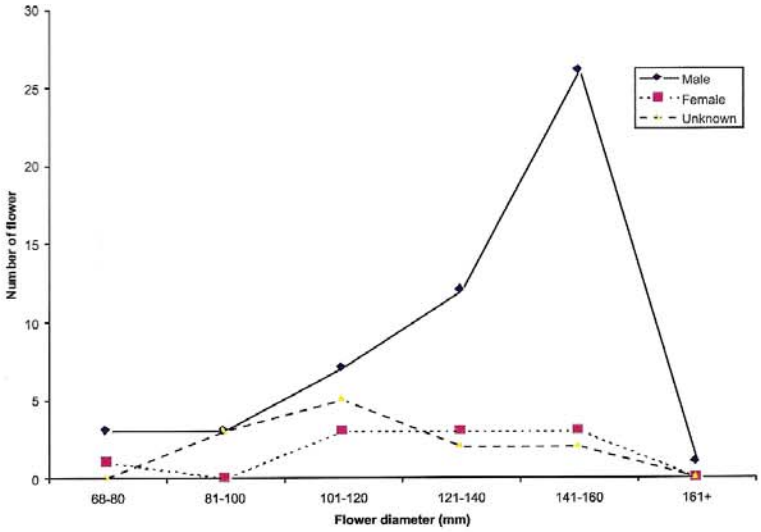


Figure 6 show the dominance of male to female flowers. In 2007, out of 74 flowers observed: 52 were males, 10 were females and 12 were unknown. There is therefore a 6:1 ratio in favour of male flowers. The unknown were heavily decomposed flowers and were either males or unfertilized females. The dominant size of male flowers were in the range between 140 to 160 mm in diameter while the females spreads from 101 to 160 mm. The largest flower was measured 168 mm male and the smallest was 68 mm and a female.

Figure 7: Site and bud status

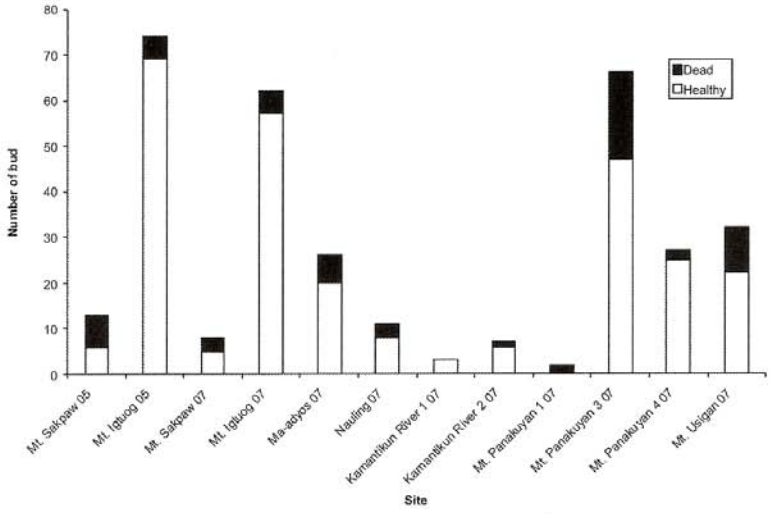


Figure 7 lists all the *Rafflesia* sites including the 2005 dataset and the bud health status. The largest population site was and still is the Mt. Igtuog site. This site was where this new species was first discovered in 2005. Mt. Panakuyan 3 and 4, and Mt. Usigan sites, found in 2007 are the other large population sites. Mt. Panakuyan 1 has all its buds dead and not on the list is Mt. Panakuyan 2 which appears to have no more viable bud and has only old decomposing flowers. This site is probably in the early stage of dormancy/inactivity.

Discussion

Bud location, size, growth rate and health status

Out of 253 healthy buds observed in 2007, 185 were on the ground and up to half a meter. That is close to the ratio of 3 out of 4 buds. This relationship is observed with diseased buds, out of 68 dead buds 50 were on the ground to half a meter. This is not unusual with most *Rafflesia* species. What is unusual with *R. lobata* is that it is frequently found high up in the vines near the canopy. For instance, in 2006, a flower was observed to be as high as 15 meter from the ground. See Photograph 1 below. In 2007, 5 flowers were observed at 5 meters, 2 were at 7 meters and 1 was at 10 meters from the ground. Flowers either fresh or past its age were more conspicuous than buds above a couple of meters from the ground so they can be seen quite readily. Buds on the other hand are harder to observe above head height, especially when the host vine is close to the main tree that is full of moss and other epiphytes. The most probable explanation for the presence of *R. lobata* on high above the ground is through dispersal by ants. Once viable seeds have been dispersed on the ground by an animal that has stepped on a ripe fruit and carried the seeds along, ants would then inoculate the vine along its length. The height of inoculation by ant depends on how industrious the ant is.

Plate 1: ***R. lobata*** 15 meter above ground in Mt. Igtuog 2006 [**Photo:** R. Galang]

The above hypothesis is agreeable, however, once a site becomes a recipient of a large quantity of viable *R. lobata* seeds, why is it then, in all *R. lobata* sites observed has varying bud growth stages? Figures 2 and 3 show this pattern clearly with the consistent presence of diseased bud. The causes of death has not been investigated and will be, in the near future research investigation. It is improbable that an established *R. lobata* site is a multiple recipients of viable *R. lobata* seeds because its fruit is extremely rare (it has been only observed in September 2005 when three fruits were seen, one was dissected for description) and the chance of an animal dispersing its seeds to the same host is highly unlikely indeed. *R. lobata* seeds must therefore remain viable for at least a couple of years and once it has been successfully inoculated on the right host it can remain dormant until the right combination of time and condition occurs for it to start parasitizing. Buds that were measured and tagged in September 2005 were re-measured in May 2007 and showed that the growth rate is between 1.1 to 1.38 mm/month. This growth rate combined with the dataset on figures 2 and 3 highlights the varying periods when the *R. lobata* seeds starts growing. The growth rate can also be used to predict the bloom period. For instance, the high number of buds between 26 to 35 mm in September 2005 were the ones that were observed blooming in large numbers in April 2006. The large number of 5 to 20 mm buds recorded in April-May 2007 can be predicted to bloom in the optimal blooming season in February-June 2008. The presence of varying bud sizes which means the maturity will be on non optimal blooming season conforms to the observed continual flowering of *R. lobata* through out the year. This continual flowering with peak seasonal bloom increases the chance of male and female flower blooming simultaneously thus successful fertilization can occur. Mature bud (i.e. when bracts start to break and the white underside of the perigone lobe becomes visible) has been observed with a diameter from 41 to 87 mm. See photograph 2. It is hard therefore to predict with great accuracy when a bud would bloom by simply measuring the diameter due to the large diameter range of mature bud. The variability in mature bud diameter clearly reflects on the range of flower diameter which is from 68 to 168 mm. See Figure 6. Note the flowers in the range between 68 to 100 mm were non fresh flowers and were predicted to be more than a month old. These "old" flowers have shrunkened when compared to the fully stretched glorious fresh blooms. In 2006, some of the freshly bloom flowers in Mt. Igtuog were measured up to 210 mm wide. Bloom prediction based on the size of white perigone underside showing between the bracts is easier and more accurate. For instance, large "white" would mean the bud will bloom within a few weeks. See photograph 2 below.

Plate 2: Mature buds of *R. lobata*. Left photo shows early stage of bracts separation exposing the white underside of the perigone lobe. Right photo shows very late bracts separation, this bud will bloom in less than a week. Note the dark brown dots on the right photo, this is quite common on very mature buds observed. [Photo R. Galang]

Bud population and gender ratio

In 2005 there were only two *R. lobata* sites known, Mt. Igtuog and Mt. Sakpaw. These sites had a population of 82 plants of which 14% were diseased. In 2007 there are 12 active *R. lobata* sites with 359 plants of which 22% were diseased. There are three more known sites but these sites had only decomposing flowers and no viable buds. These sites can be classified as inactive or dormant site (Nais 2001). The Mt. Panakuyan sites are a few hundred meters apart while Mt. Sakpaw is approximately 10 km from Mt Igtuog. The most concerning of the current 12 isolated population sites is the low number of female flowers. In fact, Mt. Sakpaw, Nauling, Kamantikun River 1 and 2, Mt. Panakuyan 1 and 4 have no female flower in the February-June 2007 flowering season. Mt. Igtuog is the only site where it has multiple female flowers, 7 observed in 2007. The low ratio of male to female flowers, 6:1, combined with no female flowers in half of the currently known populations suggest that this species has a low recruitment rate. The ability of the seeds to remain viably dormant is maybe the key to its survival.

Note: During the fieldwork in May 2007 in Mt Igtuog, I could not believe how lucky were the *R. lobata* populations there by missing a giant rockslide only a few meters away! The rockslide is approximately 200 meters wide and 2 km long! This rockslide was probably the result of heavy downpour due to unseasonal large tropical monsoons in November-December 2006. Not all populations were as lucky because the heavy rains swept off the three lobed population which produced the largest flower of 210 mm in diameter observed in 2006. Luckily three lobed flowers were observed in the newly found populations in Mt. Panakuyan, Maad-

yos and Kamantikun River sites which relieved me from thinking that this three lobed form discovered merely six months ago is now gone.

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