AN INVESTIGATION INTO THE AMPHIBIAN ASSEMBLAGES OF POLILLO ISLAND, PHILIPPINES

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ABSTRACT

A comparison of amphibian assemblages was made between different habitats and management regimes on the island of Polillo, Philippines. A variety of different techniques were used to estimate density and abundance of amphibian species in agriculture, primary and secondary forest and habitat edges. No one technique was found to be suitable for every species, the advantages and disadvantages of each technique are discussed and recommendations for future studies made. A number of species were found to be agricultural specialist species and forest specialist species. Several species were found in all habitats except the most intensive agriculture. Abundance of frogs tends to increase with distance from agriculture. Highest levels of species richness were observed at central forest sites and forest agriculture boundaries where both forest and agriculture species coexist. The forest specialist species were not found at these boundary areas and should be used as a focus of conservation efforts. 16 amphibian species were found and the calls of 12 species were recorded. Specific research and conservation priorities were identified including the taxonomic determination of three unknown species.

INTRODUCTION

Over half the amphibians species on Polillo are endemic to the Philippines. Several are restricted to the South Luzon Faunal region and *Platymantis polilloensis,* discovered by Taylor in 1922 is found only on Polillo, and has not been found since (Alcala and Brown 1998). Since Taylor’s collecting trips in 1920, only Dr R. Crombie (Smithsonian Institution) has conducted formal herpetofaunal investigations on the island, in the early 1990s. Before the Oxford-UPLB project no acoustic guide to the identification of amphibians on Polillo, nor the Philippines was available, despite recent increases in use of such techniques. This project intended to collect baseline data on amphibian species on Polillo, and produce an aural identification guide.
Amphibians sensitivity to environmental variation suggests they may be affected by habitat and landscape alteration (Wyman 1990; Wake 1991, Blaustein et al.1994). In tropical regions forest fragmentation is an important result of human activity and might influence amphibian assemblages through edge effects on environmental parameters (Ranney 1977; Ranney et al 1981; Lovejoy et al 1986; Malcolm 1994). Most of the forest on Polillo has been cut down, and much of what remains is fragmented. 200 hectares of old growth forest is protected as the Sibulan watershed reserve. Studies of amphibian diversity and richness were conducted in and around the watershed to investigate frog assemblages in different habitats from primary forest to intensive agriculture and begin to address the affect of forest fragmentation on particular species.

AIMS

- Investigate the effect of habitat type on frog assemblages by carrying out surveys of density and abundance in agriculture, primary forest, secondary forest and edge habitats.
- To record the calls of amphibians on Polillo to produce an aural identification guide.
- To devise methodology for surveying frogs on Polillo that is simple to use, efficient and robust.

Methodology

Pilot study:
A week's reconnaissance and training period was completed at the start of the project. During this time different methods of searching were assessed, different transect lengths and quadrat sizes tested, species identification practised and potential sites investigated. The methodology used in the main study was refined during this period.

Site selection:
Study sites are shown on the map. There was no suitable map of the area available beforehand, thus selection of sites in terms of distance from primary/ core forest was not possible. The arrangement of habitat type and quality was also unknown. The distance to study sites and terrain of routes prevented their random selection. On the assumption that forest nearest to the centre of the reserve (i.e. furthest from agriculture) would be most representative of the original habitat, sites were chosen in what was considered to be those representative of high quality habitat, through varying levels of disturbance to agriculture. The most intensive agriculture was paddy fields.

The project work was based around water bodies because:

1) Intensive search effort that yielded very few frogs tended to reduce searcher enthusiasm, therefore despite the potential importance of non water body sites, effort was concentrated around water bodies where frog activity was highest
2) Streams were highly abundant in the region, such that finding a non water body site (defined here as at least 25m from a water source) was very difficult, unless work was conducted along hill tops and ridges where terrain was often unworkable.
3) Streams were used as the major navigation routes within the forest, therefore logistically using them as study areas was convenient.

Habitat Characterisation:
In order to compare between sites in a quantitative way, different characteristics were measured that were chosen as indicators of forest quality, or factors that may play a role

in the distribution of frogs. The following measurements were taken along a distance of 100m, and 5m either side of the river:

- Abundance of *Pandanus* spp. by their area
- Abundance of dead logs (using a subjective size standard)
- Abundance of bamboo
- Density of ground flora (counting the number of times when walking 200m i.e. 100 down one side of the stream then 100m back on the opposite side, a 1m stick held horizontal at waist height touches under storey vegetation along its length)
- Width of the stream (to within 0.5m)
- Flow of the stream on a scale of 1 to 3
- Canopy cover
- Water parameters -pH, conductivity and Oxygen concentration

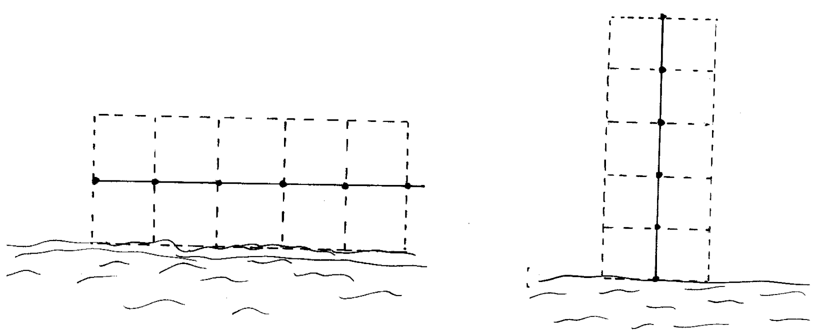
To provide a quantitative description of the composition and structure of forest habitats, density, basal area and relative species abundance of trees were estimated at all sites using the Plot less Centre Quarter Method. Distance from origin to the nearest tree (or tree stump) with Circumference at Breast Height >31cm in the four quadrats of a Cartesian grid were recorded together with species, position in the canopy and CBH, every 5m of the transect. Transects were at least 100m long, 50m on each side of the water body and running perpendicular to it. Replicate samples were recorded as such and the distance to next nearest tree measured. Trees were initially identified by local names wherever possible and subsequently by identification of voucher specimens at Dept. of Plant Sciences, University of the Philippines, Los Banos (UPLB). Details of climate (rainfall, maximum and minimum shaded and unshaded temperatures) were recorded from a hill next to base camp at 0900 hours each morning. The phase of the moon during the study period was recorded.

Amphibian Survey Methods:

Two sites were surveyed each night. At each of the 13 study sites on 4 separate occasions the following were conducted:

1. Transects: Twelve 5m by 2m transects were searched. The species, distance from the water, distance from the start of the transect and height above the ground for every frog within the $10m^2$ was recorded. Six of the transects were directly parallel to the waters edge and six perpendicular to the stream, all 12 beginning at the water's edge.

A 5m length of string, marked at 1m intervals was tied to the transect starting point, to ensure accuracy in measuring distances and consistency between searches. The rough position of the frog within the $10m^2$ transect could be estimated by the 1m markers. Searchers worked from the starting point keeping the string taut, ensuring no disturbance was caused to the area ahead. The diagrams below illustrate how knotted string was used



to conduct perpendicular and parallel transects that covered a $10m^2$ area.
2 researchers searched transects simultaneously at each site. Each searched 6 transects; 3 parallel and 3 perpendicular. The searchers worked independently and on opposite sides of the water body to avoid pseudoreplication. Transects were at least 5m apart to prevent active frogs being included in consecutive transects.
Searching began between 6.50 - 7.30pm. Searching was thorough and slow, the time taken to complete a transect was left to the searchers' discretion, given the varying terrains and abundances of frogs. Searchers worked at a pace, where they felt, given more time, unable to find any more frogs within the search area. If a frog was seen to jump from outside the transect area into the area it was not counted, if a frog was seen to jump out of the transect area it was counted. Times to complete a transect varied between 2 to 20 minutes.
The transects were designed to give absolute abundances of every species, to enable patterns in species distributions with distance from the waters edge to be deciphered and to look for signs of clustered distributions.

2. Timed counts: For 30 minutes searchers looked anywhere in the vicinity of the area. No constraints were given to search area dimensions other than that searchers worked on opposite sides of the river from each other to avoid replication. The species of the frogs found were tallied, and the time noted when 10 individuals of 1 species had been found. With the aim of saving time that would be used up by continuing to record the common species (perhaps increasing the possibility of finding more cryptic species). Timed counts are designed to be a simple, rapid and effective technique which gives reasonable relative abundances for avifauna (Bibby 1998). Therefore an adapted version of the technique was tested for assessing frog assemblages.

Ten different searchers carried out the surveys. They were chosen on a rota basis to reduce observer bias, random selection was impossible because of the logistics of the work timetable, frequency of fungused feet and other ailments preventing work. Petzl head torches were used by searchers. Searches were not completed on Sundays and were abandoned when dangerous weather conditions were anticipated. Therefore a total of 48 transects and four hours of timed counts were completed at each site. The advantages and disadvantages of these two techniques are reviewed in the discussion.

Analysis methods:
Species accumulation curves were drawn to assess what proportion of the species present were being sampled. Rank abundance plots were used to assess overall species community patterns and identify habitat specialists. Graphs of species richness and total frog abundance for each site are presented and diversity indices calculated. Ordination using the programme CAP was used to look for patterns in species composition and abundance between sites. Density of each frog species is plotted against distance from agriculture.

Considerations in Design of Methodology:
Of the recommended standard techniques for sampling amphibian populations (Heyer et al 1994) few were considered appropriate for the community being studied on Polillo. Quadrats typically 5m by 5m were rejected because they:

- create too much disturbance (especially given the small size of the watershed reserve)
- require intensive effort to be searched thoroughly
- cannot be repeated in the same location because of the induced disturbance,
- rarely find amphibians unless they are very close to water bodies,
- flush species out of the quadrat before they are found,
- must be repeated many times for statistical analysis

Long transects (100m plus) were rejected because

- As the length of transect increases, the chance of the area being searched thoroughly decreases
- They are affected strongly by observer bias

However a compromise upon both the quadrat and transect design was reached. Small 5m long, 2m wide transects were used that could be searched intensively and repeated many times. Surveying was purely conducted at water bodies, but a small gradient (5m) was used perpendicular from the water bodies to investigate whether on future occasions further work based on the forest floor would be worthwhile.

Considerations about the design of the transects:
Differences in searcher ability are very difficult to overcome and impossible to eliminate. Differences were minimised by the design of the experiment wherever possible. E.g. by keeping the search area small (5m by 2m), by working at the searchers slowest pace (to ensure searchers didn't feel rushed thereby likely to search less thoroughly), by working in one direction (thereby any frogs that jump in front are likely to be seen). A larger search area was considered to increase searcher boredom and apathy, less successful searchers might become disheartened, heightening differences between more successful searchers. (It was assumed that given enough time the searcher will find all the visible frogs no matter what ability the searcher has, given a small enough area). The area searched was small to ensure that if frogs jumped they were likely to be seen. The design was a transect rather than a quadrat to reduce the searcher disturbance and likelihood of frogs escaping before they were spotted. 2m width was considered to be a good field of vision for the observers.

Considerations about the design of the timed counts:
This method tended to be more popular during the reconnaissance period, therefore it was important to consider whether this gave the same relative levels of each species as the transect method (although area is not specified therefore neither relative or absolute abundances can be measured, only frequency of encounters). It was assumed that searchers would try to find as many frogs as possible. A limit to the number of frogs of one species recorded was made, to prevent the tendency to concentrate efforts on one species or productive microhabitat. After trying different limits, 10 frogs of one species

was chosen. In order for appropriate analysis, the number of frogs that would have been found in thirty minutes was extrapolated given the encounter rate for ten frogs.

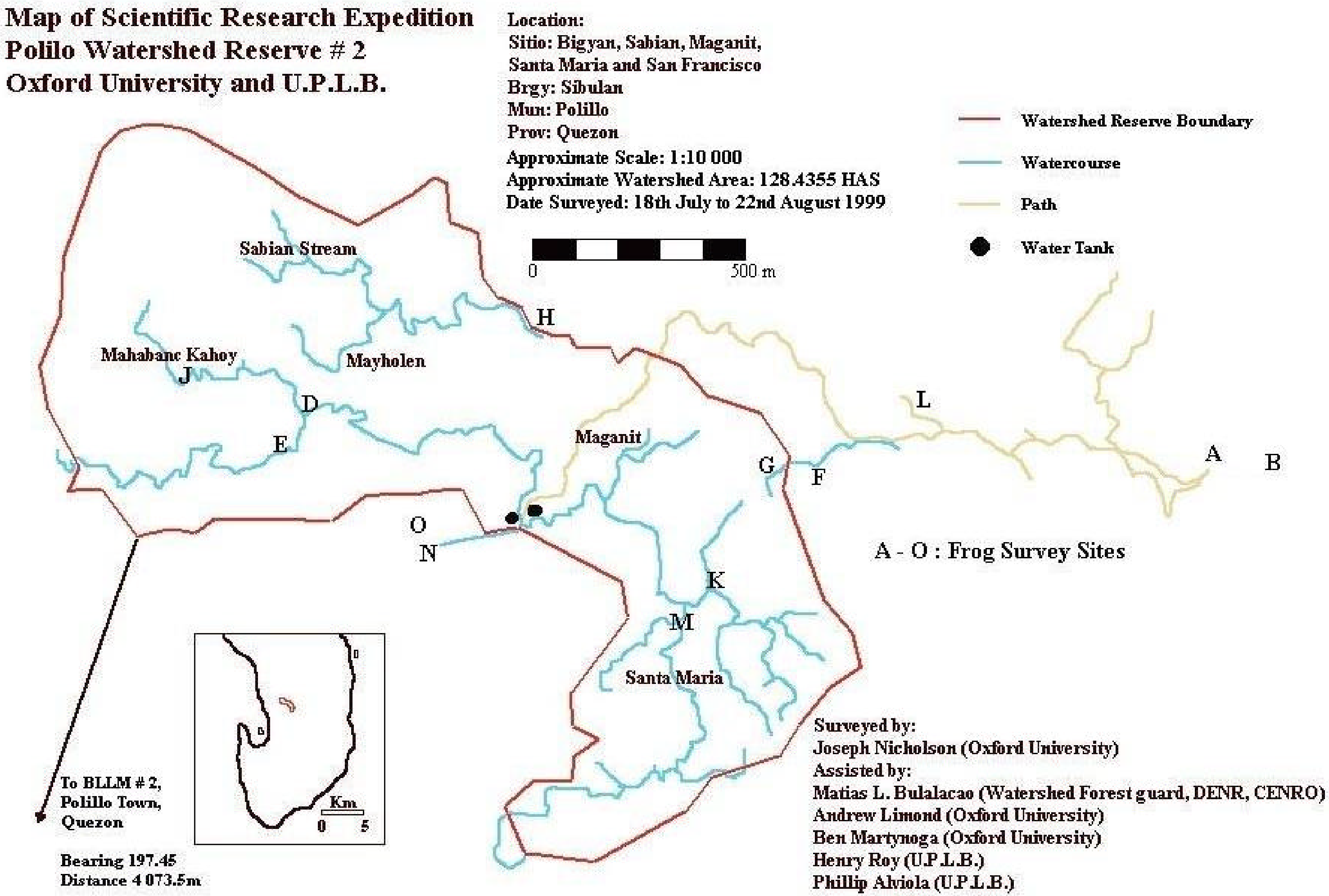
The two search techniques were suspected to collect differing results. E.g. The timed count might not pick up species that are particularly cryptic since this method is possibly less intensive. However the search area and habitats are possibly wider therefore there is more chance of finding animals with lower densities.

Audio strip transects were latterly adopted with appropriate changes for estimating density of *Platymantis* sp. This technique is not appropriate for many of the other species such as *P. dorsalis* which have a high call overlap (high densities of males calling at high rates) (Zimmerman 1994) or others such as *O. laevis* which call in choruses. For *Platymantis* sp. the technique was ideal. However as densities increase, the technique requires more concentration and skill and is more time intensive therefore shorter and shorter transects must be completed.

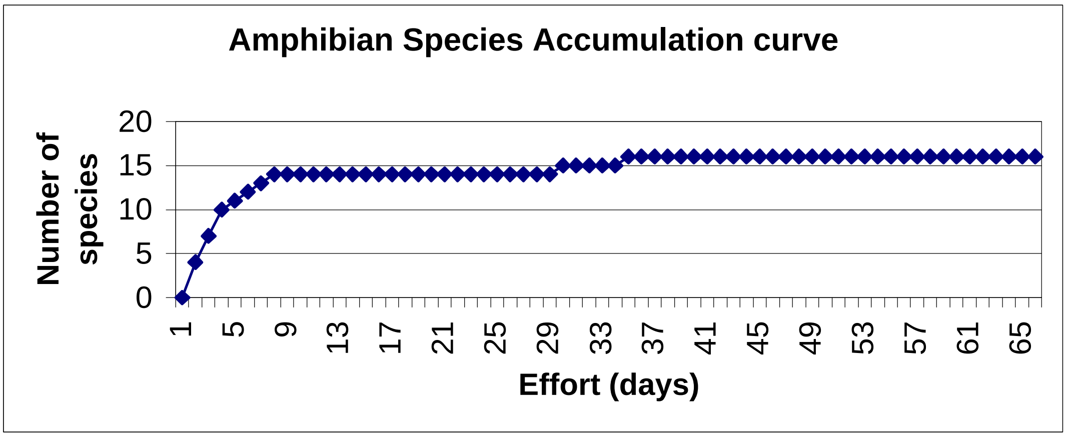
Description of Study sites:

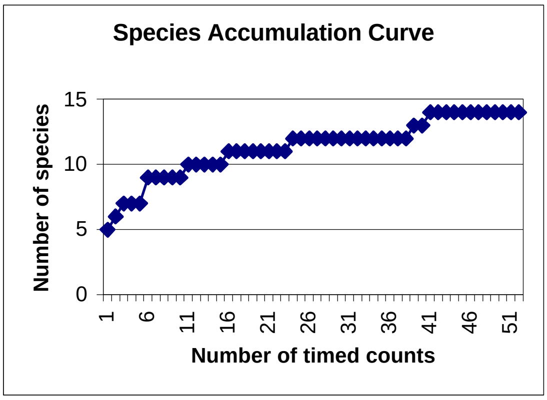
- A- Paddy field bordered by river and coconut plantation. 5 minutes walk to the nearest forest.
- B- Fast flowing river (at least 3m wide in places) within coconut plantation, bordered by a variety of agricultural trees. River passes through forest but nearest forest is at least 5 minutes walk.
- D- Central forest site with a medium sized stream (1 to 2m) with medium flow rate.
- E- Central forest site with a medium sized stream (1 to 2m) with medium flow rate, and *Pandanus* spp. very abundant.
- F- Forest edge site with small (1m) slow stream.
- G- Forest edge site with small (1m) slow stream
- H- Fast flowing river (at least 3m wide in places) within coconut plantation on one side, bordered by a variety of agricultural trees.
- J- Forest site with small stream. Varying terrain (steep sided in places, flat in others) which affects flow rate (varies from fast to slow).
- K- Central forest site with medium sized stream.
- L- Forest edge site with slow stream, widening in some places where the water is still and swamp like.
- M- Central forest site with medium sized stream.
- N- Fast flowing river (at least 3m wide in places) within coconut plantation, bordered by a variety of agricultural trees. River passes through forest. Nearest forest is about 5 minutes walk.
- O- Paddy field site bordered by coconut plantation and forest edge.

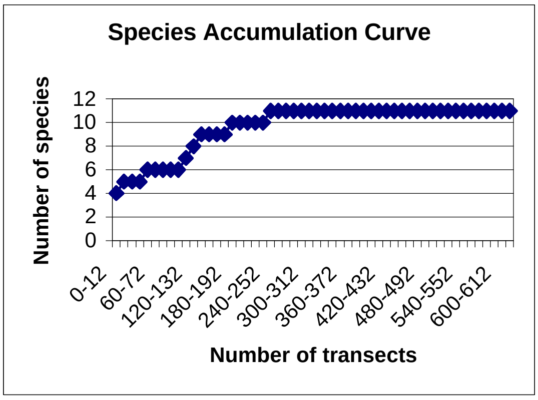
The following map of the watershed and surrounding area shows the position of the frog surveys sites listed above.


Map of Scientific Research Expedition
Polillo Watershed Reserve # 2
Oxford University and U.P.L.B.
Location:
Sitio: Bigyan, Sabian, Maganit,
Santa Maria and San Francisco
Brgy: Sibulan
Mun: Polillo
Prov: Quezon
Approximate Scale: 1:10 000
Approximate Watershed Area: 128.4355 HAS
Date Surveyed: 18th July to 22nd August 1999
Watershed Reserve Boundary
Watercourse
Path
Water Tank
0
500 m
Sabian Stream
Mahabanc Kahoy
Mayholen
Maganit
Santa Maria
A
B
D
E
F
G
H
J
K
L
M
N
O
A - O : Frog Survey Sites
To BLLM # 2,
Polillo Town,
Quezon
Bearing 197.45
Distance 4 073.5m
Km
0
5
Surveyed by:
Joseph Nicholson (Oxford University)
Assisted by:
Matias L. Bulalacao (Watershed Forest guard, DENR, CENRO)
Andrew Limond (Oxford University)
Ben Martynoga (Oxford University)
Henry Roy (U.P.L.B.)
Phillip Alviola (U.P.L.B.)

RESULTS





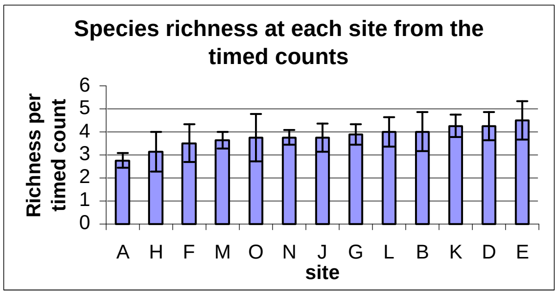


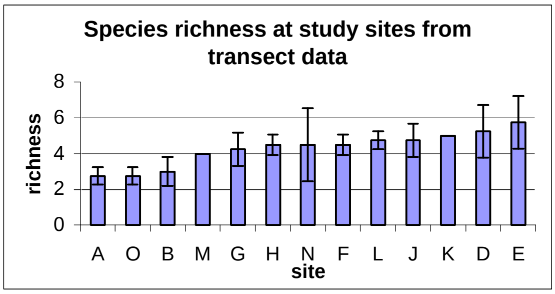
The species accumulation curves compare species richness and rate of species discovery for transect and timed count techniques. The total species richness approaches an asymptote at 16, species were still being discovered after 37 days. The transect technique found 11 of the total 16 species, whereas the timed counts found 14. The two species not found by either technique were seen once and twice respectively (see below and species accounts section). The transect data reached an asymptote one third of the way through the study, whereas the timed count curve continued to rise, although slowly at the end.

Two frog species were only not detected during the surveys; *Kaloula*.sp, a fossorial frog (2 individuals were found, 1 in a pitfall trap after rain, and 1 during the reconnaisance period approximately 5m from the stream) and *Rhacophorus appendiculatus* (found on only one occasion at a site within the watershed reserve). Based on call recognition, the species found regularly at significant distances from water were particularly cryptic, and could often only be located by their call, these were *Platymantis* sp, *P. corrugatus*, *P.dorsalis*. Individuals of other species were found at a distance from water, such as *R.woodworthi*, but only occasionally compared to their abundance at stream sites.

Species richness plotted in rank order for the two techniques does not follow a clear pattern. The forest sites tend to have higher species richness than the paddyfield sites.

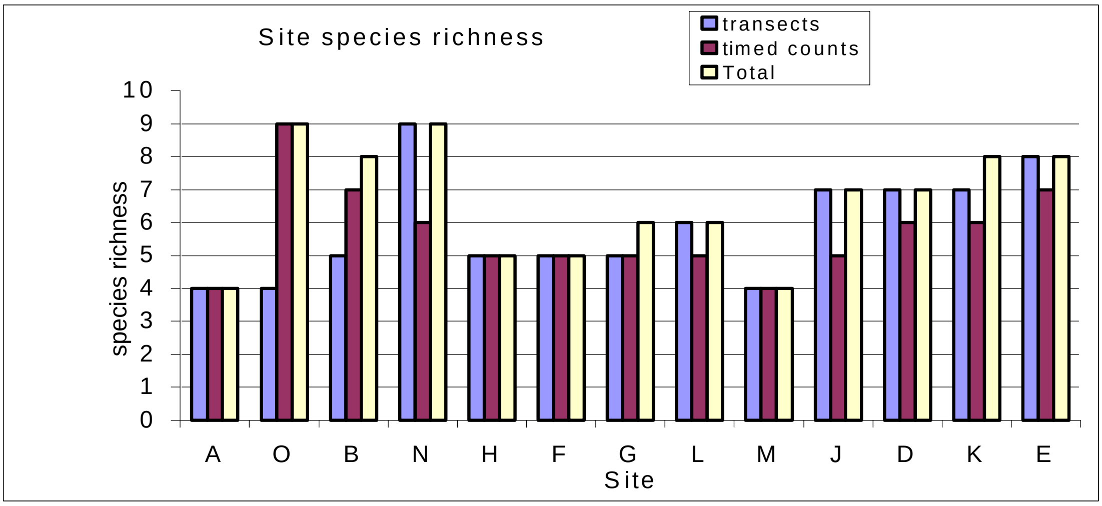
Sites are ranked in order of increasing species richness. Differences in the rank order



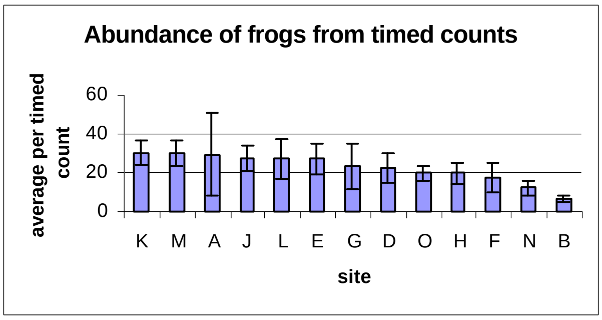


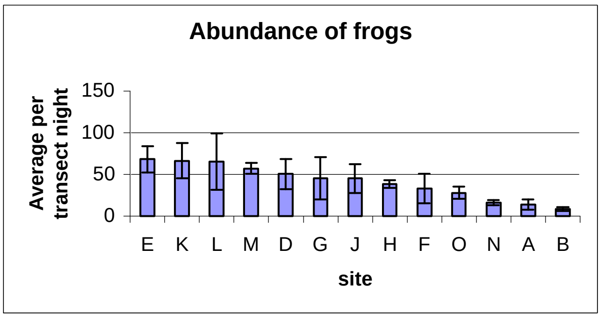
produced by the two techniques should be noted.
There is no clear distinction between forest and forest edge sites, shown clearly by the diagram combining richness estimates from both techniques with sites ranked from agriculture (A) to the most central forest areas (E). No inference is made about species known to be present but not detected by the sampling techniques.
Sites are ranked in order of their proximity to agriculture. A is a paddy field site and E is the most central forest site.

Rank Abundance Plots using both the transect and timed count results in turn have been produced for all the sites (all ranked based upon the rank abundance for site E, (i.e. the site nearest the centre of the watershed reserve). The pattern in species composition and relative abundance between the two methods is very similar. No meaningful measures of abundance can be calculated for the three species found in timed counts but not in transects, although they must be rare, cryptic or clustered in



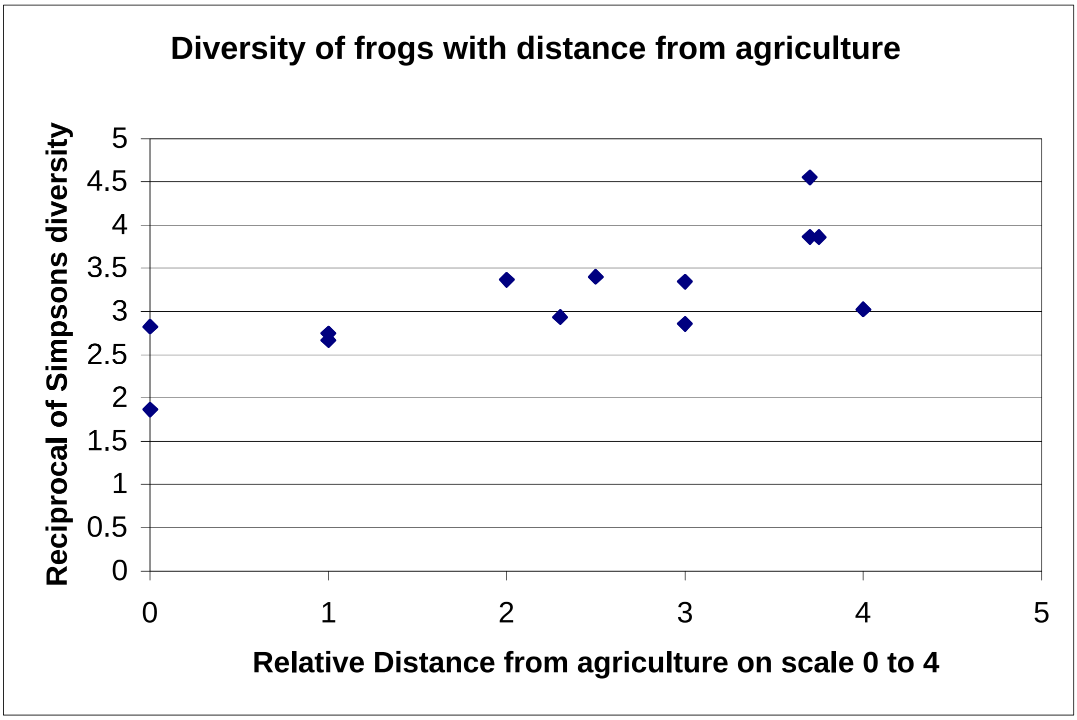
distribution. Further explanation as to their ecology is given in the species accounts section. All the forest sites have similar rank abundance plots. Both B and N which border agriculture show a larger species richness than both the paddy field sites and some of the forest sites. The diagrams on the following page summarise the Rank Abundance plots for the arbitrararily chosen habitat types; Paddy fields (sites A and O), coconut plantation (sites N and B), forest edge sites (sites H, F, G, L) and central forest (sites M, K, J, D, E).



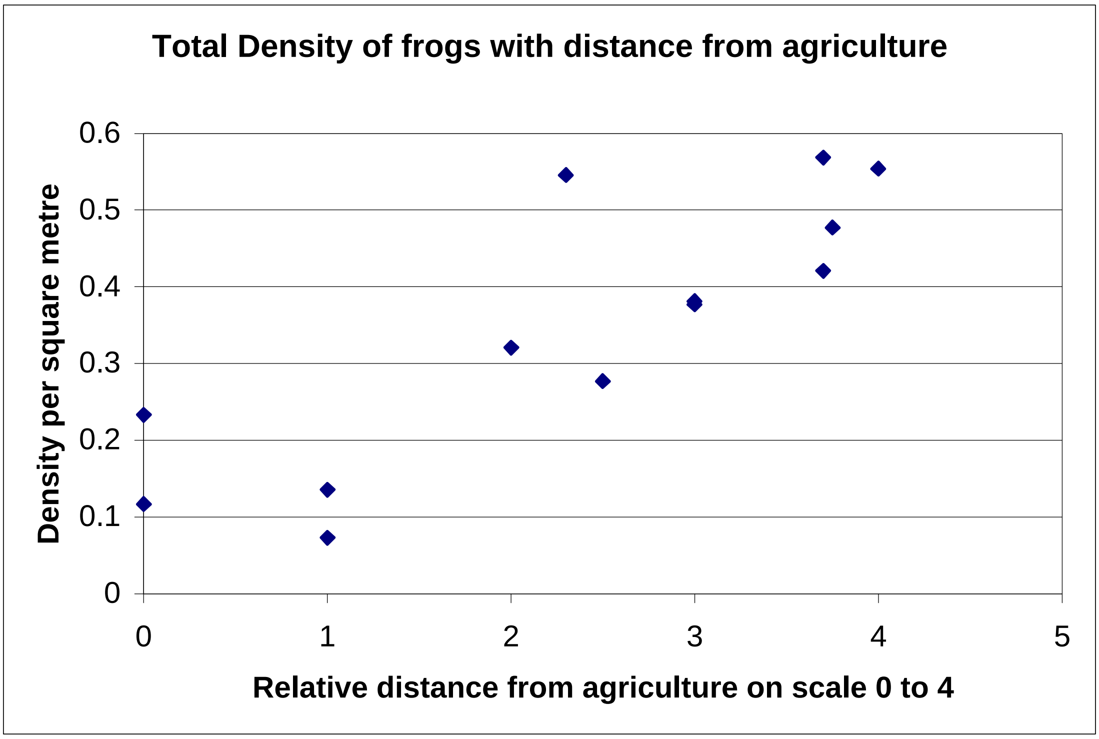


Sites are ranked in order of decreasing abundance of frogs. Changes in order for the two different techniques should be noted.

A variety of different diversity indices (Simpson's index, The Shannon Weiner Function, Brillouin's Index of species diversity and Evenness measures) for each site were calculated using the transect results. All indices produced similar patterns of diversity for the sites. Central forest sites were the most diverse, and paddy field sites the least. Sites that bordered agriculture or forest edge were more diverse than both the paddyfield sites and several forest sites.

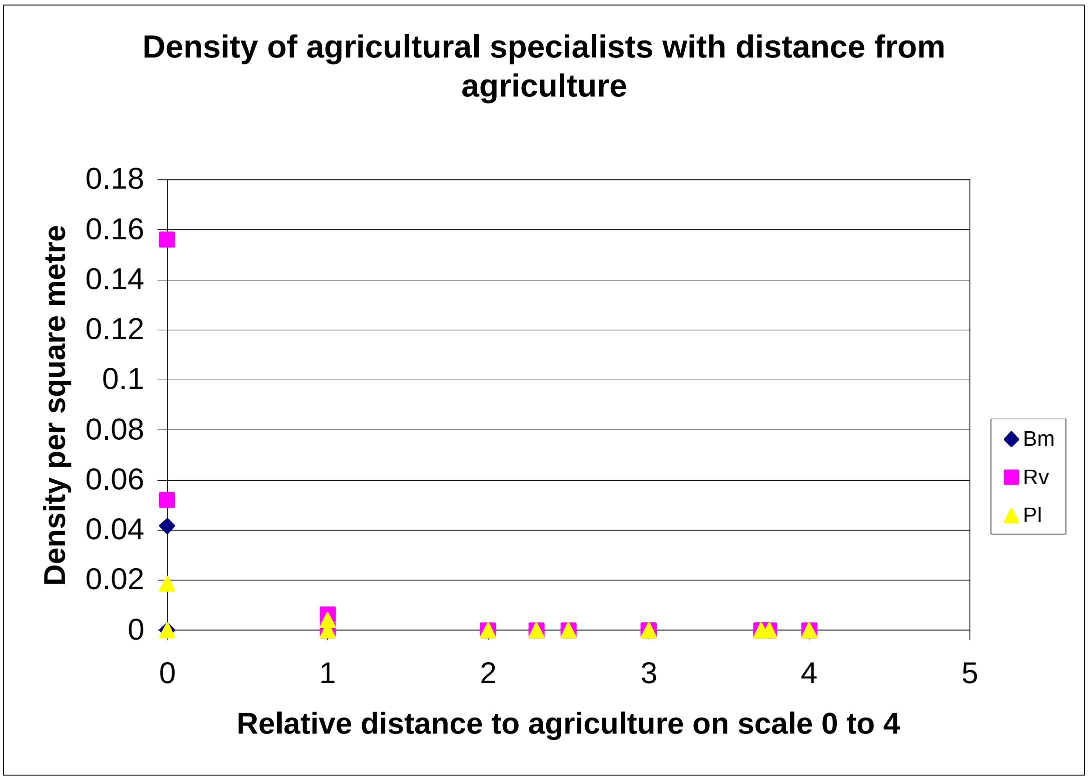


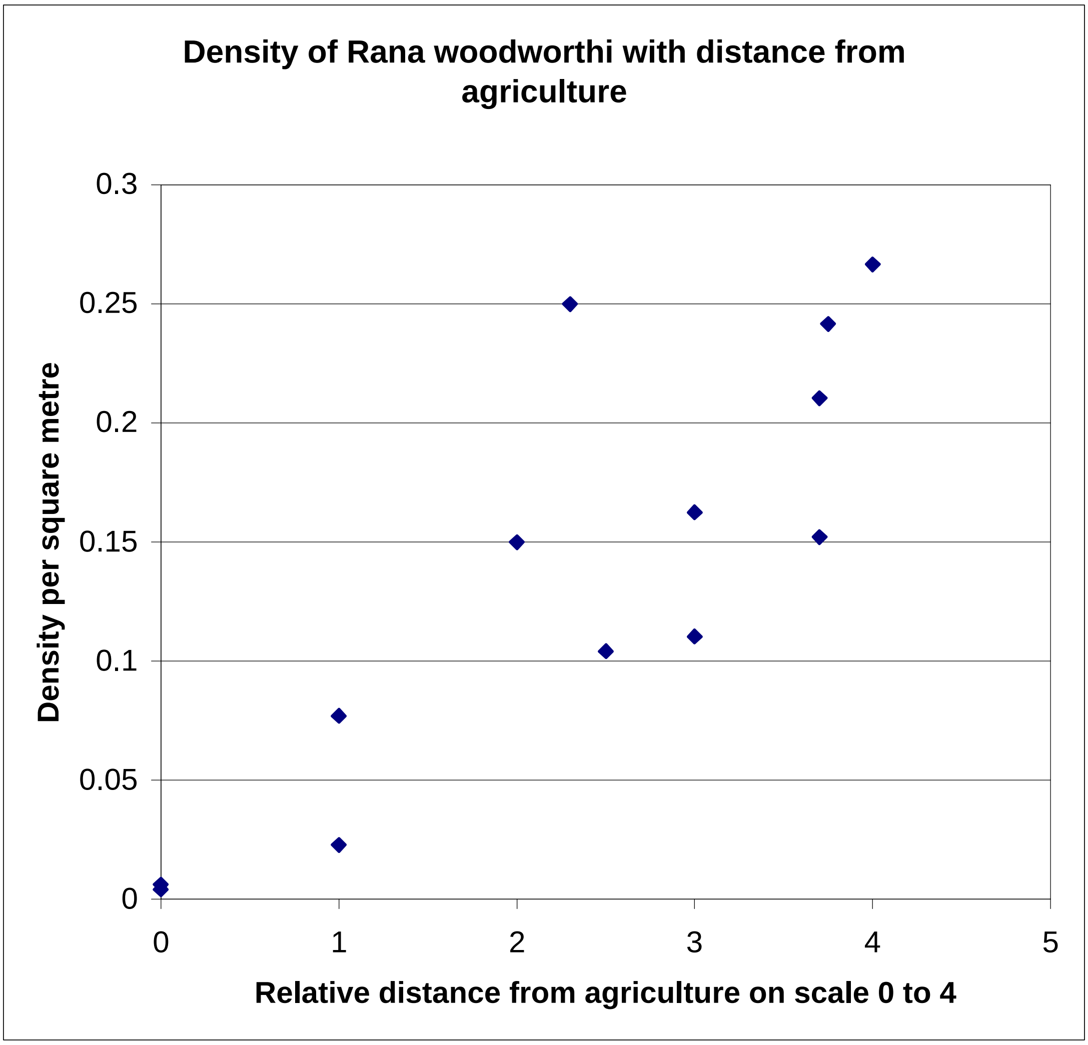
Abundance of all the common species of frog (*Rana woodworthi*, *Rana signata similis*, *Occidozyga laevis, Platymantis dorsalis*) increased with distance into forest. Central forest sites have the highest abundances of frogs. Site L is an exception, but it does have characteristics that make it a good frog habitat e.g. still but permanent water and lots of pandanus plants. *Bufo marinus*, *Rana vittigerra*, and *Polypedates leucomystax* were found exclusively in agriculture. Very few *Platymantis* sp**,** *Platymantis corrugatus, Rana magna* and *Rana everetti* were found by either technique.

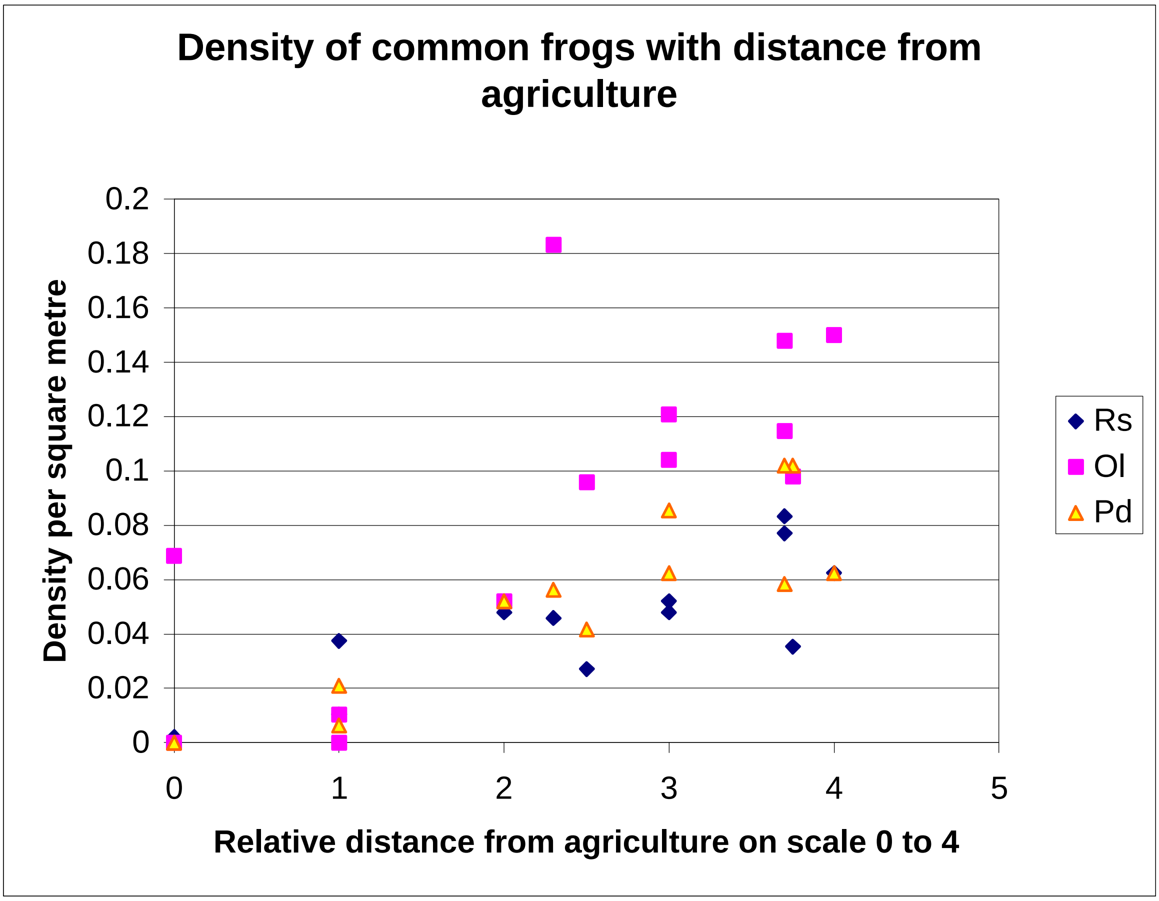


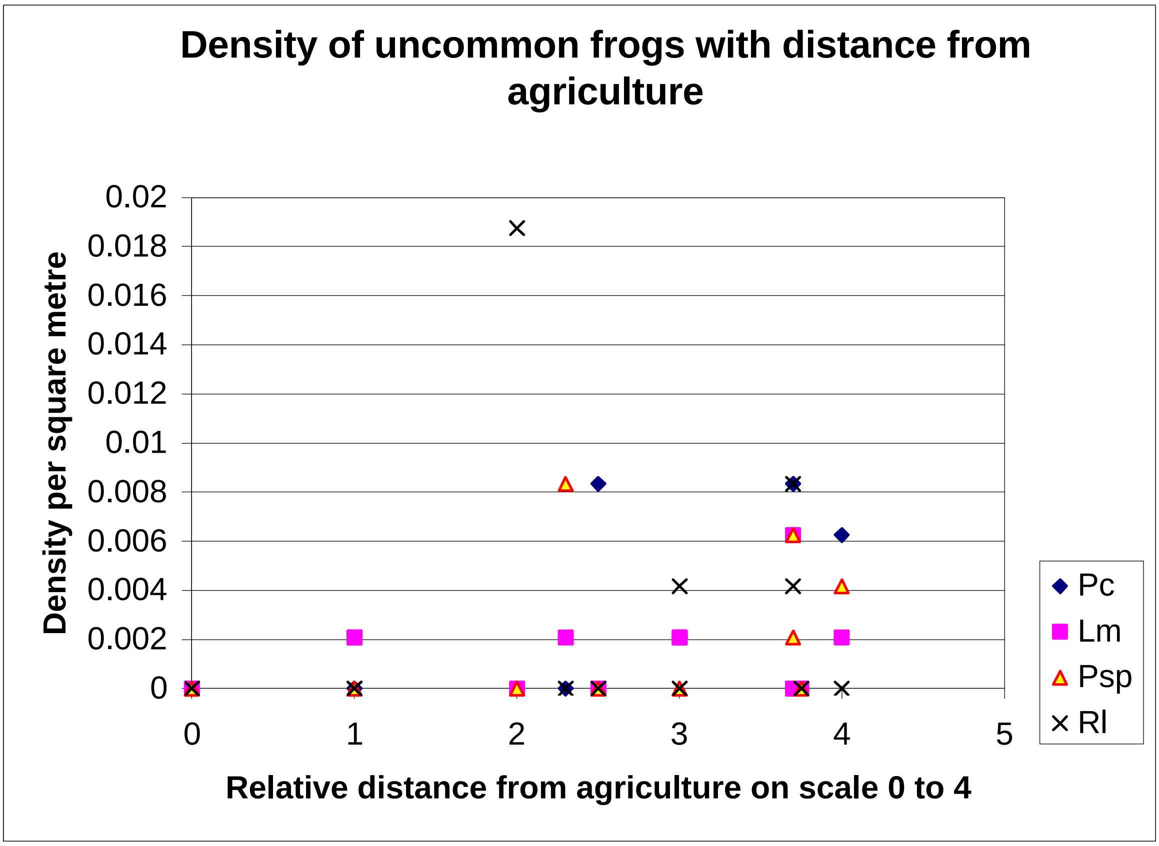
Abbreviations for the amphibian species in all the diagrams are as follows:

Bufo marinus Bm
Rana vittigerra Rv
Rana woodworthi Rw
Rana similis Rs
Polypedates leucomystax Pl
Platymantis dorsalis Pd
Platymantis sp. Psp
Platymantis corrugatus Pc
Limnonectes macrocephalus Lm
Occidozyga laevis Ol
Rana luzonensis Rl
White frog Wf
Rhacophorus appendiculatus Ra
Rhacophorus pardalis Rp
Kaloula picta Kp
Kaloula sp Ksp

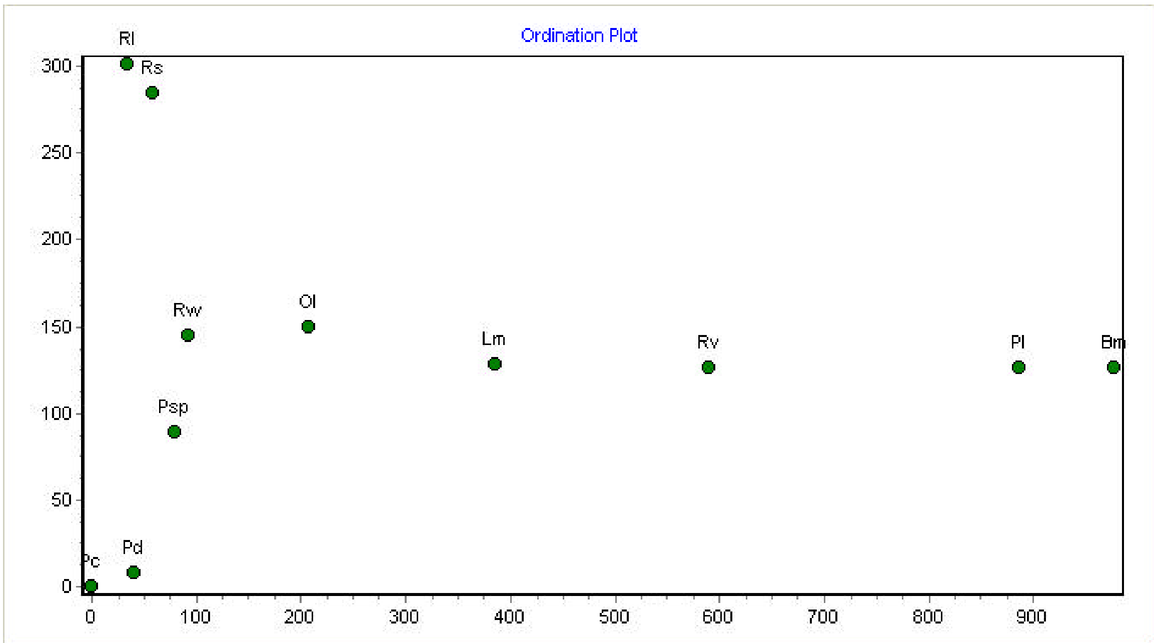

Density of agricultural specialists with distance from agriculture
Density per square metre
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
1
2
3
4
5
Relative distance to agriculture on scale 0 to 4
Bm
Rv
Pl


Density of Rana woodworthi with distance from agriculture
Density per square metre
0.3
0.25
0.2
0.15
0.1
0.05
0
0
1
2
3
4
5
Relative distance from agriculture on scale 0 to 4

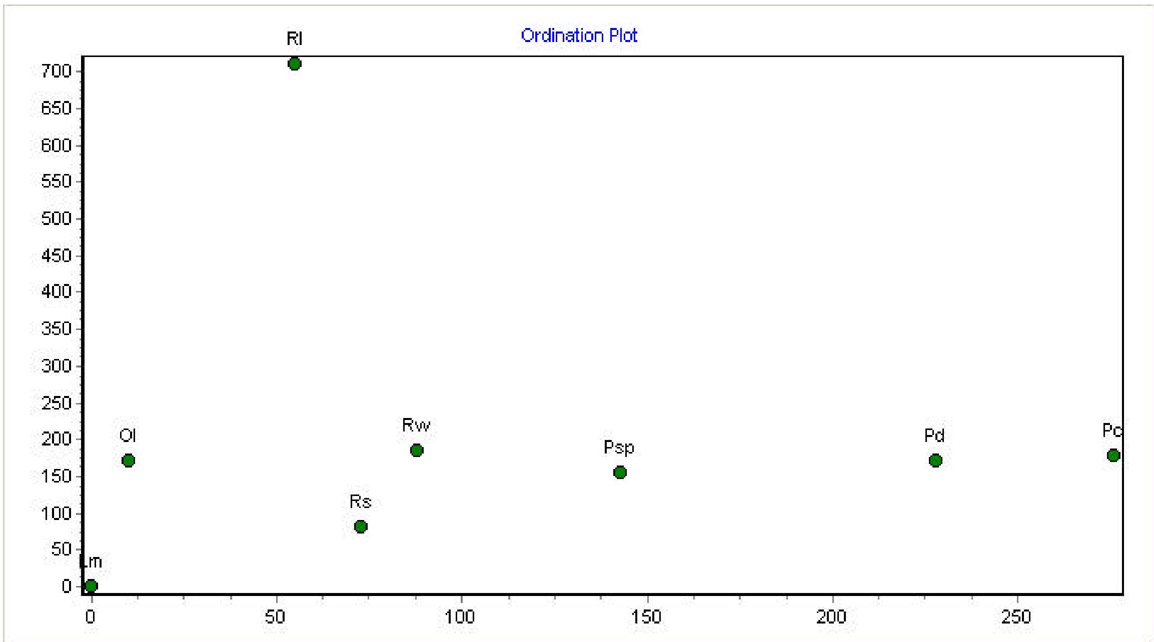

Density of common frogs with distance from agriculture
Density per square metre
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
1
2
3
4
5
Relative distance from agriculture on scale 0 to 4
Rs
Ol
Pd


Density of uncommon frogs with distance from agriculture
Density per square metre
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
0
1
2
3
4
5
Relative distance from agriculture on scale 0 to 4
Pc
Lm
Psp
Rl

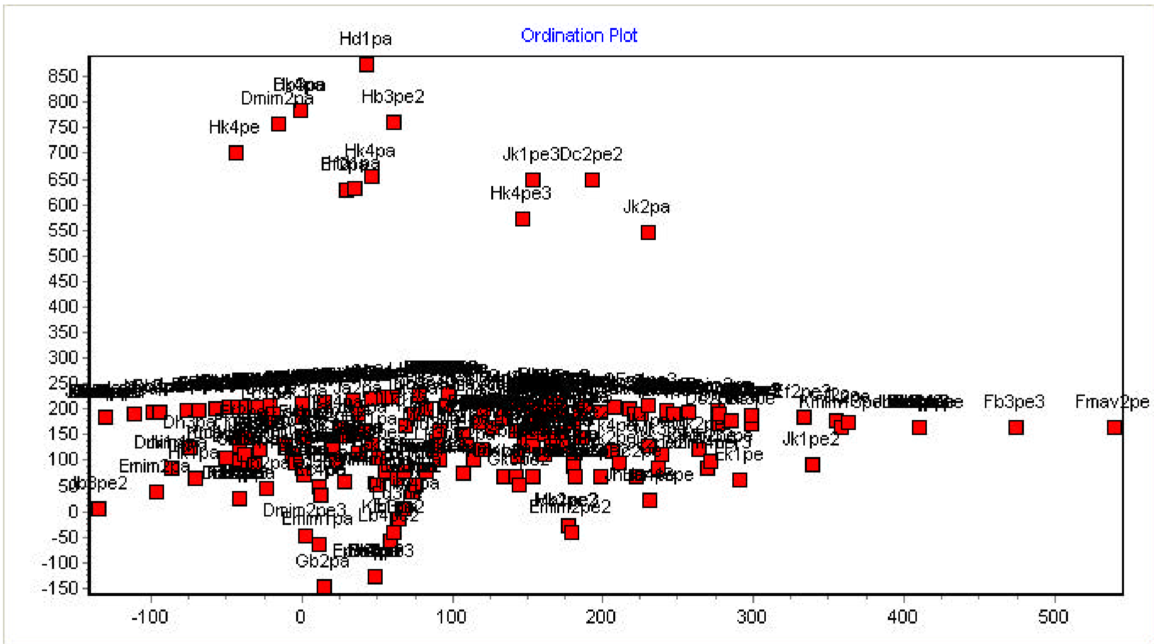
The decorana plot obtained from the complete transect data shows a gradient of ecologically different species. *B.marinus*, *P,leucomystax* and *R.vittigerra* are the species most indicative of the paddy field/ agricultural sites, (A, O, B and N). The *Platymantis* genus is clustered in the bottom right: *Platymantis* sp., *P.corrugatus* and *P.dorsalis*



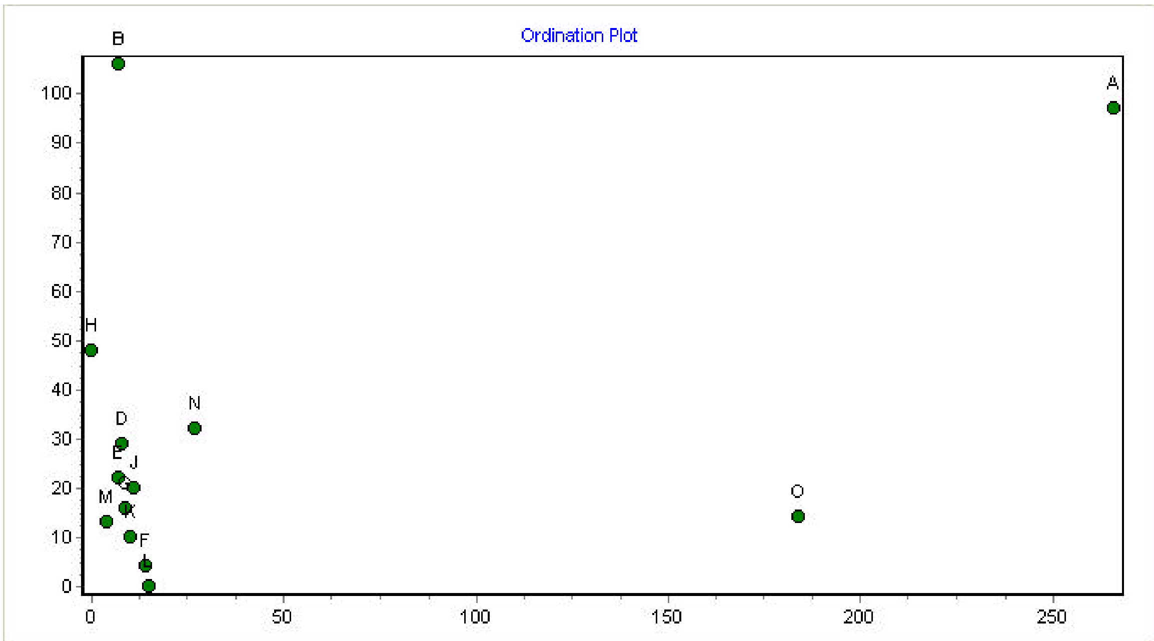
In the plot below uses the transect data but does not include the agricultural sites. The species separate out again.



The plot below shows the individual transects and their separation.



The plot below shows that all the forest sites, both central and edge cluster very closely together, but the agricultural sites separate out.



The community composition changes over the 5m gradient from the waters edge. In particular *O.laevis* was always found very close (within 1metre) to the waters edge. Both *P.leucomystax*, *R.luzonensis*, and *Platymantis* sp. are found usually at least 1m above the ground, but only *Platymantis* sp. is found at a distance from water.

Discussion

The timed count has more potential to find cryptic species (the 'white frog'), highly clustered species (*R.pardalis*) or those present at low densities (*L. macrocephalus*) because the search area is broader and calling individuals can be located, however no unit of area can be applied. Transect searches must be repeated many more times for an accurate assessment of species richness. Forest site M has one of the lowest species richness according to the transect data, but several species (*P.corrugatus*, *Platymantis* sp and *L. macrocephalus*) heard or seen were not detected during sampling. All of which are rare, clustered or cryptic species that were rarely detected by the transect techniques.

The species abundance and rank composition produced by both techniques is very similar, suggesting both provide a good representation of species relative abundance. However the timed count method is not applicable for comparisons of frog abundance between certain sites. At site A, a large number of frogs are detected by the timed count, but the transect method produces low density estimates (compared to forest densities), a result of large numbers of marine toads found in agricultural habitats. Discrepancies between the two techniques are a result of differences in the detectability of frogs and because some habitats are more difficult to search or because species found are more cryptic. For rare species sample sizes are too small to make reasonable extrapolations of density estimates.

Species assemblages

Species richness tends to be high at agriculture sites close to forest because of coexistence of agriculture and forest specialist species. Central forest areas appear to be more species rich than edge sites, but too few species are present to judge whether a clear pattern between core and edge forest exists. Therefore species richness is uninformative about species composition and quality. Some species may remain undiscovered on Polillo as suggested by the species accumulation curves; new species were found 37 days into the study.

Local habitat variables influence species richness and composition. There is a clear increase in density of the common forest species with distance from the forest edge, and rarer species may follow this pattern too (as is true for *Platymantis* sp.) or may be influenced by other factors that do not correlate with distance from forest edge (e.g. *R.luzonensis*). Parris (1999) reported a significant relationship between species richness and upstream catchment volume and Inger (1993) found stream width and stream gradient strongly influenced the compositional similarity of assemblages on both a local and regional scale. Stream width and flow may play an important role in the species composition of assemblages on Polillo. Observational trends suggests *R.luzonensis* is more abundant at wider streams, and or streams with a stronger current. In the Decorana plots the strong pull of *R. luzonensis* is very clear, suggesting its habitat requirements are quite different to the other species. In the first Decorana plot the x axis is suggestive of disturbance or proximity to agriculture because that is the axis upon which the agricultural specialists separate from the forest species. Both *Occidozyga laevis* and *Limnonectes macrocephalus* are found in forest and agriculture sites perhaps explaining their position in the Decorana plots.

Because total frog density and abundance increases with distance into forest, larger (and potentially more robust) populations of both sensitive and common species are found within forest compared to edge sites. However some of the edge sites (e.g. site L) have specific local breeding habitat variables that result in high densities of many species. These habitat variables do not necessarily suit all species, which must be understood when planning for conservation. The increase in frog abundance with distance from agriculture might not necessarily be a causal relationship, perhaps simply a correlation of suitable habitat factors with distance into forest). This study compares both abundances of frogs that have a strong dependance on water bodies for breeding as well as terrestrial breeders. It has been shown that edge has an important effect on abundance of a particular terrestrial breeder *Platymantis* sp, which presumably will not be affected to the same extent by water body size as the water breeders. It is important to establish how much of this increase in abundance of water breeders is attributed to distance and how much to factors such as increasing stream width.

Shannon's index is recommended by Hayek (1994) for determining amphibian diversity. Krebs (1999) recommends the reciprocal of Simpson's Index or the exponential form of the Shannon Weiner function to describe heterogeneity depending upon the decision to weight common species or rare species respectively. The sampling procedure did not always detect rare species known to be present. Large sample sizes were obtained for the common species that are probably more accurate. As a result of sampling inadequacies the Simpson's index is probably more appropriate for these amphibian populations than Shannon's index. The transect diversity estimates should be used because they produce accurate abundance estimates comparable between habitats, despite the timed count technique detecting more of the rare species. All the indices produced similar diversity patterns despite each giving different weight to specific properties of the species' abundance distributions.

The diversity pattern can be interpreted many ways. There is a slight trend of increasing diversity with distance from agriculture, but there are also high levels of diversity at the agriculture border forest sites. This could be a result of coexisting agriculture and forest species, at the interface, and increased number of sensitive high quality species (Hambler and Speight 1995) in the central forest. This pattern could be a reflection of sampling inadequacies. As common species increase with distance into forest, rarer species may or may not follow a similar pattern. Rarer species may contribute in unpredictable ways to the overall diversity measures resulting in higher diversity estimates for sites with an overall lower abundance of frogs (such as the interface sites).

I suggest the diversity indices should not be used as a basis for conservation measures in this study because of the difficulty in interpreting their meaning. Species richness is uninformative about species quality and therefore ranks agriculture-forest border sites together with central forest sites that contain rare species, which are not found outside forest. From the rank abundance plots sensitive forest species, and agriculture specialists can be identified, these plots are much more informative on species quality, and the effects of habitat quality. Careful accurate scaling of the plots is required for the general increases in abundances to be detected with distance from agriculture. Species abundance plots against distance from agriculture show this pattern clearly (see diagrams).

The transects identified habitat partitioning within some species. Certain species are rarely found together and when they are, both are at low densities, this may be due to overlap in their habitat requirements. Some species such *P.corrugatus* had clustered distributions, but further intensive work is necessary to quantify spatial distribution. Notably the terrestrial breeders were the only species that were found in abundances away from water bodies.

The importance of habitat structure:
Positions of frogs within transects suggest habitats with greater structural diversity will support higher numbers of species because an increased number of microhabitats is available. Most of the streams and rivers around the watershed that are surrounded by coconut plantation have a mixed variety, mainly of agriculturally important trees, at their edges. The agriculture is monoculture, either coconuts or paddies, therefore not able to support a very diverse community (*Bufo marinus*, and *R.vittigera, Kaloula picta, P.leucomystax*). The stream edges are more structurally diverse and therefore able to support more species rich communities. Stream edges that have low growing bushes and overhanging branches to water bodies provide habitat for some of the more arboreal species such as *R.luzonensis* and *P.leucomystax*,. Even *R.pardalis* was found at paddyfield site O and over a temporary pool amongst agriculture not far from base camp. Sites between agriculture and forest have been shown to have the most species present possibly due to the close proximity of two habitats, allowing agriculture species to mix with some of the 'forest' species (i.e. *Bufo marinus, R.vittigera, Kaloula picta, P.leucomystax, R.woodorthi, R.similis, O.laevis, P.dorsalis* all found at one site).

Fragmentation and corridors:
Vegetation bordering streams allow species to breed in coconut plantations and rice paddies. Streams act as wildlife corridors, especially where they link otherwise unconnected patches of forest and what would otherwise be isolated frog populations. Therefore as a conservation measure these corridors should be preserved together with the surrounding trees and vegetation. This is at present a fortunate consequence of local farming practices around Sibulan.

Without further indepth analysis any minor changes in the frog communities within the forest cannot be detected. Possibly more samples would allow discrimination between sites. Community analysis by decorana suggests all the sites in forest even H which is coconut on one side and forest on the other, support essentially the same communities (despite the likely differences in forest quality/ disturbance levels etc) (differences in overall abundance is possibly due to increased capacity of the breeding habitat). No major differences in the structure of the forest can be identified from the PCQM data at the sites. The decorana plot of the forest sites (excluding site M and K for which tree species data was not collected) would seem to confirm the choice of sites, because edge sites cluster together and central sites cluster together. Therefore in this case Primary forest is differentiated from edge sites and smaller patches of forest by its species composition, not its structure. Presumably there is little difference in the structure of the habitat for the frogs, which would adequately explain why both edge and central forest support the same communities. Further analysis of understorey vegetation and other habitat characteristics are necessary to identify whether they are not different between edge and forest sites, and how they correlate to the frog communities.

***Platymantis* sp transects**

Introduction

The status and distribution of *Platymantis* sp was investigated. Nothing is known about this frog, which has a potentially highly restricted distribution. It has not been found on Luzon, therefore may be endemic to Polillo. The most similar frog on Luzon is *Platymantis luzonensis* however the call of *P.luzonensis* differs from *Platymantis* sp as described in the sound analysis section. A detailed study is required to determine the comparative morphological differences between the two frogs.

Only 10 individuals were found in total from the transects and 7 from the timed counts. This species was also only found at the forest sites, making it one of the rarer frogs. Many of the anecdotal Platymantis sp sightings were 2m or more above the ground. The chance of finding frogs at heights greater than 2m is much less than below 2m i.e. within our field of vision. Discovering the call of *Platymantis* sp made it possible to locate individuals more easily to within 1m square (pinpointing the individual takes much more time and effort). The call also confirmed anecdotal evidence that most individuals call from at least 2m above the ground. Therefore search techniques used previously may not be effective in finding individuals because of their spatial location and habitat preference.

A technique was devised based on detecting the calls of male frogs to estimate absolute densities (density of calling/ breeding males) in forest sites. This provides an opportunity to compare densities to the estimates of the other methods, therefore assess their effectiveness.

AIMS

- Determine the absolute density of *Platymantis sp* in the central area of the watershed forest
- Determine if density changes with distance from agriculture and distance from core forest
- Investigate the effect of forest edge on *Platymantis sp* abundance
- Compare relative abundance for *Platymantis sp* with timed counts and transect estimates
- Produce conservation recommendations based on the results

Methods

Transects were walked along a chosen set navigable route and the distance recorded. For every *Platymantis* sp heard, the distance along the transect and the perpendicular distance to the location of the calling frog was recorded. Initially transects were completed along a gradient, from outside the watershed reserve amongst coconut plantation, towards the centre of the watershed reserve and the potentially least disturbed forest. Transects that entered the watershed from different directions were completed to try and omit any landscape directional gradient biases. Later transects were completed in central sites in the watershed to compare with forest edge estimates. Totally random placement of transects was impractical. Original transect routes were repeated and numbered ribbons were tied to branches within 1m of calling frogs, therefore on a subsequent transect the position could be recognised again.

The Programme DISTANCE (Laake *et al*., 1993) was used to estimate density. Four different estimator models were used, and the optimum model, with the best fit and the lowest Akaike information criterion (AIC) was selected by DISTANCE. The histograms for best fit of the detection function were examined for potential problems (e.g. input errors, heaped and spiked data) (Brady.L 1993). The forest transects have been split into different sections appropriate to their distance from agriculture, and densities calculated to assess whether densities change with distance from the edge.

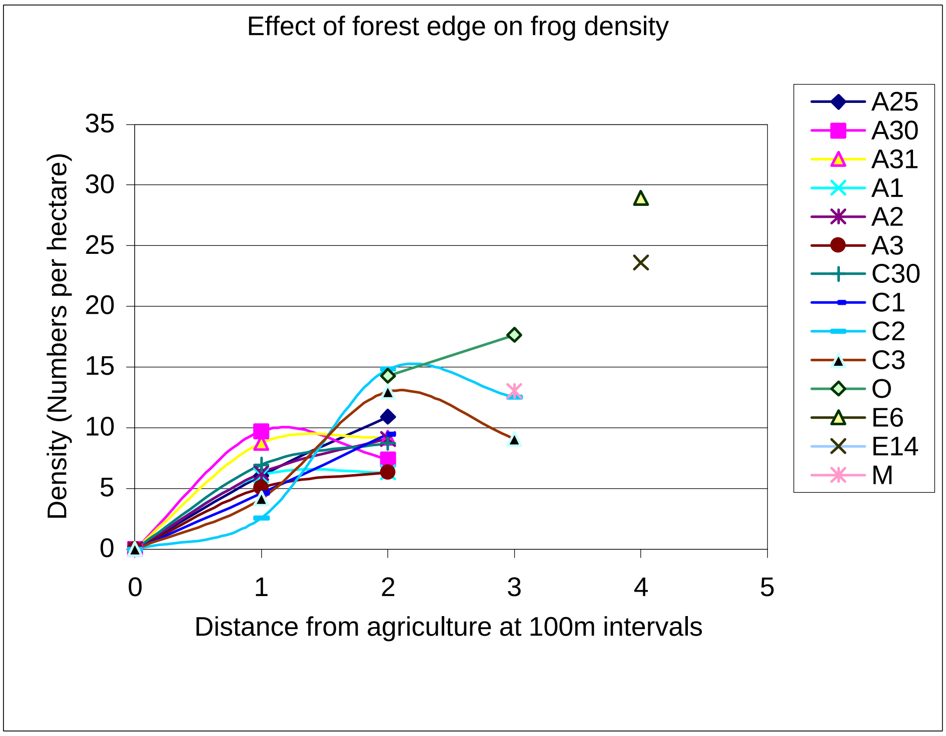
RESULTS

Density estimates are given in individuals per hectare.

Graphs (see appendices) show the distribution of frogs encountered on transects. Clusters of points from different transect nights often correspond to the same calling location, it is not possible to determine if the same frog was calling from that location. The 'edge' transects have been analysed from where the first *Platymantis* sp starts calling from, although the transects started several hundred metres before, to ensure no frogs were overlooked. The third edge transect starts from where fewest frogs were heard calling, because of time constraints.

Forest edge transect A density estimates ranged from 5.2 to 11.8 per hectare (mean 7.85, n=6). Forest edge transect C density estimates ranged from 3..8 to 6.2 per hectare (mean 5.15, n=4). Central forest transect estimates were 13 (transect M, n=1) and 26.2 (transect E, n=2).

Splitting the edge transects up into 200m blocks revealed that densities tended to increase with distance into forest (see appendix for the 1st, 2nd and 3rd 200m density estimates which are also illustrated in the graph below).



Distance from agriculture is plotted by approximate distance from agriculture. The distance to the edge of the forest is used approximated to the nearest 100m , with the edge transects divided up into sections 200m long (see appendix). Each transect is labelled by site (A, C, M, O, E) and by the date (25/8/99, 30/8/99, 3/9/99 etc. For full dates see appendix). Repeated transect nights and transect sites are therefore displayed together. The data legend therefore corresponds to the transect and the day of the month the transect was completed.

Discussion

Highest densities of *Platymantis* sp are found in the central forest areas, in particular site E. This site had the highest diversity indices and was predicted to be the most pristine habitat by all other assessments. *Platymantis* sp were absent in agriculture and found at their lowest densities where forest meets coconuts, with increasing densities with distance from agriculture.

The data set was relatively small and it would be expected that the detection function for an aural cue (such as a calling *Platymantis* sp) would be different to a visual cue. However the chance of detecting a calling frog was high and all transects contained reasonable numbers of frogs such that sensible confidence limits and well fitting detection models were applied. All suggesting the model selected by DISTANCE is realistic.

The densities calculated for one site varies from one transect night to the next. All lie within the appropriate confidence levels of the estimates except for one (see appendix) and most estimates are very similar. This suggests the frog activity changes from night to night, but a reasonable estimate of total density of calling males at a site can be made from one transect night.

Absolute population size cannot be estimated, because male and female survivorships may not be related and because maximum counts of calling males may not be constant proportions of the adult population (Zimmerman 1994). Therefore densities estimated by the aural transects are only for male frogs and are an underestimate of total population densities, whereas males, females and juveniles where found using the timed counts and transects.

Disagreement exists on whether edge has important effects on tropical amphibians (Duellman 1978; Zimmerman & Rodrigues 1990 vs. Gambold & Woinarski 1993; Culotta 1995). My results suggest a significant edge effect whereby frog density does not reach maximum levels until at least 200m or more from the forest edge. The highest densities recorded reach up to 28 frogs per hectare. None of the edge transects reach these densities despite travelling at least 600m into the forest. However other central forest sites (such as site M, density =13 frogs/ hectare), do not approach such high densities. The edge transects A and C are very suitable for this kind of study, but not necessarily typical, because when the forest stops, there is a definite boundary where agriculture replaces forest. Edge transect O is not so clear cut, agriculture and small forest patches are interspersed, which explains the immediately higher densities of frogs at transect O than A and C.

Forest fragments are often much smaller than the 200 edge threshold required to reach maximum densities and so presumably support lower densities than larger forest tracts. The importance of forest for the survival of this species is essential. Individuals were heard calling outside forest (on the 3 hour walk from Polillo town 45 different frogs were heard calling. All were heard in isolation and only amongst patches of trees), but this species is highly restricted to forest habitat. Amphibians vary in dispersal ability (Sinsch 1990), which suggests that species may exhibit differential success in surmounting barriers created by habitat fragmentation (Pearman 1997). The dispersal powers of this frog are unlikely to be large. This species clearly prefers living above 2m from the ground with at least some canopy cover. Without linked patches of forest this species is likely to decline due to isolation and reduced densities resulting from edge effect on small forest patches.

When the frogs are in lower densities calling sites seem to be more constant, as can be seen from the diagrams of transects A and C (see appendices) i.e. nearer to forest edge than in core forest. At high densities there is still evidence for favoured calling sites. It is not possible to say whether the same frogs are calling from the same position on consecutive nights. Possibly lower densities of calling males reduces competition for calling positions. Favoured calling sites may be due to a lack of suitable calling positions sites at edge sites compared to core forest. Pinpointing individual frogs was more accurate when frogs called at low densities, compared to high densities where it takes longer. Reduced clustering of calling positions on consecutive transect nights in forest may be due to increased inaccuracy of pinpointing locations. The labelled ribbons showed that relocating an identical calling position can result in discrepancies in measurements of more than 5m.

Densities per hectare calculated for *Platymantis* sp from the transect data are:

	O	N	M	L	K	J	H	G	F	E	D	B	A
Psp	0	0	0	83	42	0	0	0	0	63	21	0	0

There is no distinction between forest and edge sites from the above data. Some of the central forest sites have densities of 0, whilst some of the edge sites have densities of 83 (affected by finding a frog repeatedly in exactly the same position on two consecutive nights by independent observers). However averaging the densities and assuming all the forest sites have the same densities produces an average density of 26.1 per hectare. Considering that females and juveniles are calculated in that estimate it is probably a reasonable comparison to the estimates generated by DISTANCE. This suggests that transect data would approach accurate density estimates if the sample size increased greatly. However from this study the density estimates from transects are not reasonable, because too few frogs were found.

Platymantis sp is spatially separated from the other *Platymantis* which are all ground dwelling or found amongst shrubs and bushes up to a metre above the ground. The other frogs frequently found above 2m (*P.leucomystax*,*R.pardalis*,*R.everetti*) all depend on water to breed and are usually found clustered at the edges of water bodies, whereas the DISTANCE data shows *Platymantis* sp are found at a distance from water.