5. THREATS TO POLLINATION SYSTEMS

The collapse of pollinator mutualisms has been identified as one potential consequence of anthropogenic land use change (Kearns and Inouye 1997; Allen-Wardell *et al.* 1998; Kearns *et al.* 1998; Wilcock and Neiland 2002). Declines in pollinators have been reported from most continents (Kearns *et al.* 1998; Kevan and Phillips 2001). Land clearance, fragmentation, agricultural practices, herbicides, pesticides and the introduction of exotic plant and pollinator species (Table 10) have all been implicated in a serious decline in pollinators that has been referred to as a "pollination crisis" (Buchman and Nabhan 1996).

Loss of or interruption to pollinator services may have several outcomes. The most obvious result is a loss or reduction in seed set, however, impacts may also extend to reduced offspring vigour as a result of self-pollination, decreasing heterozygosity, and in the increased expression of deleterious traits, resulting from inbreeding (Kearns and Inouye 1997). Ultimately, loss of seeds, fruits or plants will affect animals that rely on these resources.

Table 10: Summary of threats to pollination systems.

Threat	Effect	Impacts
Fragmentation	• Reduced population size • Isolation • Hostile matrix • Alteration of visitor behaviour	• Increased genetic drift, in-breeding depression, increased threat of extinction, reduced pollen dispersal, reduced fitness (Rathcke and Jules 1993; Kearns *et al.* 1998). • Increased reproductive success (Cunningham 2000). • Temporary reduction in pollinator activity (Becker *et al*. 1991). • Genetic erosion of small populations (Cane and Tepedino 2001, Ghazoul *et al*. 1998, Oostermeijer *et al.* 1998). • No reduction of reproductive success, substantial between- and within-site variability (Costin *et al.* 2001). • Effect of isolation tied to pollinator mobility (Law 2001). • High genetic differentiation among geographically close patches (Dutech *et al*. 2002). • Pollen clogging by generalist pollinators (Kunin 1997, Groom 2001).
Agricultural Practices	• Land clearing • Pesticide spraying • Herbicide spraying • Extensive monocultures • Grazing • Resource depletion	• Pesticides reduce pollinator numbers (Batra 1981). • Poisoning of pollinators resulting in death, behavioural changes and reduced mobility (Johansen 1977). • Contamination of pollen and honey (Kearns *et al.* 1998). • Herbicides reduce availability of nectar plants, remove nesting sites, destroy larval food sources for pollinators (Kevan 1975, Kearns *et al.* 1998, Richards 2001). • Grazing changes nesting sites, decreasing water availability, and replacement of native grass species with introduced pasture grasses (Kearns and Inouye 1997).
Invasive Species	• Displacement of pollinators by feral competitors • Displacement of native plants	• Feral honeybees compete for pollen normally available to native pollinators, altering pollen dispersal patterns through foraging that differs from native pollinators, and depleting nectar supplies to nectar feeding pollinators (England *et al.* 2001). • Introduced bees implicated in successful spread of exotic plant species where native animal species are not suitable pollinators (Stout *et al.* 2002).

Like most tropical landscapes, the Wet Tropics have been subjected to processes of fragmentation over the last one hundred years or so. Plant species 'marooned' in these fragments may or may not be part of viable populations – and it may take much longer than one hundred years before this becomes evident. Pollination and the subsequent reproductive performance of plants in fragments becomes a crucial issue. Understanding the changes that will occur to pollination processes and outcomes in fragments is an essential first step in managing these changes and attempting to ensure the long-term future of our forests. That having been said, there is almost no data available on this topic. The study by Law and Lean (1999) on *Sygygium cormiflorum* did demonstrate that visits by vertebrates to the flowers were skewed in favour of bats over birds in fragmented situations. Far more work has been carried out in other countries (see references in Table 10), and what is clear from this work is that the little work that has been done shows that the impacts are complex.

We do have in progress studies on the visitor assemblages of isolated and garden individuals of *Syzygium sayeri* and *Normanbya normanbyi*, as well as investigations into the movement of pollen in continuous forest, but no results are yet available. There is no question that much more work of this nature is required and, indeed, is crucial to future management decisions. The key questions for the pollination system of any disturbed system include:

- Has the flowering pattern been altered?
- What level of successful pollination occurs?
- What is visiting the flowers?
- How far is pollen being moved?
- How does any of this differ from continuous forest?

Many of the methods already described can be used to investigate these questions. We briefly describe some additional methods we are currently using in the rest of this section.

5.1 POLLEN MOVEMENT

Understanding how far pollinators can move pollen can give some understanding of gene flow and the potential for pollinators to move pollen between isolated trees (especially in fragmented systems).

Tagging or Marking

There are a number of ways to tag or mark pollen to determine the movement of pollen between individual trees. We have used fluorescent powder to determine the movement of pollen amongst individual *S. gustavioides* trees at the Australian Canopy Crane site. In this case, we marked flowers on each tree using a different coloured powder for each tree. We then returned to the trees at night and used a UV torch to detect the fluorescent powder on other flowers. Using this, we saw that while most movement was within a tree, there was certainly some movement between trees. This method could be used on understorey trees elsewhere, however without crane access this method is not suitable for use in canopy trees.

Genetic Techniques

Genetic markers can be a useful tool for determining the flow of pollen between individual plants, and the rates of outcrossing. These techniques have been used extensively throughout the neotropics, based on allozyme and microsatellite data (Ward *et al.* 2005). The difficulty with this technique lays in the cost, and in some cases the failure, to obtain sufficient variability to successfully determine gene and pollen flow (Squirrell *et al.* 2003).

We are currently using micro-satellite markers in the hope of determining the distance that pollen is transferred within a continuous forest by pollen vectors. Our expectation is that by determining the paternity of fruit from focal tree, where the pollen donor tree can be identified we will know the distance pollen has been transferred.

To date, we have mapped and sampled all *S. sayeri* and *S. gustavioides* trees within a 250-metre radius of the canopy crane. Mapping was done using a Garmin Gecko GPS, which proved reasonably reliable within the rainforest. To find trees, we set up a series of 500-metre transects running north-south at every ten metres. We searched along the transects, looking approximately five metres on either side of the transect for the target trees. When trees of either species were located, they were tagged using tree tags and an individual number. To profile the DNA of each potential father tree, we collected a small core of cambium (Colpaert *et al.* 2005). A 10 mm leather punch was hammered into the tree trunk to extract the cambium. The core was stored in a labelled plastic vial with silica gel crystals until analysed.

Fruit has been collected from the maternal trees within the access area of the canopy crane, and then frozen and stored in a freezer at -80°C prior to analysis. A library of micro-satellites is developed for a plant species, in our case, we have a library of 6 loci for *S. sayeri*, but where less successful with *S. gustavioides*. The cambium will be analysed and compared to the DNA of the fruit to determine paternity. Identifying the father will give us a distance travelled by the pollinator. For those with no identified father, we can speculate that pollen has travelled further than 250 metres.

5.2 CONCLUSIONS – CONSERVATION AND MANAGEMENT

It is apparent from the literature that at present we do not know the net effect of anthropogenic disturbance on plant-pollinator interactions. It seems likely that activities such as habitat fragmentation, agriculture and changes to habitats caused by introduced species will be detrimental to some native species; potentially beneficial to others; and will sometimes have subtle and counter-intuitive effects (Cane and Tepedino 2001). The difficulties in understanding plant-pollinator interactions are matched by the difficulties of managing and conserving for these interactions. Conservation and management is likely to be frustrated by a lack of basic information on the reproductive ecology of individuals; detection of declines in populations and the interactions of individual populations; and the different scales at which processes operate. There is a clear lack of empirical evidence. The number of review papers on the subject of pollinator declines and the impacts of disturbance on the pollinator almost outweigh the number of field studies on which those reviews are based. The few studies that have been done provide conflicting and inconsistent results.

The recognition that most pollinators are far from obligate changes how they should be conserved (Kearns *et al*. 1998). The notion that the loss of one species will cause the linked extinction of another (Rathcke and Jules 1993) can no longer be maintained. Kearns *et al*. (1998) argue that if the fundamental nature of plant-pollinator interactions is that of a complex web, varying both in time and space, then the job of conservation is made more subtle and complex. But in turn, this may mean that these systems are more robust to change than previously thought. Consider the fundamental evolutionary nature of pollination. Plants and their pollinators are mutualists, both benefiting from the relationship. However, each has separate goals. The plant desires reproductive success via pollination; the pollinator is rewarded with a source of food, shelter or a mate. The selfish rather than cooperative nature of pollination is evidenced by nectar robbers and flower cheaters (Maloof and Inouye 2000). The result of conflicting interests is divergent natural selection, with plants responding with different floral phenotypes, and animals, their phenotype. The resulting morphologies are not optimal for the other, and in this way the relationship is more opportunistic and flexible (Kearns *et al*. 1998). This can create conflicts in conservation management between the needs of endangered animal species and that of endangered plant species (Simon *et al*. 2001). While generalist pollinators may respond better to disturbance than specialists, the isolation and reduced densities of individual plant species created in disturbed areas may result in increased pollination failure in these systems (Wilcock and Neiland 2002). Both generalist and specialist pollination syndromes are likely to be impacted by disturbance, but the impacts will be different and will require different conservation and management strategies.

The demographic and genetic consequences of habitat fragmentation and land use change are likely to be species-dependent (Cane 2001). Determining the impacts on individual species will require the uncoupling of factors such as habitat management practices, population size, isolation, genetic effects, pollination and sexual systems. It would be unwise to assume that pollination systems are robust enough to adapt to current rates of anthropogenic change and disturbance. With implications for essential ecological processes, potential for flow-on effects to other species and serious economic implications, the conservation and management of pollination systems requires serious attention. Pollinators may not only be important for the long-term success of our forests. For example, on the Atherton Tablelands, native pollinators found in rainforest fragments played an important role in crop pollination (Blanche and Cunningham 2005). Conservation should not be placed on hold for lack of consistent evidence, but better understanding of the variation should be sought. Further information on pollination systems, carefully designed studies of potentially impacted systems and protocols for measuring pollinator declines are urgently needed.

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APPENDIX 1 – EQUIPMENT LISTS

Suggested suppliers of equipment are provided in Appendix 2.

Section 2.2.2 – Observing and Recording Flower Phenology

- Small swing tags
- Lead pencils
- Data sheet
- Clipboard

Section 2.3.2 – Morphology of Individual Flowers

- Dissecting microscope with graticule
- Dissection kit
- Verniers

Section 2.4.2 – Testing Stigma Receptivity

- 3% hydrogen peroxide
- Pipette
- Watch glass
- Hand lens

Section 2.4.2 – Testing Self-compatibility

- Plastic acetate sheets
- Fine mesh fabric
- Stapler and staples
- String
- Cotton pads
- Flagging tape
- Permanent marker pens
- Pencils
- Note book
- Scissors
- Fine paint brush

Section 2.5.2 – Nectar Measurements

- Micro-syringe or capillary tubes
- Handheld refractometer
- Soft tissues
- Water

Section 2.5.2 – Pollen Viewing and Morphology

- Beaker or small vase
- Large filter papers
- Plastic bag big enough to cover an inflorescence
- Fuchsin jelly (see recipe on page 29)
- Microscope slides
- Cover slips
- Slide warmer (we use an old pie warmer)

Section 3.2.1 – Washing Technique to Sample In-fauna

- A4 plastic zip lock bags
- Slayafe® or equivalent spray insecticide
- 70% ethanol
- Fine artist's brushes
- Takeaway containers

Section 3.3.2 – PAS (plastic acetate strip) Traps

- Plastic acetate sheets
- Plastic coated wire
- Tangletrap®
- Mineral spirits
- Takeaway containers
- Soft artist's brushes
- Funnel
- Fine gauze
- Collection bottle for cleaned mineral spirits
- Ethanol
- Vials
- Labels

Section 3.3.2 – Interception Traps

- Plastic acetate sheets
- Wire
- Petroleum jelly
- Takeaway containers
- String
- Permanent marker pens
- Funnel
- Fine gauze
- Ethanol
- Vials
- Labels

Section 3.3.3 – Observations

- Data sheets
- Pencils
- Ethyl acetate
- Cotton wool
- Glass jars
- Large butterfly net
- Small vials
- 70% ethanol
- Binoculars
- Stopwatch / timer

Section 4.2.1 – Examining Pollen Loads

- Fuchsin jelly (see recipe on page 29)
- Pin
- Slide
- Cover slip
- Slide warmer

Section 4.3.1 – Size Class Exclusion Experiment

- Plastic acetate sheets
- Various sized mesh fabric
- Stapler
- Waterproof glue
- Waterproof tape
- Cotton pads
- Flagging tape
- Scissors
- Permanent marker pens
- Pencils
- Notebook

Section 4.3.2 – Day / Night Exclusion Experiment

- Plastic acetate sheets
- Fine mesh fabric
- Stapler
- Waterproof glue
- Waterproof tape
- Cotton pads
- Flagging tape
- Scissors
- Permanent marker pens
- Pencils
- Notebook

Section 4.4.1 – Pollen Tube Fieldwork

- Plastic acetate sheets
- Fine mesh fabric
- Stapler and staples
- String
- Cotton pads
- Swing tags
- Flagging tape
- Permanent marker pens
- Pencils
- Notebook / data sheet
- Small vials
- Fixative (1:3 acetate:ethanol)

APPENDIX 2 – RESOURCES

REFERENCE BOOKS

Pollination – General

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Hymenoptera – General

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EQUIPMENT AND SUPPLIERS

Fluorescent Dye Powders ....Brada Fine Colour Group (www.brada.com.au)

Hand lens .... Australian Entomological Supplies (www.entosupplies.com.au)

Micro-syringe..Alltech (www.alltechaust.com.au)

Refractometer..John Morris Scientific (www.johnmorris.com.au)

Stains (e.g. basic fuchsin) ....ProSciTech (www.proscitech.com.au)

Swing tags.. newsagents, stationers

Tangle trap .... Australian Entomological Supplies (www.entosupplies.com.au)

UV light... Dick Smith Electronics (www.dse.com.au),
Australian Entomological Supplies (www.entosupplies.com.au)