Donaldson JS. 2002 Pollination in Agricultural Landscapes, a South African Perspective. IN: Kevan P & Imperatriz Fonseca VL (eds) - Pollinating Bees - The Conservation Link Between Agriculture and Nature - Ministry of Environment / Brasília. p.97-104.

POLLINATION IN AGRICULTURAL LANDSCAPES, A SOUTH AFRICAN PERSPECTIVE

J S Donaldson

ABSTRACT

Pollination represents possibly one of the greatest areas of interaction between natural systems and agricultural systems. A consistent pollination service is one of the key factors supporting agricultural production but land use and farming practices also have a substantial impact on pollinators. The decline of pollinators threatens agricultural production and the extent of this impact has recently been highlighted by the collapse of honeybee colonies. Although the general problem of pollinator decline has been discussed in several books and publications, there is still value in obtaining regional perspectives on the extent of the problem and what is being done about it. In this paper, I review the current situation in South Africa.

INTRODUCTION

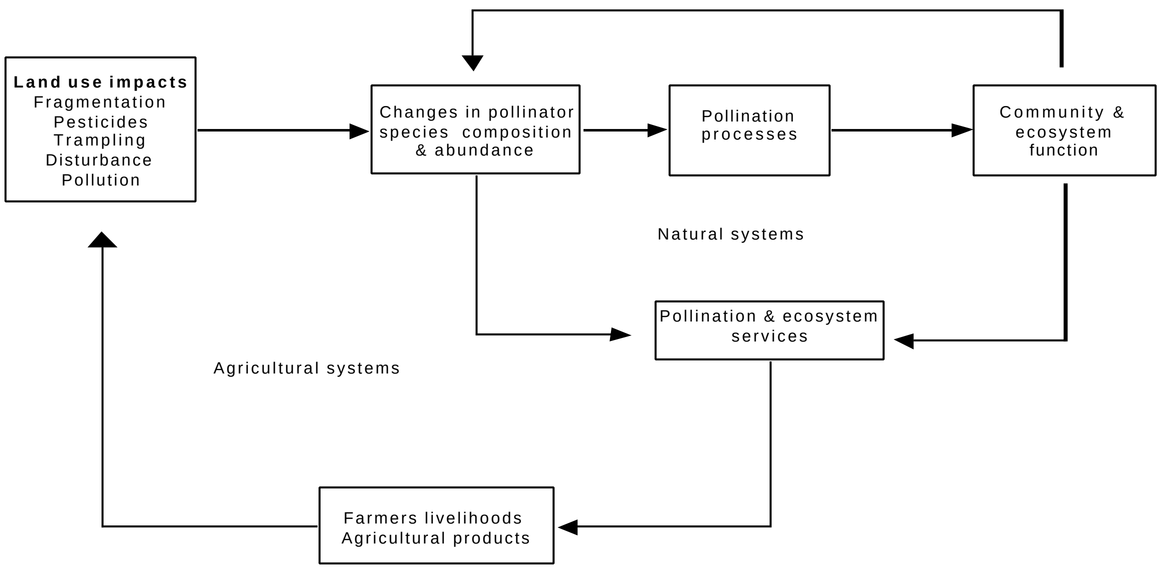
The problem of declining pollinator populations and the consequences for agriculture and conservation biology have been highlighted in several recent books and articles (Buchmann and Nabhan 1996; Kearns and Inouye 1997; Allen-Wardell *et al.* 1998). Many of the issues raised by these authors are universal, but there are almost certainly going to be regional differences arising from variation in the pollinator faunas, the natural occurrence of honeybees in some areas, different land use options, and the choice of agricultural crops. In this paper, I review what is known about pollinator decline in South Africa, the possible consequences for agriculture and what is being done in South Africa with regard to pollinator conservation.

Pollination: a South African perspective

South Africa encompasses a diversity of environments from summer rainfall areas with subtropical rainforests to arid winter rainfall areas with dwarf succulent shrublands (Cowling and Hilton-Taylor 1997). Southern Africa also has an extremely rich flora comprising more than 20 500 species (80% endemics) (Cowling and Hilton-Taylor 1997) and an exceptional diversity of other taxa such as amphibians, reptiles, birds, mammals (Siegfried 1989) and insects (Scholtz and Holm 1985). With such generally high levels of diversity, the species richness of insect pollinators may be expected to follow the general trend. Indeed, Michener (1979) ranked the warm temperate xeric areas of Australia, Chile, and South Africa fourth (out of 10 regions) in terms of relative bee abundance and diversity although they had far fewer species than other warm temperate areas such as the Mediterannean. The dry western parts of South Africa have high levels of diversity and endemism for aculeate Hymenoptera (Gess and Gess 1993) and the Cape Florisitic Region of South Africa appears to be a centre of diversity for long-proboscid fly pollinators that include Tabanidae, Nemestrinidae and Bombyliidae. Monkey beetles (Rutelinae: Hopliini) are an important group of pollinators that are endemic to southern Africa and Lepidoptera are a diverse group within southern Africa, comprising ca. 8% of the world total (Henning 1985). South Africa therefore has an impressive diversity of insect pollinators that are unquestionably important for native plants and that may be of considerable benefit in agricultural systems.

Pollination services in agriculture represents possibly one of the greatest areas of interaction between natural systems and agricultural systems (Fig. 1). In many instances, the productivity of agricultural landscapes (crops and pastures) relies on natural pollination although production of fruit and seed crops is often enhanced by bringing in additional honeybee colonies (Anderson, Buys and Johannsmeier 1983). Agriculture is also likely to have the greatest impact on native pollinators through the modification and elimination of pollinator habitats and the use of agricultural chemicals (pesticides, herbicides, fertilizers). This is most obvious in transformed landscapes, which accounts for ca. 22% of South Africa's land area, but is also true of the vast tracts of land used for stock farming (e.g. Gess and Gess 1993).

FIGURE 1: A diagrammatic representation of the pollinator interaction between natural ecosystems and agricultural systems



Despite the potential importance of the interaction between native pollinators and agricultural systems, a survey of published work on pollination in South Africa (Fig. 2) shows that this interaction has received very little attention. Most research has focussed on descriptions and evolutionary studies of pollination systems in indigenous plants. Considerably less work has been done to determine the effectiveness of different pollinators or the impact of a pollination deficit on fruit set. This is particularly true of published studies of crop plants. In contrast, the majority of studies on threats to pollinators and on pollinator biology have dealt with honeybees, especially within an agricultural context. The trend in research publications leads to two conclusions. Firstly, that there has been relatively little interest in studying the pollination systems of crop plants in South Africa (as opposed to the tremendous interest in pollination of indigenous plants) and secondly, that honeybees have been regarded, almost exclusively, as the prime agents for pollination in agricultural systems. In this respect, the situation in South Africa is similar to that in other parts of the world (Buchman and Nabhan 1996).

Pollinator decline

There has been no comprehensive assessment of pollinator decline in South Africa but there has been ongoing research into factors that have a detrimental effect on pollination. As in other parts of the world, honeybees have received most attention and two threats to honeybee populations have been of particular concern. First, the so-called 'Cape honeybee problem' in which workers of the Cape honeybee (*Apis mellifera capensis*) gain access to the hives of the African honeybee (*A. mellifera scutellata*) and destroy the host colony (Cooke 1993). Beekeepers have lost up to 75% of their colonies annually as a result of the Cape honeybee problem. Second, *Varroa* mite was first recorded from South Africa in 1997 (Allsopp, Govan and Davison 1997) and has subsequently spread to seven of the country's nine provinces (M. Allsopp pers com.). The effect on wild and commercial hives is being monitored and there appear to be geographical differences in the response of bees to *Varroa* that may be related to variation in climate or to different levels of resistance between *A. mellifera capensis* and *A. mellifera scutellata* colonies (M. Allsopp pers com.).

FIGURE. 2. The frequency of scientific and semi-scientific publications on topics related to pollination systems and pollinator biology in South Africa. Bars for 'pollinator effectiveness' and 'pollinator limitation' include only papers that dealt specifically with these issues. Publications dealing primarily with plant or pollinator taxonomy were not included.

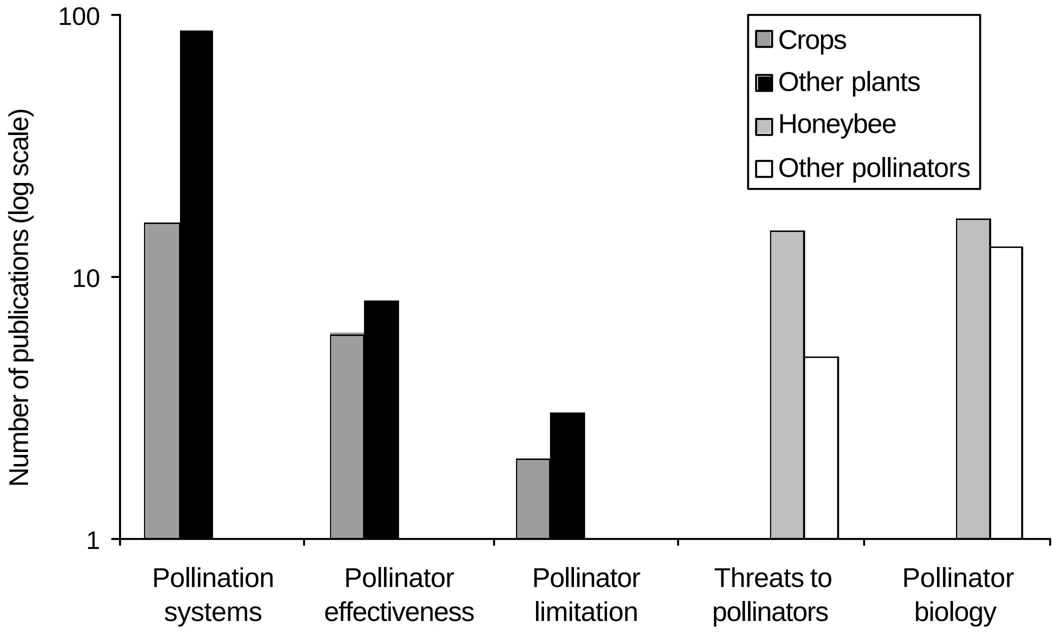


Fig. 2 shows that threats to non honeybee pollinators have hardly been studied at all in South Africa. Nevertheless, the few available studies indicate that landuse practices have probably had the greatest impact on non honeybee pollinators. Habitat fragmentation has been identified, worldwide, as a major cause for the loss of biodiversity (Hobbs *et al.* 1992; Haila *et al.* 1993) including pollinators (Aizen and Feinsinger 1994a,b; Bronstein 1995; Kearns and Inouye 1997). Studies of habitat fragments in wheatlands in the Western Cape province (Donaldson *et al.* MS) showed that bees were relatively resilient to changes in fragment size and isolation but were affected by changes in habitat related to the process of fragmentation (e.g. changes in vegetation cover). In contrast, butterflies were more sensitive to fragment size (R. Bowie unpublished data).

Fragmentation occurs mainly in intensive agricultural systems. However, extensive systems such as stock farming affect vast areas of South Africa (Macdonald 1989) and farming practices in these areas can have a substantial impact on the pollinator fauna (Gess and Gess 1993). Grazing practices can change the availability of plant resources (nest sites, nectar and pollen) and trampling can make areas unsuitable for ground and bank nesting species (Gess and Gess 1993). Different land use practices in the same area can result in different pollinator faunas even in adjacent fields (A. van der Spuy, unpublished data).

Introduced plants have had a devastating effect on natural vegetation in several parts of South Africa. The change in floral composition and vegetation could also have affected the composition and distribution of indigenous pollinators (Rebelo 1987) but this aspect of pollination biology has not been investigated.

Two introduced insects have been regarded as a potential threat to indigenous pollinators. The argentine ant, *Linepithema humile* (Formicidae) has been recorded from *Protea* inflorescences (Paton, 1986; Visser, Wright and Giliomee 1996) and large infestations of *L. humile* resulted in a significant reduction in insect visitors to *Protea eximea* and *Protea nitida* inflorescences. There has also been speculation that the argentine ant would result in a decline in butterfly populations (Henning *et al.* 1997). However, the overall impact of argentine ant on pollinator abundance and diversity is unknown. There is a similar paucity of information on the impact of the yellowjacket wasp, *Vespula germanica* that has invaded parts of the Western Cape province. *V. germanica* may compete for nectar with indigenous wasps (Rebelo 1987) and has been known to exterminate weak honeybee hives in New Zealand (Line, 1965) but it is restricted to parts of the Western Cape and its overall impact is unknown.

In other parts of the world where honeybees have been introduced, there has been concern about the displacement of indigenous bees. Honeybees are indigenous to South Africa but commercial beekeeping nevertheless poses a potential threat to other pollinators because commercial hives may be placed in natural vegetation during periods of peak nectar flow thereby depriving other insects of nectar and pollen resources (Rebelo 1987). The extent of this practice and its impact on non honeybee pollinators has not been evaluated.

Due to the poor performance of honeybees on some crops (e.g. tomatoes) there have been several applications to import bumblebees (*Bombus*) into South Africa. The initial applications have been for greenhouse crops where, it is argued, the bumblebees can be contained within an artificial system. However, there is a high probability that bumblebees can escape from greenhouse colonies and there is evidence for *Bombus* species establishing in areas outside their natural range (A. Dafni personal communication). This has the potential to disrupt sensitive pollination systems involving native bees. As a result, the importation of bumblebees has, so far, not been approved. As yet, there has been no assessment of the value of local bees for buzz pollination as an alternative to bumblebees.

Pollination deficit

Pollinator limited fruit set has been has been of concern in both agricultural and natural systems. Pollinator limited fruit set appears to be a common phenomenon among plants in fynbos (e.g. Johnson and Bond, 1997) and may explain some of the floral diversity in the Cape Floristic Region (Johnson, 1994). However, there is also evidence for the disruption of pollination due to local extinction of native pollinators (Donaldson *et al.* MS) and one of the challenges to conservation theory has been to identify plants that are most at risk as a result of pollinator decline (Bond 1994). Despite the potential impact of pollinator limitation on fruit set in agriculture, the problem appears to have received less critical experimental and theoretical attention in South Africa. Johannsmeier (1995) listed numerous plants in South Africa where fruit or seed set is dependent on insect pollinators, particularly bees. Among the plants are many crop species where seed or fruit production or quality is increased by the addition of honeybees, e.g. *Brassica napis* var. *oleifera* (oilseed rape), *Cynara scolymus* (globe artichoke), *Eriobotrya japonica* (loquat), *Fragaria x ananassa* (strawberry), *Helianthus annuus* (sunflower), *Persea americana* (avocado), *Rubus* spp. (black- youngberries), *Sinapis alba* (white mustard), *Trifolium* spp. (clover), *Vicia* spp. (vetch), *Vicia faba* (broad bean). The implication is that there is a pollination deficit in these crops unless honeybee colonies are increased at the time of pollination. It is unclear how great this deficit will be if honeybee colonies decline as a result of the Cape honeybee problem or the spread of *Varroa.*

Even with the widespread use of honeybees in South African agriculture, poor fruit set remains a problem for some crops, notably *Mangifera indica* (mango) (du Toit and Swart 1993a; Eardley and Mansell 1994a), *Persea americana* (avocado) (du Toit and Swart 1993b, 1994a; Eardley and Mansell 1993), *Litchi chinensis* (litchi) (Eardley and Mansell 1994b) and other subtropical fruits (du Toit 1990). Although poor pollination may not be the only cause of low fruit set (e.g. Thomas, Eicker and Robbertse 1994), it is clear that much further work is needed on the pollination of subtropical fruits (du Toit 1990). Of particular importance in the context of pollinator decline, is to determine the potential for pollination of these crops by native pollinators. Johannsmeier (1995) listed 15 crop species from the Western Cape province (17% of crops) for which the pollination needs were unknown or for which there was no information. This is likely to underestimate likely pollination problems since much of the pollination data for other crops is derived from areas outside South Africa and does not take local conditions into consideration.

In crops where honeybees do not increase fruit set, other native pollinators may be appropriate. Watmough studied the biology of carpenter bees that may be of particular value for the pollination of crops in the Fabaceae, but there has been little success in developing the agricultural potential of these bees. Nevertheless, Gess and Gess (1994) noted that Xylocopinae, Megachilinae and Masaridae were essential for the successful pollination of rooibos tea (*Aspalathus linearis,* Fabaceae) and that the management of tea plantations needed to promote the abundance of these pollinators. A similar situation probably exists in the case of honeybush tea (*Cyclopia* spp.: Fabaceae) that is now being extensively harvested in parts of South Africa.

Conservation of pollinator diversity

Until very recently, conservation activity in South Africa focussed almost exclusively on large mammals (Pringle 1982). As a result, the reserve system that comprises ca. 6% of the total land area (Siegfried 1989) was established in areas that suited this particular focus with little reference to other taxa. The current broader focus on biological diversity has highlighted some of the gaps in the existing reserve system. Of particular note for bees and aculeate Hymenoptera is the low level of conservation in areas with high diversity such as the succulent karoo (2.36% included in reserves) and Nama karoo (0.45%). Field sampling at four sites in these areas (Gess and Gess 1993) indicates high levels of species turnover and emphasizes the need for a more representative reserve system.

A more complete reserve system is unlikely conserve all or even the majority of pollinator species. The mosaic of farmland that surrounds reserves must be included in the conservation programme. At present, South Africa has a network of Natural Heritage Sites and private nature reserves that extend the reserve system onto private land. However, a more comprehensive system is required that promotes pollinator friendly land use practices. In this respect, research on the impacts of land use on pollinators is needed to guide conservation actions. Several studies on the impacts of land use on pollinators and other insects have already been undertaken in South Africa (e.g. Gess and Gess 1993; Ingham and Samways 1996; Rivers-Moore and Samways 1996; Donaldson *et al.* MS) but more information on appropriate land use practices is needed and existing information must be made accessible to farmers.

In conclusion, if native pollinators are to be conserved because of their value to agriculture, then further work is needed. Firstly we need to identify areas where native pollinators are likely to play an important role in agriculture and, secondly, we need to promote ways of integrating native pollinators with other agricultural activities.

REFERENCES

Aizen MA, Feinsinger P. Forest fragmentation, pollination, and plant reproduction in a Chaco dry forest, Argentina. Ecology 1994 a; 75: 330-51.

Aizen MA, Feinsinger P. Habitat fragmentation, native insect pollinators, and feral honeybees in Argentine "Chaco serrano". Ecological Applications 1994b; 4**:** 378-92.

Allen-Wardell G, Bernhardt P, Bitner R, Burquez A, Buchmann S, Cane J, et al. The potential consequences of pollinator declines on the conservation of biodiversity and stability of food crop yields. Conservation Biology 1998; 12: 8-17.

Allsopp M, Govan V, Davison S. Bee health report: *Varroa* in South Africa. Bee World 1997; 76: 171-4.

Anderson RH, Buys B, Johannsmeier MF. Beekeeping in South Africa. Department of Agriculture Bulletin 1983; 394: 1-207.

Bond WJ. Do mutualisms matter? Assessing the impact of pollinator and disperser disruption on plant extinction. Philosophical Transactions of the Royal Society B 1994; 344(1307): 83-90.

Bronstein JL. The plant-pollinator landscape. In*:* Hansson L, Fahrig L, Merriam G, editors. Mosaic landscapes and ecological processes. London: Chapman and Hall; 1995.

Buchman SL; Nabhan GP. The forgotten pollinators. Washington (DC): Island Press; 1996.

Cooke MJ. The Cape bee problem in South Africa - an update. American Bee Journal 1993; 133: 285-6.

Cowling RM, Hilton-Taylor C. Phytogeography, flora and endemism. In: Cowling RM, Richardson DM, Pierce SM. Vegetation of Southern Africa. Cambridge(UK):Cambridge University Press; 1997. p.43-61.

Donaldson JS, Nanni I, Kemper K, Zachariades C. (MS) Pollination in a fragmented landscape: is there evidence for a pollinator driven extinction debt in remnants of Renosterveld vegetation, South Africa? [Submitted to Conservation Biology]

Du Toit AP, Swart TD. Foraging activity of honeybees in an avocado orchard. Avocado Gower's Association Yearbook 1993 a; 16: 37-8.

Du Toit AP, Swart TD. Pollination of mango in the Letsitele Valley during the 1992 flowering season: first report. Mango Grower's Association Yearbook 1993b; 13: 49-50.

Du Toit AP, Swart TD. Pollination of 'Bengal' litchi during the 1992 flowering season at Politsi: first report. Litchi Grower's Association Yearbook 1994 a; 6: 7-8.

Du Toit AP. Pollination research: a missing link in subtropical fruit production. Acta Horticulturae 1990; 275: 239-43.

Eardley CD, Mansell MW. Preliminary report on the natural occurrence of insect pollinators in an avocado orchard. South African Avocado Grower's Association Yearbook 1993; 16: 127-8.

Eardley CD, Mansell MW. Preliminary report on the natural occurrence of insect pollinators in a litchi orchard. South African Litchi Grower's Association Yearbook 1994 a; 6: 13-14.

Eardley CD, Mansell MW. Report on the natural occurrence of insect pollinators in a mango orchard. South African Mango Grower's Association Yearbook 1994 b; 14: 65-6.

Gess FW, Gess SK. Effects of increasing land utilization on species representation and diversity of aculeate wasps and bees in the semi-arid areas of Southern Africa. In: Laselle J, Gauld ID, editors. Hymenoptera and biodiversity. Wallingford: CAB International; 1993. p.83-113.

Gess SK, Gess FW. Potential pollinators of the Cape group of Crotalarieae (*sensu* Polhill) (Fabales: Papilionaceae), with implications for seed production in cultivated rooibos tea. African Entomology 1994; 2: 97-106.

Haila Y, Saunders DA, Hobbs RJ. What do we presently understand about ecosystem fragmentation? In*:* Saunders DA, Hobbs RJ, Ehrlich PR, editors. Nature conservation. 3. Reconstruction of fragmented ecosystems. Chipping Norton(Australia): Surrey Beatty and Sons; 1993. p.45-55.

Henning GA, Henning SF, Joannou JG, Woodhall SE. Living butterflies of Southern Africa. Hatfield(South Africa):Umdaus Press; 1997.

Henning SF. Lepidoptera. In: Scholtz CH, Holm E, editors. Insects of Southern Africa. Durban(South Africa): Butterworths; 1985. p.341-92.

Hobbs RJ, Saunders DA, Lobry de Bruyn LA, Main AR. Changes in biota. In: Hobbs RJ, Saunders DA, editors. Reintegrating fragmented landscapes: towards sustainable production and nature conservation. New York: Springer-Verlag; 1992. p. 65-106.

Ingham DS, Samways MJ. Application of fragmentation and variegation models to epigaeic invertebrates in South Africa. Conservation Biology 1996; 10: 1353-8.

Johannsmeier MF. Beeplants of the South-Western Cape. Pretoria: Department of Agriculture; 1995.

Johnson SD. Pollination and the evolution of floral traits: selected studies in the Cape flora [PhD thesis]. University of Cape Town; 1994.

Johnson SD, Bond WJ. Evidence for widespread pollen limitation of fruiting success in Cape wildflowers. Oecologia 1997; 109: 530-4.

Kearns CA, Inouye DW. Pollinators, flowering plants, and conservation biology. Bioscience 1997; 47: 297-307.

Line S. Preventing wasp raids on beehives. New Zealand Journal of Agriculture 1965; 110: 161.

Macdonald IAW. Man's role in changing the face of Southern Africa. In: Huntley BJ, editor. Biotic diversity in Southern Africa: concepts and conservation. Cape Town: Oxford University Press; 1989.

Michener CD. Biogeography of bees. Annals of the Missouri Botanical Garden 1979; 66: 277-347.

Pringle JA 1982. The conservationists and the killers. Cape Town (South Africa): TV Bulpin; 1982.

Rebelo AG. Conservation. In: Cowling RM, Richardson DM, Pierce SM. Vegetation of Southern Africa. Cambridge (UK): Cambridge University Press; 1997. p.571-90.

Rebelo AG, editor. A preliminary synthesis of pollination biology in the Cape flora. Pretoria: CSIR; 1987. [SANSP Report 141]

Rivers-Moore NA, Samways MJ. Game and cattle trampling, and impacts of human dwellings on arthropods at a game park boundary. Biodiversity and Conservation 1996; 5: 1545-56.

Scholtz CH, Holm E. Insects of Southern Africa. Durban (South Africa): Butterworths; 1985. p.341-92.

Siegfried WR. Preservation of species in Southern African nature reserves. In: Huntley BJ, editor. Biotic diversity in Southern Africa: concepts and conservation. Cape Town: Oxford University Press; 1989.

Thomas TV, Eicker A, Robbertse PJ. Possible role of fungi in negatively affecting fruit set in Avocados. South African Journal of Botany 1994; 60: 251-6.

Plantâ€“pollinator interactions are essential for maintaining both pollinator and plant communities in native and agricultural environments. Animal-instigated pollination can be complex. Plants are usually visited by a number of different animal species, which in turn may visit flowers of several plant species. Therefore, the identification of the pollen carried by flower visitors is an essential first step in pollination biology. The skill and time required to identify pollen based on structure and morphology has been a major stumbling block in this field. Advances in the genetic analysis of DN Landscape perspectives may draw from the field of landscape ecology, which is typically focused on ecological processes and phenomena in areas that are ten to hundreds of kilometers in size, and that show heterogeneity in some feature of interest to researchers or conservationists. This approach characterizes the land mosaic in terms of its land cover composition, the spatial arrangement of the patches and corridors, the dynamics of the mosaicâ€™s elements, and the use of the mosaic by organisms. A landscape approach may also be informed by a watershed perspective, which defines the portion of t