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Pollinators: Indicators for changing ecosystem services- A brief review

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Pollination is a vital ecosystem service to plants provided by pollinators. About 80% of the flowering plants are hermaphrodite, of the remaining 10% have separate sexes in flowers. Although selfing is possible, cross-pollination is favored. It provides genetic variability, thus helping in evolution which assists the organism in colonizing the changing environment and resistance to pests and diseases. Secondly, changes in gene function due to mutation may condition the plant to survive with greater tolerance. Animal pollination is of great importance for sexual reproduction of cultivated plants (McGregor 1976, Nabhan and Buchmann 1997; Westercamp and Gottsberger, 2000) as well for majority of wild (Burd, 1994; Kearns 1998; Ashman *et al.*, 2004). Roubik (1995) listed 1330 tropical crops of which 70% of at least one variety. In Europe, of the 264 crop plants studied 84% depended on animals for pollination up to some extent (Williams 1994). Insect pollinators itself has been said to contribute to an annual income of € 153 billion (Gallai *et al.*, 2009). Majority of the pollination is facilitated by animals, of which bees form the chief pollinators (Delaplane and Mayer, 2000, Potts *et al.*, 2010), pollinating about 87.5% of the world's flowering plants (Ollerton *et al.*, 2011). Besides improving seed and fruit set that assure nutritious food (Sundriyal & Sundriyal 2004), pollinators benefit people whose livelihoods depend on non timber forest products (NTFP) (Rehel *et al.*, 2009). The role of pollinators due to their presence, abundance and activities are revealed to act as bioindicators and may be useful to indicate the status of ecosystem and its overall health (Kevan 1999). Decline of pollinators have of late been in discussions of ecologists, conservationists and amateurs, owing to their important functional role in terrestrial natural ecosystems (Ashman *et al.*, 2004) as well across agro-ecosystems (Aguilar *et al.*, 2006). Numerous crops and wild plants depend on pollinators and their services. Many of these pollinators belong to the wild and unmanaged (Biesmeijer *et al.*, 2006). This decline has been recorded world over

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at an alarming rate. Recently numerous studies about mutualistic interaction of plant-pollinators are being discussed. Kearns and Inouye (1997) have highlighted the cascading effects pollinator decline can have on different life forms, since no single species can survive in isolation. For obligate mutualisms such as pollination, we need to consider and conserve not only the interacting organisms but also the functional interactions among plants (Elle *et al.*, 2012). In this review we look at different aspects of pollinators. We firstly discuss terminologies related to pollination and pollinators in general. Later we look at different studies pertaining to pollinators and their decline; from global to local. Further we look at the importance of pollinators in Doon Valley. The review concludes with the research gaps at global and local level.

Pollination and pollinators

Pollination can be described as the transfer of pollens from the male reproductive part of plants (anther) to receiving female reproductive part of the plant called the stigma. Pollination is brought about by abiotic or biotic means. Pollens are transferred abiotically by wind, water or gravity (Kevan 1999). Biotic pollination is brought about by animals, foraging on plants for nectar, pollen, oil rewards etc. required for their own nutritional requirements (Kevan an Baker 1983; 1998, Kevan 1999). These animals that forage on plants are termed as anthophils. These anthophils consist of animals across the taxa *viz.* invertebrates to vertebrates. Pollinators belonging to the invertebrate taxa include a wide orders of insect families, the most prominent being orders Hymenoptera (consisting of bees, most of the bees have scopa (hair) either on legs or the metastomal region to which pollen gets attached during foraging. When these bees approach flower, the pollen get transferred to the stigma of the flower and thus crosspollination occurs. Hence, bees are the most efficient pollinators), Diptera (true flies, especially those belonging family Syrphidae), Lepidoptera (moths and butterflies) and Coleoptera (beetles). Other insect orders pollinating include Thysanoptera, Orthoptera and Collembola. Insects may have gradually evolved from non-flower visitors to flower visitors with simultaneous modifications and adaptations in the mouth parts to forage on floral rewards (Muller 1883).

Vertebrate taxa include birds like humming birds (Trochilidae), honeyeaters (Meliphagidae), honeycreepers (Coerebidae), flowerpeckers (Dicaeidae) and sunbirds (Nectariniidae) (Nayak, Devidar 1983). Mammals like lories (Loriinae), bats (Pteropidae, Phyllostomatidae) (Aritaz & Martinez 1990, Kevan 1999) and some primates (Kress *et al.*, 1994). Leppik (1977) pointed out the late but gradual evolution of birds and bats developing their own ornithophilous and chiropterophilous flowers. Pollinators and their floral

partners have been coevolving for over four hundred million years (Leppik 1977). With this has also evolved the pollination syndromes that floral species fall into depending on the type of pollinator (Kevan 1984, Willemstein 1987). For example, bird-flowers are diurnal, with vibrant colours *viz.* scarlet red, fire-red etc, where as bat-flowers are are nocturnal blooming, with whitish or creamy colour with a strong odor at night (Leppik 1977).

Decline of Pollinators

Pollinators wild as well as domesticated provide pollination services. A variety of environmental changes may affect their service (Potts *et al.*, 2010). These changes may include anthropogenic activities affecting habitats and climate. Losses of pollinators may be of concern due to the parallel decline in the plants dependent on them for sexual reproduction (Biesmeijer *et al.*, 2006). Potential drivers of pollinator declines were land-use change leading to habitat loss (Ricketts *et al.*, 2008, Brown & Paxton 2009); alien species of plants may disrupt the native plant-pollinator interactions leading to native pollinator decline (Traveset and Richardson 2006). Alien pollinators may compete with native pollinators for floral resources (Thomson 2006). Pests and pathogens like *Varroa* mite are spread through introduction of alien bees (Stout & Morales 2009). Another cause of pollinator decline is the intensification of agriculture. It degrades the habitat and has lethal or sub-lethal effects on pollinator populations (Winfree 2009). Electromagnetic radiation is yet another cause of decline in pollinators predominantly in areas housing mobile network towers (Kumar 2010, Favre 2011). This has been reported in numerous places in the world including India. High frequency electromagnetic radiation have been found to alter the resonant stimulus of the honeybee brain thus resulting in disorientation of flight in honeybees (Harst *et al.*, 2006, Diagnose-Funk 2007 and Stever *et al.*, 2007). This may to the Colony Collapse Disorder (CCD) where the honeybees fail to return to their hives (Favre 2011) abandoning the queen, eggs and hive-bound immature bees (Sahib Pattazy 2009).

Domestic pollinators include honeybees which are managed in agricultural practices for the reproductive benefits to crops and honey, however their decline are poorly documented. Still deprived is the documentation of wild bees and other pollinators. Though wild bees and other insects pollinate many crops, benefits of their services have been overlooked (Klein *et al.*, 2006). Due to increasing awareness about role wild pollinators (O'Toole 1993, Slaa *et al.*, 2006) slowly efforts are being taken to manage agro-ecosystems and conserve natural and semi-natural landscapes that harbor them (Richards 2001).

Pollinators in Doon Valley

India is an agriculture based country (Fazal, 2007) with marginal farming having 80% of farm holdings and is the second largest vegetable producer globally that largely depend on pollinator (Sidhu, 2005). Crop partitioning based on pollinator dependence has revealed decline of pollinator dependent crops over a period of 45 years (1963-2008, FAO data) (Basu *et al.*, 2011). Forests are significant part of land-use in India as they occupy 20.6% of the total geographical area of the country (Bandyopadhyay, 2005). Doon valley is geomorphologically fragile, aggravated by destruction of forest cover, increase in rural pressure, and urban expansion. The land-use is dominated by forest and cultivated areas. Subsistence farming, based on cereal production, dairy cattle, and exploitation of forest biomass, predominates in the hills but small scale cash cropping is practiced on the lower slopes while off-season vegetables are produced in accessible villages at higher elevations (Datta & Virgo, 1998).

Numerous studies on pollinators of Himalayan crops and beekeeping are found in the literature (Abrol, 1986, Dutta, 2008; Gangasaran *et al.*, 2010). The focus of these studies has been bee keeping and management. Gangasaran (2010) and Kumar *et al.* (1996) have quantified the economic importance of honeybees in crops' fruit and seed set increase. Jiju (2011) listed pollinator species besides hymenopterans. Foraging behaviour of honey bees have been studied by Joshi and Joshi (2010) on *Apis cerana* and *Apis mellifera*. Foraging plants of *Apis dorsata* have been identified using melissopalynological analysis of honey samples from Garhwal Himalaya (Tiwari *et al.*, 2010). A similar study was conducted on the honey samples from apiries across Upper Gangetic region in Uttarakhand previously by Dutta *et al.* (2008).

Conclusion

Most evidences of pollinator losses are recorded from Europe and North America and very few from other continents (Potts *et al.*, 2010). This questions the global crisis of pollinator decline (Ghazoul 2005). Studies on how pollinators benefit wild plants are inadequate. Given that unrestricted destruction of forests, grazing, forest fires and urban expansion, take place indiscriminately in Doon Valley, pollinators may be at risk. Numerous workers have tested the economic importance of honey bees to crops. However status of wild bees and their role in pollinating wild plants and its economic importance is neglected. Mayer *et al.* (2011) highlight the key areas to be addressed in pollination ecology for future research in understanding the patterns and processes and the conservation of these interactions between

plants and pollinators is essential. Therefore, there is immediate need to document the status and diversity pattern of pollinators in different land-use. Understanding the effect of habitat composition and change in plant-pollinator interactions (generalization/ specialization) would help to evaluate the severity of disturbances on them.

References

Abrol, D.P. 1986. Ecophysiological adaptations between polliating bees and their flowers, Environ. Ecol. 4, 161-162.

Aguilar, R., Ashworth, L., Galetto, L. and Aizen, M.A. 2006. Plant reproductive susceptibility to habitat fragmentation: review and synthesis through a meta-analysis. Ecol. Lett. 9, 968-980.

Ashman, T.L. Ashman, T.L., Knight, T.M., Steets, J.A., Amarasekare, P., Burd, M., Cambell, D.R., Dudash, M.R., Johnston, M.O., Mazer, S.J., Mitchell, R.J., Morgan, M.T. and Wilson, G.J. 2004. Pollen limitation of plant reproduction: Ecological and evolutionary causes and consequences. Ecology 85: 2408-4241.

Arita, H.T., Martinez, C.del Rio, 1990. Interacciones Flor-Murcielago: Un Enfoque Zoocentrico, Universidad Nacional Autonoma de Mexico.

Bandyopadhyay, Soumya, H.B. and Shah, P.J. 2005. Briefing Paper on Forest Policy: Community Stewardship and Management. Terracotta Summit: Forest Policy.

Basu, P., Bhattacharya, R. and Iannetta, P.P.M. 2011. A decline in pollinator dependent vegetable crop productivity in India indicates pollination limitation and consequent agro-economic crises. Nature Proceedings. http://hdl.handle.net/10101/npre.2011.6044.1

Biesmeijer, J.C., Roberts, S.P.M., Reemer, M., Ohlemuller, R., Edwards, M., Peters, T., Schaffers, A.P., Potts, S.G., Kleukers, R., Thomas C.D., Settele, J. and Kunin, W.E. 2006 Parallel Declines in Pollinators and Insect- Pollinated Plants in Britain and the Netherlands. Science. 313:351-354.

Brown, M.J.F. and Paxton, R.J. 2009. The conservation of bees: a global perspective. Apidologie. 40:410-416.

Delaplane, K.S. and D.F. Mayer. 2000. Crop pollination by bees. CABI Publishing, Oxon, United Kingdom.

Devidar, P. 1983. Similarity between flowers and fruits in some flowerpecker pollinated mistletoes. Biotropica. 15: 32-37.

Elle, E., Elwell, Gielens and G.A. 2012. The use of pollination networks in conservation. Botany 90: 1-10.

Datta, K., Praveen, C.V. and Avijeet, C. 2008. Mapping of key bee flora of upper Gangetic region of India- a palynological assessment through regional honeys. Grana 47(2): 159- 170.

Datta, S.K. and Virgo, K.J. 1998. Towards Sustainable Watershed Development through Peopl's Participation: Lessons from the Lesser Himalaya, Uttar Pradesh. Mountain Research and Development 18(3): 213-233.

Diagnose-Funk. 2007. Te big bee death. http://www.hese-project.org/hese-uk/en/papers/bigbeedeath_0407.pdf.

FAOSTAT. Data available at http://faostat.fao.org/site/526/default.aspx. Accessed at 2011.

Fazal, S. 2000. Urban expansion and loss of agriculture land: a GIS based study of Saharanpur City, India. Environment and Urbanization 12: 133-149.

Favre, D. 2011. Mobile phone-induced honeybee worker piping. Apidologie. 42:270-279.

Gallai, N., Salles, J., Settele, J. and Vaissiere, B.E. 2009. Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. Ecol. Econ. 68:810-821.

Gangasaran, P.L., Mall, P. and Garhwal, O.P. 2010. Economic impact of extensive pollination through honey bee in peach orchard. Indian Journal of Horticulture 64(4): 475-477.

Ghazoul, J. 2005. Buzziness as usual? Questioning the global pollination crisis. Trends in Ecology and Evolution. 20:367-373.

Harst, W., Kuhn, J. and Stever, H. 2006. Can electromagnetic exposure cause change in behaviour? Studying possible non-thermal influences on honeybees- an approach within framework of educational informatics. http://agbi.uni-landau.de/material_download/IAAS_2006.pdf.

Jiju, J.S. 2011. Masters Dissertation Report: Assessment of Pollinators in Navdanya organic farm, Utarakhand. Forest Research Institute (Deemed) University.

Keven, P.G. 1999. Pollinators as bioindicators of the state of the environment: species activity and diversity. Agriculture, Environment and Ecosystem. 74:373-393.

Kevan, P.G. 1984. Pollination by animals and angiosperm biosystematics. In: Grant, W.F. (Ed.), Plant Biosystematics. Academic Press, Toronto. pp. 271-292.

Klein, A.-M., Vaissiere, B.E., Cane, J.H., Steffan-Dwenter, I., Cunningham, Kremen, C. and Tscharntke, T. 2006. Importance of pollinators in changing landscapes for world crops. Proc. R. Soc. B. pp. 1-11.

Kress, W.J., Schatz, G.E., Andrianifahanana, M., Morland, H.S. 1994. Pollination of *Ravenala madagascariensis* (Strelitziaceae) by lemurs in Madagascar: evidence for an archaic coevolutionary system. Am. J. Bot. 81:542-551.

Kumar, G. 2010. Cell tower radiation. Electrical Engineering Department. IIT Bombay, Powai, Mumbai, India.

Kumar, R., Chaudhary O.P. and Lenin, J.K. 1996. Studies on pollination of litchi (*Nephelium litchi* Camb.) in Dehradun India. Indian Bee Journal. 58 (1): 9-12.

Mayer, C., Alder, L., Armbruster, W.S., Dafni, A., Eardley, C., Huang, S.-Q., Kevan, P.G., Ollerton, J., Packer, L., Ssymank, A., Stout, J.C., and Potts, S.G. Pollination ecology in the 21st century: key questions for future research. Journal of Pollination Ecology. 3:8-23.

Muller, H. 1883. The fertilization of flowers. Translated and edited by D'Arch, W. Thomson with a preference of Charles Darwin. Macmillan Co., London, pp. 670.

Nayak, G. 2008. Plant-pollinator interaction in Tropical Dry Evergreen Forests, Southern India: PhD thesis in Ecology. Pondicherry University.

Leppik, E.E. 1977. Floral Evolution in Relation to Pollination Ecology. In: Varghese, T.M., (Ed.) International Bioscience Monographs, Today and Tomorrow's Printers and Publishers, India. pp. 107-108.

Ollerton, J. *et al.*, 2011. How many flowering plants are pollinated by animals? Oikos 120: 321-326.

O'Toole,C. 1993. Diversity of native bees an agroecosystems. In Hymenotera and biodiversity (ed. J. La Salle & I.D. Gould). pp. 169-196. London, UK: CAB International.

Potts, S.G., Biesmeijer, J.C., Kremen, C., Neumann, P., Schweiger, O. and Kunin, W.E. 2010. Global pollinator declines: trends, impacts and drivers. Trends in Ecology and Evolution. 25:345-353.

Rehel, S., Varghese, A., Bradbear, N., Devidar, P., Roberts, Roy, P. and Potts, S.G. 2009. Benefits of Biotic Pollination for Non-Timber Forest Products and Cultivated Plants. Coservation and Society 7(3): 213-219.

Richards, A.J. 2011. Does low biodiversity resulting from modern agriculture practice affect crop pollination and yield? Ann. Bot. 88:165-172.

Ricketts, T.H., Regetz, J., Steffan-Dwenter, I., Cunninghum, S.A., Kremen, C., Bogdanski, A., Gemmill-Herren, B., Greenleaf, S., Klein. A.M., Mayfield, M.M., Morandin, L.A., Ochieng, A. and Viana, B.F. 2008. Landscape effects on crop pollination services: are there general patterns? Ecol. Letters. 11:499-515.

Sahib-Pattazhy, S. 2009. Mobile phone towers a threat to honeybees: Study. The Times of India, 31 August 2009. http://timesofindia.indiatimes.come/NEWS/Science/Mobile-phone-towers-a-threat-to-honey-bees-Study/articleshow/4955867.cms

Sidhu, M.S. 2005. Fruit and vegetableprocessing Industry in India: an appraisal of the post reform period. Economic and Political Weekly.

Slaa, E.J., Sanchez, C.L.A., Malagodi-Braga, K.S. & Hofstede, F.E. 2006. Stingless bees in applied pollination. Practice and perspectives. Apidologie. 37:293-315.

Stout, J. and Morales, C.L. 2009. Ecological impacts of invasive alien species on bees. Apidologie. 40:388-409.

Stever, H., Harst, W., Kimmel, S., Kuhn, J. Otten,C. and Wunder, B. 2007. Change in behaviour of honeybee *Apis mellifera* during electromagnetic exposure- follow up study 2006. (Unpublished research report). http://agbi.uni-landau.de/material_download/eimagex_bienen_06.pdf.

Sundriyal, M. and Sundriyal, R.C. 2004. Wild edible plants of the Sikkim Himalayas: nutritive values of selected species. Econ Bot. 58: 286-299.

Thomson, D.M. 2006. Detecting the effects of introduced species: a case study of competition between *Apis* and *Bombus*. Oikos. 114:407-418.

Traveset, A. and Richardson, D.M. 2006. Biological invasions as disruptions of plant reproductive mutualisms. Trends in Ecology and Evolution. 21:208-216.

Willemstein, S.C. 1987. An Evolutionary Basis for Pollination Ecology. Reiden Botanical Series, Vol. 10, 425 pp.

Winfree, R., Aguilar, R., Vazquez, D.P., LeBuhn and Aizen, M.A. 2009. A meta-analysis of bees' responses to anthropogenic disturbance. Ecology. 90:2068-2076.