The Role of Invertebrates in Ecosystem Function and Services

Seventh Symposium in Memory of Merav Ziv

Mitrani Department of Desert Ecology, Blaustein Institute for Desert Research
Ben-Gurion University, Sede Boqer Campus
The Zoological Society of Israel & The Israel Entomological Society

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09:45 Introduction and opening remarks

10:00 Ecology student award in memory of Merav Ziv

Scientific Program

10:15-11:00 **Plenary: Avital Gasith (Tel Aviv Univ.) - Use of macroinvertebrates assemblage and surrogate bioindicators for stream health assessment**

11:00-11:20 **Tamar Keasar (Achva College) - In search of solutions to the pollination crisis in agro-ecosystems**

11:20-11:40 **Refreshments**

11:40-12:00 **Phyllis Weintraub (Volcani Inst. - Gilat) - The use of predatory mites for biological control in vegetables**

12:00-12:20 **Ally Harari (Volcani Inst.) –The management of a scarab beetle pest of sorghum in Ethiopia: a case study**

12:20-12:40 **Ezer Miller (Hebrew Univ.) – Differential predation on juveniles and adults promotes stability of ecological systems**

12:40-14:00 **Lunch**

14:00-14:20 **Nancy Nicolai (Texas A&M /Ben-Gurion Univ.) - Harvester ant nests facilitate grassland recovery after drought in long-term grazing regimes**

14:20-14:40 **Merav Vonshak (Tel Aviv Univ.) – The little fire ant, *Wasmannia auropunctata*, in Israel.**

14:40-15:00 **Noam Cohen (Haifa Univ.) - The effects of secondary metabolites in *Nicotiana glauca* nectar on ants.**

15:00- 15:20 **Refreshments**

15:20-15:40 **Guy Pe'er (Hebrew Univ.) - Rare butterflies, rare habitats and diminishing ecosystem functioning in Israel**

15:40-16:00 **Gal Yaacobi (Ben-Gurion Univ.) – Effects of interactive scale-dependent variables on beetle diversity patterns in a semi-arid agricultural landscape**

16:00- 16:20 **Elli Groner (Ben-Gurion Univ.) – Is maximizing diversity the ultimate goal in conservation of sand dune arthropods?**

Macroinvertebrate assemblage and surrogate species approach to stream health assessment – the Israeli experience (Yarqon stream)

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Biological monitoring is widely used for assessing ecosystem state. The level of biological organization used varies from intracellular, through the organism and the community levels. The former is useful for early warning of potential effect whereas the latter indicate the eventual impact. Invertebrates are the group of organism most widely used in the assessment of aquatic ecosystem health. I will discuss the advantages and disadvantages of using invertebrates for biological monitoring, present the uni- and multi-metric approaches and demonstrate its application in a model stream – Yarqon.

Analysis of macroinvertebrate assemblage along an urban stream (Yarqon), generally agreed with the results obtained by examination of a surrogate snail (*Melanopsis lampra*) and a cyprinid fish (*Acanthobrama telavivensis*). The findings suggested that from the source down, the stream may ecologically be divided into three sections: a relatively unpolluted (mean Index of Biological Integrity = 69%), impaired by effluent (mean IBI= 29%), and partially recovered (mean IBI= 49%). IBI values showed highest temporal variability (CV 22-40%) in the impacted sections of the stream and lowest (CV 12-14%) in the relatively unimpaired section, reflecting variation in water quality. Whereas water quality and surrogate species analyses suggested that the upper, relatively unimpaired section (7 km) is ecologically uniform, macroinvertebrate assemblage analysis was sensitive enough to demonstrate deterioration of the biological integrity along this section (from 81% to 53%). We attribute the latter to instability of habitat conditions caused by factors other than pollution.

In search of solutions to the pollination crisis in agro-ecosystems

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Pollination by insects is an ecosystem service that is crucial for the reproduction of many wild plants and agricultural crops. Pollinator populations have been declining globally in recent decades due to loss of nesting and foraging habitats, outbreaks of parasites and pathogens, and poisoning by insecticides. This decline is manifest in reduced agricultural yields, and in threats to the conservation of insect-pollinated endangered plants.

The honeybee is the main pollinator in agro-ecosystems, and also the species with the most detailed record of population declines. In recent years, my colleagues and I investigated the following approaches for coping with the deterioration in honeybee pollination services in Israeli agro-ecosystems:

a. Conservation of honeybee populations through enhancement of foraging habitats. To this end, potential forage plant species were evaluated for flowering season, flower number, nectar yields and bee visitation rates. Suitable plants were then recommended for planting in forestry, and in urban and roadsides gardening.
b. Economic use of honeybees for agricultural pollination in enclosures. The viability and pollination efficiency of mini-nucleus honeybee colonies (each containing ca. 400 individuals) were compared with standard-size colonies of about 30,000 workers.
c. Domestication of additional bee species as alternative, or backup, pollinators. Foraging activity and pollination efficiency of the local carpenter bee *Xylocopa pubescens* was assessed in a melon greenhouse as an example of this approach.

The use of predatory mites for biological control in vegetables

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Vegetable crops, both covered and in open fields, are subject to a number of pest species that can be controlled by predatory mites. In Israel the only mite commercially available at present is *Phytoseiulus persimilis*. This predatory mite, with its long legs, is a specialist feeding on spider mites (*Tetranychus* spp.) that form webbed colonies. A bio-type, adapted to feed on tomato plants, is also available. A new mite currently being developed is *Neoseiulus californicus*. In a multi-national collaborative effort, *N. californicus* races are being collected world-wide and tested for their efficacy to control spider mites in hot dry climates found in the Mediterranean Basin. Since this mite feeds on pollen and other small arthropods, it can be released prophylactically, before spider mite populations develop. Until recently another predatory mite, the generalist *Neoseiulus cucumeris*, was also commercially available. This mite is a generalist feeder, and has been used to control of thrips, broad mites, and can also control the tomato russet mite. Additionally it feeds on plant pollen; therefore populations can be sustained during periods of low host densities. The newest mite under development is *Amblyseius swirskii*, a generalist predator feeding on pollen, whiteflies, thrips and broad mites.

The management of a scarab beetle pest of sorghum in Ethiopia: a case study

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Sorghum is among the major cereals produced in most parts of Ethiopia covering more than 1.13 million hectares of land. It is an important staple food, particularly in areas with low annual rainfall. Since 1993, the production of sorghum has been threatened by the sorghum chafer, *Pachnoda interrupta*, (Olivier) (Coleoptera: Scarabaeide: Cetoniinae). During the year 2002 the beetle infested over 112 thousand hectares of crops in east Ethiopia and was declared by the United Nation as a national crisis. The phenology of the beetles was not known, its hibernating places vague and the source of the population enigmatic.

The aims of the study were to elucidate the phenology of the pest, to follow the pest's population dynamics and to develop control means (preferably Integrated Pest Management (IPM)) to be used by local farmers. The beetle life cycle was studied in a laboratory under natural conditions. Adult emergence was monitored using food-baited traps, which were placed in the acacia forests, near cattle dung heaps and in the sorghum fields. Eggs were looked for in cattle dung, in sorghum field soil, under the wild vegetation near the sorghum and in the soil under acacia trees. The population dynamics in and away from the sorghum field was measured using food-baited traps arranged in the field margins facing outward and inward and with traps distributed in the forests, and near dung heaps. The timing of mating was studied in laboratory and latter, the beetle mating behavior was followed in the acacia forests. For practical IPM we tested locally obtainable food as baits, available cans and baskets as traps and the efficacy of attract-and-kill methods to reduce populations. We managed without chemical applications to reduce the beetle populations in household sorghum fields.

Differential predation on juveniles and adults promotes stability of ecological systems

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In many invertebrates, especially insects, young instars differ greatly from their adults, and live in different environments. As a result, juveniles and adults are susceptible to different levels and types of predation. In the present study we tested how differential predation (i.e., each life stage is attacked by a different predator) on juveniles and adults influence the stability of the system. We modeled two systems where prey has two life stages, juvenile and adult: (i) 1 predator -1 prey and (ii) 2 predators -1 prey. Proportion of predation on each of the two stages was used as a control parameter – '*q*'. Parameter '*q*' can vary between 0 and 1, where 1 or 0 represents predation on one stage only (adults or juveniles, respectively) and q=0.5, for example, means equal predation on both stages.

We showed analytically that when *q* is close to 0 and 1, the systems are locally stable. This stability is lost in both systems as q approaches 0.5. Numerical simulations support these results. Under these conditions (*q*=0.5), populations tend to diverge or go extinct; i.e., no periodic solutions were found. We therefore conclude that differential predation on juvenile and adults probably promotes system stability and permanence.

Harvester ant nests facilitate grassland recovery after drought in long-term grazing regimes

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Long-term studies on semiarid grasslands of Texas, U.S.A. show that large-scale vegetation dynamics are driven by large mammalian grazing, fire and drought. Smaller-scale patch dynamics are influenced by *Pogonomyrmex barbatus* (red harvester ant) because their nests act as drought refugia for grasses owing to high survivorship on nests compared to surrounding areas. It was hypothesized that recovery after drought would be faster on nests compared to away and that recovery would also depend on level of grazing. Significantly greater cover of grasses was found at nests compared with surrounding habitat through the first year of recovery. Relative recovery on the nests was faster in ungrazed and lightly grazed treatments compared to heavily grazed. Grasses near nests may be the seed source for surrounding habitats during drought recovery.

The little fire ant (*Wasmannia auropunctata*) in Israel

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Biological invasions are considered as the second most important factor in biodiversity decline worldwide. Among these invaders, species of social insects, especially ants, are particularly destructive. In Israel there are around 30 alien ant species, i.e., have been found at least once. The little fire ant (*Wasmannia auropunctata*), which is on the "one hundred of the world's worst invasive alien species" list of The World Conservation Union, was recently discovered in Israel. This is the first record of this ant in the Middle East, which is also the northern most point ($32^0$43') of this ant's distribution. The little fire ant is known for its devastating impact on the native fauna in its alien range, for its ferocious sting to humans, and as an agricultural pest both in its native and alien ranges.

We conducted a limited survey in the area where it was first reported (3 villages) in order to study the ant's distribution in Israel, using baits, hand collection and pitfall traps. We also located the ants in 5 additional villages in the same area as well as in a nature reserve and at the edges of agricultural fields. A substantial difference was found in the ant's population density between the various sites studied. In the two most heavily infested sites, Kibbutz Afikim and the adjacent Kibbutz Bet Zera, the little fire ant is found almost everywhere, and constitutes the only ant species. In such heavily infested areas other ant species can be found only on the periphery of the fire ant's distribution, whereas in non-infested areas 10 to 15 different ant species can co-occur.

To assess whether the little fire ant forms supercolonies in Israel we conducted intra- and interspecific aggression tests. There was no intraspecific aggression even between workers from the most distant poles within their local distribution. However, hand interspecific aggression was high and generally culminated in death of the heterospecific ant species. This suggests that, as in other invaded areas in the world, *W. auropunctata* forms supercolonies. It further supports the hypothesis that its ecological success lies in its ability to outcompete other ant species. We are now conducting chemical molecular and behavioral analyses to substantiate these conclusions.

Interactions between *Nicotiana glauca* and ants – the role of toxic nectar

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Ant-pollination is relatively rare and in many cases ants are considered as "nectar thieves" i.e. they consume floral nectar without serving as pollinators. Ants may reduce floral attractiveness to legitimate pollinators and may also damage sexual organs and interfere with pollen germination and growth. Toxic nectar produced by plants might have evolved as a defense against ants and other nectar robbers. Little research effort has been devoted to evaluating the influence of repellent compounds in floral nectar on ants.

In a series of field and lab experiments, we investigated the influence of the two pyridine alkaloids (nicotine and anabasine), which are found in *Nicotiana glauca* nectar on ants and the impact of the ants on the fitness of the plant. More specifically, our research addressed three aspects: a) the effect of ants on seed production, b) the effect of pyridine alkaloid concentration on food preference of six ant species that visits *N. glauca*, and c) the effect of pyridine alkaloid on orientation, water consumption and food preference of *Tapinoma simrothi* in non-choice feeding experiments.

Ants had no impact on seed production of the plant. Thus, we have not yet found any evidence of a negative influence by the ants on *N. glauca* fitness. In the field, the ants have not been deterred by the natural alkaloids concentrations (0.5-5 ppm) in the nectar but 500 ppm was highly deterrent. Hence, foragers were deterred only from concentrations (500 ppm) that were one hundred or one thousand times higher than naturally occurring concentrations of anabasine and nicotine in floral nectar, respectively. These concentrations are significantly higher than those that deterred bees and birds visiting *N. glauca's* nectar. In non-choice feeding experiments, laboratory colonies of *T. simrothi* fed and survived on 500ppm alkaloid solutions. This species is capable of consuming high concentrations of anabasine and nicotine for long periods without diluting it with water. Moreover, colonies that fed on higher alkaloid concentration developed tolerance to lower alkaloid dosages.

Finally, we found in laboratory experiments that *T. simrothi* covered liquid drops that contained high alkaloid concentrations (500 ppm) with mud. The more the colony was deterred by the alkaloid, the more they tended to cover the drops. It appears that ants can handle high alkaloids concentrations and we suggest that covering liquid substance with mud might be a way of dealing with noxious materials.

Rare butterflies, rare habitats and diminishing ecosystem functioning in Israel

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Many studies indicate that butterflies can serve as excellent biological indicators for the functioning of communities and ecosystems. This can be demonstrated by the rare butterflies of Israel. Fourteen species of rare butterflies, hopefully soon to become protected, represent a variety of equally rare landscapes and rare or endangered ecosystems, some of which receive only little attention. The stories of three species are presented in order to demonstrate what can be learned from these species about the functioning of their ecosystem. (1) *Tomares nesimachus* (Lycaenidae) is strongly affiliated with open grasslands in the north of Israel. The butterfly's abundance is strongly correlated not only with the commonness of its sole host-plant, but also with the diversity of large bees (the plant pollinators). Hence, the butterfly's decline may indicate on diminishing ecosystem functioning in terms of pollination services. (2) *Melitaea arduinna* (Nymphalidae), the rarest butterfly in Israel, can be found only on a unique form of lime bedrock in the upper Galilee. Both the butterfly's distribution and its life cycle seem to represent the uniqueness of a rare landscape, encompassing unique plants and endemic insects - all critically endangered, at least some of direct value for humans. (3) *Apharitis cilissa* (Lycaenidae) can only live in cooperation with ants of the genus *Crematogaster*. The butterfly exhibits an exceptional life cycle, along with a unique distribution pattern. Its main habitat in Israel lay in semi-stabilized and stabilized sands of the coastal plains, in places where succession has not yet formed a macqui. Thus, the butterfly seems to indicate that one of Israel's most endangered ecosystems is a subset of the 'sandy habitats', which so far received only little attention, namely the semi-stabilized and stabilized sands. Whether this 'subset' encompasses a unique set of species, and how to maintain these habitats, is currently under investigation.

Effects of interactive scale-dependent variables on beetle diversity patterns in a semi-arid agricultural landscape

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Understanding species-diversity patterns in heterogeneous landscapes invites comprehensive research on how scale-dependent processes interact across scales. We used two common beetle families (Tenebrionidae, detrivores; Carabidae, predators) to conduct such a study in the heterogeneous semi-arid landscape of the Southern Judean Lowland (SJL) of Israel, currently undergoing intensive fragmentation. Beetles were censused in 25 different-sized patches (500-40000 m^2). We used Fisher's α and non-parametric extrapolators to estimate species diversity from 11,125 individuals belonging to 56 species. Patch characteristics (plant species diversity and cover, soil cover and degree of stoniness) were measured by field transects. Spatial variables (patch size, shape, physiognomy and connectivity) and landscape characteristics were analyzed by GIS and remote-sensing applications. Both patch-scale and landscape-scale variables affected beetle species diversity. Path-analysis models showed that landscape-scale variables had the strongest effect on carabid diversity in all patches. The tenebrionids responded differently: both patch-scale and landscape-scale variables affected species diversity in small patches, while mainly patch-scale variables affected species diversity in large patches. Most of the paths affected species diversity both directly and indirectly, combining the effects of both patch-scale and landscape-scale variables. These results match the biology of the two beetle families: Tenebrionidae, the less mobile and more site-attached family, responded to the environment in a fine-grained manner, while the highly dispersed Carabidae responded to the environment in a coarse-grained manner. We suggest that understanding abiotic and biotic variable interactions across scales has important consequences for our knowledge of community structure and species diversity patterns at large spatial scales.

Is maximizing diversity the ultimate goal in conservation of sand dune arthropods?

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Over the last few decades coastal sand dunes in Israel have been subjected to several pressures which threaten this habitat, its flora and fauna. Two main processes are causing the destruction of the habitat in Israel, though paradoxically one is the result of an increase in human disturbance and the other a decrease: (1) Massive human development has resulted in the destruction of about half of the coastal sand dunes. (2) In the remaining dunes, local nomads who practiced grazing and wood collection have been excluded from the dunes, resulting in shrub encroachment. While the increase in human disturbance leaves hardly any wildlife in the destroyed habitats, the changes in the "protected" dunes are more complex. The encroachment stabilizes the dunes, reducing wind speed and sand movement and bringing about changes in the entire dune community. There is a concern that these changes will eventually eliminate the typical species of coastal sand dunes. This study looks at the species composition and population changes on sand dunes as a result of the encroachment. Specifically we looked at the beetle species, an order whose global distribution is well documented.

The dunes, in which shrub density increased and began to stabilize, have a richer species diversity and a higher abundance of beetles compared with the shifting sand dunes. If our aim was to maximize species diversity at each dune the recommended management should therefore be to continue protecting the dunes from grazing and any human involvement. This would result in stabilization of the dunes and create a rich and abundant arthropod community. However, when we examine the species composition at each dune, we find that there is a strong species turnover that depends on the plant cover. The shifting sand dunes are home to arid psammophile (sand-loving) species. The stabilized dunes house Mediterranean, mesophilic (humid-loving) species. Most psammophile species are being depleted and disappearing from the stabilized sand dunes.

Maximizing the local species diversity of each dune may therefore come at the expense of protecting vulnerable specialist species. Management recommendations should consider biodiversity at several scales. From this point onwards, the decision is a philosophical one: do we want to protect local, regional, national or global diversity? It appears that each answer requires a different conservation practice.