HONDURAS DISSERTATION/THESIS PROJECT

HO13 Aquatic invertebrate communities in tank bromeliads

Dr Tom Martin | Terrestrial research officer | tom.martin@opwall.ac.uk

Bromeliads (Bromeliaceae) are a characteristic component of Neotropical forests. Found from ground level to high in the canopy, they contribute significantly to the habitat complexity of Neotropical forests (Benzing, 2000), in particular for invertebrates. Bromeliads in a large subset of the family, called tank bromeliads, are capable of holding considerable quantities of water in their leaf axils, creating aquatic habitats that are inhabited by aquatic invertebrate communities (Fish, 1976; Greeney, 2001; Frank and Lounibos, 2009). Tank bromeliads can occur in high densities, and, based on their three-dimensional distribution in forests, may be the phytotelm (plant-held water body) habitat occurring in the highest densities anywhere. For example, Sugden and Robins (1979) recorded a mean density of 17.5 plants per square metre of ground area in a cloud forest in Colombia. If the volume of water retained per plant is on average of the order of 100 cm^3, then such densities translate into tens of thousands of litres of water available for colonization by aquatic animals, per hectare. In the absence of other lentic water bodies, as is often the case in mountainous tropical forest areas, phytotelm habitats provide an important freshwater habitat. The profusion of bromeliads, and their use as breeding habitats by vectors for human diseases such as malaria and dengue, render bromeliads important from a range of perspectives. In addition, bromeliads represent self-contained aquatic communities, present naturally and at high replication, making them potentially valuable as a study system for tackling prominent ecological and evolutionary questions (Srivastava et al., 2004). The well-defined aquatic communities occurring in clusters are highly suitable for studying metacommunity dynamics (Leibold et al., 2004). Further, bromeliads can be effectively imitated by artificial containers (Srivastava, 2006). These features allow easy manipulation and great flexibility in research design.

Despite the great advantages conferred by tank bromeliads, knowledge of their aquatic invertebrate communities, and what structures them, remains limited—even though research on aquatic invertebrates in phytotelmata dates back at least to 1915 (Picado, 1915; see also Laessle, 1961; Maguire, 1971; Frank and Lounibos, 1983; Kitching, 2000). Most studies on aquatic invertebrates in bromeliads to date have focused on cataloguing species not previously known in phytotelmata (e.g. Mendes et al., 2011). Recently, however, ecological studies have started to contribute to the understanding of this habitat (e.g., Armbruster et al., 2002, Jabiol et al., 2009; Brouard et al., 2011). Some studies point towards the importance of light and organic material (a proxy for productivity; Srivastava et al., 2008) in influencing community assembly (e.g. Dezerald et al., 2013). Habitat complexity, measured as the number of leaves, affects the whole invertebrate system (Armbruster et al., 2002). Most of these observations are based on descriptive data to gain insight in these habitats. For a sound understanding of how environmental factors (patch characteristics) affect the colonization rates and to determine how post colonization processes interact to shape communities, an experimental or manipulative approach in the field is needed (Kraus and Vonesh 2010).

In this project the student will, through a combination of bromeliad sampling and experimental set-ups, investigate the effect of selected factors on community structure and diversity patterns in aquatic microcosms. For this, artificial phytotelmata (plastic containers) will be mounted on trees in a cloud forest in Honduras. Phytotelmata are ephemeral habitat patches and the required high colonisation rate in these systems lends itself perfectly for colonization and community assembly experiments. The well defined habitat patches and enclosed communities provide an excellent system for metacommunity studies and more specifically habitat selection studies (e.g. Kneitel & Miller 2003). Bromeliad communities are often locally abundant, small, well defined and can easily be manipulated experimentally. The high colonisation dynamics in these systems make it a valuable tool for short term (6-8 week) projects. The wide environmental range in which bromeliads are found, mean a lot of variability. This variability combined with the flexibility that goes with the placement of artificial bromeliads offers considerable opportunities to test specific hypotheses. This project departs from the metacommunity concept (Leibold et al. 2004), and evaluates how alfa (in one bromeliad), beta (in between bromeliads) and gamma (in a cluster of bromeliads) diversity are influenced by selected factors. The student is stimulated to come up with own hypotheses to test. A wide range of classic ecological and biogeographic diversity relationships such as species richness–altitude, richness–environment, richness–size, richness–habitat complexity and richness–isolation relationships can be tested. In general, the extent to which invertebrate communities in bromeliads are structured by classic ecological and biogeographic rules remains fragmentarily evaluated. In addition to the classic biogeography patterns, environment (often measured as productivity; Field et al., 2009), habitat complexity (Hortal et al., 2009) and altitude (Rahbek, 1995; McCain, 2007) are factors affecting species richness in a wide range of taxa globally. The suggested research direction in this project is, however, towards some current "hot topics" in community ecology regarding dispersal and biotic interactions. Most contemporary ecological and conservation research is placed within a metacommunity framework where individual communities are connected by dispersal (Wilson 1992).

Variation in dispersal frequency is one of the main aspects used to classify natural metacommunities in different conceptual categories of theoretical metacommunity models: mass effects, species sorting, patch dynamics, neutral model (Leibold et al. 2004; Logue et al., 2011) and dispersal is usually assumed random. Resetarits et al. (2005) expanded upon this by highlighting three different situations. First of all, random colonization, assumes that organisms either have no control over their dispersal or disperse actively and settle randomly (no habitat selection). As such, local communities can all interact in the same way with a regional species pool (propagule rain) or dispersal dynamics may be driven by the spatial structure of the system. Secondly, the authors define the extreme habitat selection example of philopatry where organisms only breed in their natal patches. Finally, the concept of Interactive habitat selection is launched where attraction or avoidance of patches is continuously updated taking into account changes in habitat quality and biotic interactions. As such habitat selection refers to a dynamic hierarchical process of behavioral responses that may result in the disproportionate use of certain habitat types to promote survival and fitness of individuals (Jones 2001). The occurrence of habitat selection and in particular multispecies habitat selection has strong ecological consequences for metacommunity dynamics (Binckley and Resetarits 2005) and may generate distinct patterns from random dispersal. The distinct patterns result from individuals actively redistributing over habitat patches compared to individuals dispersing randomly and surviving in the appropriate places. However, the mere thriving of a species in an environmentally defined subset of habitat patches does not necessarily imply a habitat selection strategy. Patterns like these could be generated by an efficient species sorting process, where the species disperses over all habitat patches and is inhibited in the less favorable environments.

Dispersal is a crucial component in diversity patterns and in current theoretical models (e.g. the metacommunity model), but the empirical data, and in particular quantitative data on dispersal and how it affects diversity patterns and community structure, is still limited. Besides providing quantitative insights in the importance of dispersal on metacommunity structure, this project also feeds in the need for experimental work designed to disentangle the processes underlying the patterns of biodiversity observed in tank-bromeliads (Jabiol et al., 2009) and with the broader aim of understanding whether and how processes operating in these small systems could be extrapolated to larger ecosystems (Srivastava et al. 2004).

Recommended Reading

Anderson M. J., T. O. Crist, J. M. Chase, M. Vellend, B. D. Inouye, A. L. Freestone, N. J. Sanders, H. V. Cornell, L. S. Comita, K. F. Davies, S. P. Harrison, N. J. B. Kraft, J. C. Stegen, N. G. Swenson. 2011. Navigating the multiple meanings of β diversity: a roadmap for the practicing ecologist. Ecology Letters 14: 19-28.

Armbruster, P., R. A. Hutchinson & P. Cotgreave, 2002. Factors influencing community structure in a South American tank bromeliad fauna. Oikos 96: 225–234.

Baselga, A., 2010. Partitioning the turnover and nestedness components of beta diversity. Global Ecology and Biogeography 19: 134–143.

Bentley M.D.& Day J.F. (1989). Chemical Ecology and Behavioral-Aspects of Mosquito Oviposition. Annual Review of Entomology 34: 401-421.

Bernath B., Gal J.& Horvath G. (2004). Why is it worth flying at dusk for aquatic insects? Polarotactic water detection is easiest at low solar elevations. Journal of Experimental Biology 207(5): 755-765.

Binckley, C. A. & W. J. Resetarits, 2005. Habitat selection determines abundance, richness and species composition of beetles in aquatic communities. Biology Letters 1: 370–374.

Blaustein L., Kiflawi M., Eitam A., Mangel M.& Cohen J.E. (2004). Oviposition habitat selection in response to risk of predation in temporary pools: mode of detection and consistency across experimental venue. Oecologia 138(2): 300-305.

Brendonck L.& Riddoch B.J. (1999). Wind-borne short-range egg dispersal in anostracans (Crustacea : Branchiopoda). Biological Journal of the Linnean Society 67(1): 87-95.

Brouard, O., A.H. Le Jeune, C. Leroy, R. Cereghino,O. Roux, L. Pelozuelo, A. Dejean, B. Corbara & J.F. Carrias, 2011. Are algae relevant to the detritus-based food web in tank-bromeliads? PLoS ONE 6, e20129. doi: 10.1371/journal.pone.0020129.

Brown, J.H. & A. Kodric-Brown, 1977. Turnover rates in insular biogeography – effect of immigration on extinction. Ecology 58: 445–449.

Cereghino, R., C. Leroy, J. F. Carrias, L. Pelozuelo, C. Segura, C. Bosc, A. Dejean & B. Corbara, 2011. Ant–plant mutualisms promote functional diversity in phytotelm communities. Functional Ecology 25: 954–963.

Chase, Jonathan M., Nathan J. B. Kraft, Kevin G. Smith, Mark Vellend, and Brian D Inouye. 2011. Using null models to disentangle variation in community dissimilarity from variation in α-diversity. Ecosphere 2:art24. http://dx.doi.org/10.1890/ES10-00117.1

Cotgreave, P., M. J. Hill & D. A. J. Middleton, 1993. The Relationship between body-size and population-size in bromeliad tank faunas. Biological Journal of the Linnean Society 49: 367–380.

De Meester, L., A. Gomez, B. Okamura & K. Schwenk, 2002. The Monopolization Hypothesis and the dispersal–gene flow paradox in aquatic organisms. Acta Oecologica-International Journal of Ecology 23: 121–135.

Dézerald O., T. Stanislas, C. Leroy, J. Carrias, B. Corbara, A. Dejean & R. Céréghino, 2013. Environmental determinants of macroinvertebrate diversity in small water bodies: insights from tank-bromeliads. Hydrobiologia 1-10.

Dodson, S., 1992. Predicting Crustacean Zooplankton Species Richness. Limnology and Oceanography 37: 848–856.

Eitam A.& Blaustein L. (2004). Oviposition habitat selection by mosquitoes in response to predator (Notonecta maculata) density. Physiological Entomology 29(2): 188-191.

Field, R., B.A. Hawkins, H.V. Cornell, D. J. Currie, J. A. F. Diniz-Filho, J.-F. Guégan, D. M. Kaufman, J. T. Kerr, G. G. Mittelbach, T. Oberdorff, E. M. O'Brien & J. R. G. Turner, 2009. Spatial species-richness gradients across scales: a meta-analysis. Journal of Biogeography 36: 132–147.

Field, R. & P. R. Long, 2007. *Cusuco National Park, Honduras: ecology of a Meso-American cloud forest.* Operation Wallacea, Ltd, Old Bolingbroke, UK.

Fish, D., 1976. *Structure and composition of the aquatic invertebrate community inhabiting epiphytic bromeliads in South Florida and the discovery of an insectivorous bromeliad.* PhD dissertation. University of Florida.

Frank, J. H. & L. P. Lounibos, 1983. *Phytotelmata: terrestrial plants as hosts for aquatic insect communities.* Medford, New Jersey; Plexus.

Frank, J. H., S. Sreenivasan, P. J. Benshoff, M. A. Deyrup, G. B. Edwards, S. E. Halbert, A. B. Hamon, M. D. Lowman, E. L. Mockford, R. H. Scheffrahn, G. J. Steck, M. C. Thomas, T. J. Walker & W. C. Welbourne, 2004. Invertebrate animals extracted from native Tillandsia (Bromeliales: Bromeliaceae) in Sarasota County, Florida. Florida Entomologist 87: 176–185.

Frank, J. H. & L. P. Lounibos, 2009. Insects and allies associated with bromeliads: a review. Terrestrial Arthropod Reviews 1: 125–153.

Greeney, H. F., 2001. The insects of plant-held waters: a review and bibliography. Journal of Tropical Ecology 17: 241–260.

Greif S.& Siemers B.M. (2011). Innate recognition of water bodies in echolocating bats. Nature Communications 1.

Grytnes, J. A. & C. M. McCain, 2007. Elevational patterns in species richness. *Encyclopedia of Biodiversity* (Ed S. Levin), Elsevier, Inc.

Hortal, J., K. A. Triantis, S. Meiri, E. Thebault & S. Sfenthourakis, 2009. Island species richness increases with habitat diversity. American Naturalist 174: E205–E217.

Jabiol, J., B. Corbara, A. Dejean & R. Cereghino, 2009. Structure of aquatic insect communities in tank-bromeliads in an East-Amazonian rainforest in French Guiana. Forest Ecology and Management 257: 351–360.

Jocque, M., A. Kernahan, A. Nobes, C. Willians & R. Field, 2010a. How effective are non-destructive sampling methods to assess aquatic invertebrate diversity in bromeliads? Hydrobiologia 649: 293–300.

Jocque, M. & J. Kolby, 2012. Acidity of tank bromeliad water in a cloud forest, Cusuco National Park, Honduras. International Journal of Plant Physiology and Biochemistry 4: 59–70.

Jocque, M., R. Field, L. Brendonck & L. De Meester, 2010b. Climatic control of dispersal–ecological specialization trade-offs: a metacommunity process at the heart of the latitudinal diversity gradient? Global Ecology and Biogeography 19: 244–252.Jones J. 2001. Habitat selection studies in avian ecology: a critical review. The Auk 118: 556-562.

Jurasinski G, Retzer V, Beierkuhnlein C. 2009. Inventory, differentiation, and proportional diversity: A consistent terminology for quantifying species diversity. Oecologia 159: 15-26.

Karger, D. N., J. Kluge, T. Kromer, A. Hemp, M. Lehnert & M. Kessler, 2011. The effect of area on local and regional elevational patterns of species richness. Journal of Biogeography 38: 1177–1185.

Kiflawi M., Blaustein L.& Mangel M. (2003). Predation-dependent oviposition habitat selection by the mosquito Culiseta longiareolata: a test of competing hypotheses. Ecology Letters 6(1): 35-40.

Kitching, R. L., 2000. *Food webs and container habitats: the natural history and ecology of phytotelmata.* Cambridge Univeristy Press, Cambridge.

Kraus J.M.& Vonesh J.R. (2010). Feedbacks between community assembly and habitat selection shape variation in local colonization. Journal of Animal Ecology 79(4): 795-802.

Kneitel, J. M. and T. E. Miller. 2003. Dispersal rates affect species composition in metacommunities of Sarracenia purpurea inquilines. American Naturalist 162: 165-171.

Laessle, A. M., 1961. A micro-limnological study of Jamaican bromeliads. Ecology 42: 499–517.

Lehtinen R.M. & Carfagno G.L.F. Habitat Selection, the Included Niche, and Coexistence in Plant-Specialist Frogs from Madagascar. Biotropica 43(1): 58-67.

Leibold M.A., Holyoak M., Mouquet N., Amarasekare P., Chase J.M., Hoopes M.F., Holt R.D., Shurin J.B., Law R., Tilman D., Loreau M.& Gonzalez A. (2004). The metacommunity concept: a framework for multi-scale community ecology. Ecology Letters 7(7): 601-613.

Loeuille N.& Leibold M.A. (2008). Evolution in metacommunities: On the relative importance of species sorting and monopolization in structuring communities. American Naturalist 171(6): 788-799.

Logue J.B., Mouquet N., Hannes Peter H., Hillebrand H., and The Metacommunity Working Group. (2011) *Empirical approaches to metacommunities: a review and comparison with theory.* Trends in Ecology and Evolution 26: 482-491.

Lopez L.C.S., Filizola B., Deiss I.& Rios R.I. (2005). Phoretic behaviour of bromeliad annelids (Dero) and ostracods (Elpidium) using frogs and lizards as dispersal vectors. Hydrobiologia 549: 15-22.

Lopez L.C.S., Rodrigues P.& Rios R.I. (1999). Frogs and snakes as phoretic dispersal agents of bromeliad ostracods (Limnocytheridae : Elpidium) and annelids (Naididae : Dero). Biotropica 31(4): 705-708.

Lounibos L.P., O'Meara G.F., Nishimura N.& Escher R.L. (2003). Interactions with native mosquito larvae regulate the production of Aedes albopictus from bromeliads in Florida. Ecological Entomology 28(5): 551-558.

MacArthur, R. H. & E. O. Wilson, 1967. The theory of island biogeography. Princeton University Press, New Jersey.

Maguire, B. 1971. Phytotelmata: Biota and community structure determination in plant-held waters. Annual Review of Ecology and Systematics 2: 439–464.

McCain, C. M., 2007. Area and mammalian elevational diversity. Ecology 88: 76–86.

Mendes, H. F., T. Andersen & M. Jocque, 2011 A new species of *Polypedilum* Kieffer from bromeliads in Parque Nacional Cusuco, Honduras (Chironomidae: Chironominae). Zootaxa 3062: 46–54.

Montero G., C. Feruglio & I. M. Barberis, 2010. The phytotelmata and foliage macrofauna assemblages of a bromeliad species in different habitats and seasons. Insect Conservation and Diversity 3, 92–201.

Mukhin A., Chernetsov N.& Kishkinev D. (2008). Acoustic information as a distant cue for habitat recognition by nocturnally migrating passerines during landfall. Behavioral Ecology 19(4): 716-723.

Picado, C., 1913. Les Bromeliacees Epiphytes. Bulletin Scientifique Tome XLVII: 216–360.

Qian H. and R. E. Ricklefs 2012 Disentangling the effects of geographic distance and environmental dissimilarity on global patterns of species turnover. Global Ecology and Biogeography. 21: 341-351.

Rahbek, C., 1995. The elevational gradient of species richness – a uniform pattern. Ecography 18: 200–205.

Rahbek, C., 2005. The role of spatial scale and the perception of large-scale species-richness patterns. Ecology Letters 8: 224–239.

Rangel, T., J. A. F. Diniz-Filho & L. M. Bini, 2006. Towards an integrated computational tool for spatial analysis in macroecology and biogeography. Global Ecology and Biogeography 15: 321–327.

Reich, A., J. J. Ewel, N. M. Nadkarni, T. Dawson & R. D. Evans, 2003. Nitrogen isotope ratios shift with plant size in tropical bromeliads. Oecologia 137: 587–590.

Resetarits, Jr, W. J., Binckley, C. A. & Chalcraft, D. R. 2005. Habitat selection, species interactions, and processes of community assembly in complex landscapes: a metacommunity perspective. In *Metacommunities: spatial dynamics and ecological communities* (ed. M. Holyoak, M. A. Leibold & R. D. Holt). University of Chicago Press.

Richardson, B. A., 1999. The bromeliad microcosm and the assessment of faunal diversity in a Neotropical forest. Biotropica 31: 321–336.

Sabagh L.T., Dias R.J.P., Branco C.W.C.& Rocha C.F.D. (2011). News records of phoresy and hyperphoresy among treefrogs, ostracods, and ciliates in bromeliad of Atlantic forest. Biodiversity and Conservation 20(8): 1837-1841.

Srivastava, D. S. & J. H. Lawton 1998. Why more productive sites have more species: An experimental test of theory using tree-hole communities. American Naturalist 152: 510–529.

Srivastava, D. S., 2006. Habitat structure, trophic structure and ecosystem function: interactive effects in a bromeliad-insect community. Oecologia 149: 493–504.

Srivastava, D. S., J. Kolasa, J. Bengtsson, A. Gonzalez, S. P. Lawler, T. E. Miller, P. Munguia, T. Romanuk, D. C. Schneider & M. K. Trzcinski, 2004. Are natural microcosms useful model systems for ecology? Trends in Ecology & Evolution 19: 379–384.

Srivastava, D. S., M. K. Trzcinski, B. A. Richardson & B. Gilbert, 2008. Why are predators more sensitive to habitat size than their prey? Insights from bromeliad insect food webs. American Naturalist 172:761–771.

Sugden, A. M. & R. J. Robins, 1979. Aspects of the ecology of vascular epiphytes in Colombian cloud forests .1. Distribution of the epiphytic flora. Biotropica 11: 173–188.

Yanoviak S.P. (2001). The macrofauna of water-filled tree holes on Barro Colorado Island, Panama. Biotropica 33(1): 110-120.Binckley C.A.& Resetarits W.J. (2005). Habitat selection determines abundance, richness and species composition of beetles in aquatic communities. Biology Letters 1(3): 370-374.

Vanschoenwinkel B., Waterkeyn A., Vandecaetsbeek T., Pineau O., Grillas P.& Brendonck L. (2008). Dispersal of freshwater invertebrates by large terrestrial mammals: a case study with wild boar (Sus scrofa) in Mediterranean wetlands. Freshwater Biology 53(11): 2264-2273.