Seeing mangrove swamps from a distance: Development of a virtual field trip

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Looking back on the relationship between field work and biology, Darwin spent most of his life pottering about at Down House, but his gift to humanity started with indulging in the same past-time as new graduates today–taking a year (or two) off for a trip round the world. He did lots of field work, field and ocean work to be more precise: how he would have enjoyed SCUBA diving if there had been the chance! Then, Mendel's gardening observations, without which Watson and Crick could not have written 'It has not escaped our attention...' only started after he knew about different plants which I like to think involved examining plants in nature. So the starting point for genetics as well as evolution and ecology was field work. Going further back it is easy, if not trivial, to claim that systematics, physiology, morphology and palaeobotany all derived in the first instance from going out and looking at plants.

The days of reductive biology, so strikingly successful in revealing biochemical, biophysical and molecular processes in cells, are now leading on to the study of interactions between processes, computational biology, and complex systems. This means that whole plants (and animals) in their natural or agricultural environment will increasingly become the stuff of experiments. Therefore computer-capable, molecular-capable students should begin to sign up for field trips alongside those interested in evolutionary and ecological questions. In short, it looks as though field biology will become more important for all types of biologists.

Let us look at the relationship between field work and professional activity in the earth sciences. The techniques of observation and mapping can only realistically be learned in the field. Such work has to be part of degree work and is a major part of undergraduate life. For professional biologists field measurement techniques may not be as central as mapping is to the earth sciences, but they are vital for some and, as suggested above, may be increasingly important for others. Field techniques are important for investigating such things as the origin and evolution of flowering plants (Amborella and the ANITA grade), the cause of maintained diversity in tropical rain forest (niche or randomness?), the limitation on the height of trees, adapting and adjusting to saline environments, and many questions to do with the practicalities of growing genetically modified plants.

For the sake of discussion let us distinguish three activities in field work–seeing, measuring and sampling.

Here I am discussing mainly plants. First, in the natural habitat we *see*, we also live in the habitat we are studying. This shows the scale of the plants and the habitat and their complexity in three dimensions; and incidentally, maybe not unimportantly, we also sample sounds, smells and weather. The real thing, in other words. It fires the imagination, engages interest, allows us to touch, handle and identify species, and explore and make the habitat our own.

Second, *measuring* in the field. We can do pressure bomb estimates of xylem pressure, gas exchange and florescence rates in leaves, light intensity, temperature and humidity; measure leaf area ratios; mark quadrats, and estimate coverage by identified plants; measure soil salinity and so on.

Thirdly, we can take *samples* of soil, soil water, leaves and roots for more detailed analysis back in the laboratory.

This lets us engage students with the plants and habitats under study, prepare them for at least some aspects of professional field activity, and follow through old observations or explore new hypotheses experimentally. With question and answer, discussion, exploring and investigating we have a decent educational activity, eschewing the older, non-participatory ‘Cook’s Tour’. Now in practice we do not trample a habitat underfoot, dig up root and rhizome systems and defoliate the vegetation. Balancing individual learning activity against habitat perturbation is a serious matter, indeed it is one part of biological education itself.

Despite these virtues, there are obstacles to field trips—availability of staff, time and funding; safety matters and the impossibility of non-mobile students taking part. All of these are becoming greater problems.

Coming to specifics: in introducing students to coastal plants I deal with mangroves, salt marsh, sea grasses and seaweeds. It is impractical to take 50 marine biology students SCUBA diving off the coast of Northumberland to see *Zostera* and *Fucus*, so we make do with photos and samples. Salt marsh is accessible, given funding, time and staff. But from northern Europe, mangroves are a different matter. At the University of Sydney we could take a bus load of students to Botany Bay to see both mangrove and salt marsh vegetation, but the nearest mangroves to Northumberland are in the Red Sea, 5000 km distant, and these are only a monoculture of *Avicennia marina* (coincidentally the same species as in Sydney), barely worth a special visit. Next nearest would be central Africa or the Caribbean. South East Asia would be ideal, but funds, time and staff are not available for a routine field trip to any of these.

So what can we do? How can we give students the benefits of field work without actually doing it? Can we manage a virtual field trip? Is there some way to approximate seeing, sampling and measuring mangroves?

The destination

The first matter to decide is where to ‘go’? To see the world’s mangroves the minimum is once to equatorial SE Asia, once to the southern Caribbean, and once north or south of the tropics. Thus one would see thirty to forty species together at the centre of diversity in, say, Malaysia; five or so species also on the equator in the centre of the depauperate Afro-American subgroup – a biogeographical history; and only one or two species near the limit of distribution–a story of varying physiologies.

The UK Learning and Teaching Support Network supported this view and helped finance a visit to the island of Hoga in SE Sulawesi, Indonesia, and to Sydney, where I worked with colleagues from Operation Wallacea and from the University of Sydney. These sites represent two of the three primary target areas. Subsequently I have revisited the Sungei Buloh Wetland reserve, but have not yet videoed in the Caribbean.

Seeing in a virtual field trip

My basic idea was that anyone surveying a mangrove swamp would walk through, once at low water and once at high, and a virtual field trip should do the same. A video would be at eye level, just the right height. Tracking twice though the mangroves would then be the centre of a web page with links to subsidiary videos or still shots focusing on details. (The problem with visiting mangroves is that the high tide is never there. Helpful colleagues, knowing I needed to collect some leaves, arranged visits at low tide, and when we took students in Sydney it was always at low tide so that we could get in amongst the mangroves easily. Eventually I did see mangroves at high tide, and it was magic. There they were, in their element—sea water—washing up to the trunks, gently swirling round them, touching the lowest leaves.)

To convey the impression of scale at the island of Hoga, we recorded from a small boat as we approached the bay with mangroves. There is a beach, coconut trees, people walking and a small village, then rounding the point the mangrove vegetation is spread in the distance. The approach at high tide reveals the detail gradually, including the young plantlets with just a few leaves above water at the top of long leafless stems. We then slide into the water and record the final approach on foot. This would all be better with a wider angle lens and inbuilt stability to eliminate the motion of the boat and of walking, but the cost of renting a professional video recorder was too high.

Alongside the approach and transect we collected close-up videos of whole plants, branches, leaves, flowers and propagules and roots, generally with a hand, foot or some other scale object in the field of vision.

A few days later I repeated the approach at about the same time of day but low tide, walking across sand instead of wading through water. This time mangrove roots were the main object, which are much more interesting when seen clearly. We report here for the first time that occasionally, at more than 10 m from the parent tree, shoots grow up from the horizontal roots of *Sonneratia*. This has been reported previously only in *Bruguiera*.

The web pages constructed from this as a final year ‘biology information’ project have been available on the web since mid 2003, and are in process of being added to the School of Biology web site at Newcastle University.

The next two sites have been Botany Bay in Sydney, Australia, and Sungei Buloh Wetlands Reserve in Singapore.

In Sydney there are only two species and we had less time. In this case we recorded from the outside of the mangroves along the water front, and then round and through to the salt marsh at the back. We videoed just after high tide at 9.00 am when the pneumatophores of *Avicennia marina* were submerged and again at about 1.00 pm near low tide. To fix the times my helpful assistant held a large clock against a leafy background for the start of each walk-through. The closest approach to weather was the back page of the *Sydney Morning Herald* with forecast for the day and a useful tide chart.

In 2003 at Sungei Buloh in northern Singapore I was given friendly help in the form of a boat trip out into the Kranji estuary and back into the mangroves. This was combined with shots along the fabulous board–walk from land to seaward side.

Taking measurements in a virtual field trip

The object of grasping the scale of mangrove vegetation, height, density, extent along the shore, is one small step in this direction, and one could conceivably manage to present a photographic transect of quadrats for characterising on the web pages (though more easily in salt marsh vegetation). We do not seriously attempt to simulate more than this. If we make measuring available to students, it is done on sampled material in the laboratory as described below.

Sampling in a virtual field trip

Cannot be done.

Alternatives to sampling and measuring in the field

However, with appropriate local permission I have collected a small set of samples of *Avicennia marina* pneumatophores and sets of leaves from branches of several species of mangrove.

In practical classes we examine the structures of pneumatophore and horizontal roots, measure sizes and estimate percentage air space, and then calculate from published respiration rates how long the pneumatophores can sustain aerobic respiration under water. We then discuss how the answer relates to rise and fall of the tide.

A second practical exercise involves analysing progressively older leaves along a branch for Na^+, K^+, and Cl^- contents per unit leaf area, 'concentrations' per unit dry weight, and leaf thickness from fresh weight and area measurements. We discuss how to test the hypothesis that old leaves gather NaCl and then drop, thus acting as a third means of salt allocation in mangrove shoots after vacuolar accumulation during growth and secretion by glands in those species that have them. Newcastle university students have now disproved the hypothesis in several species (Cram, Torr, Rose 2002).

Overall

I think we have something more than 'my holiday snaps of mangroves' on our developing web site. Maybe it approaches several of the features of real field work.

Can we see scale? Just about, from distant video views and wide angle photographs. Diversity? Yes, viewers should be able to distinguish species one from another from videos and photographs. This is one of the things students should be able to learn. Detail of structure? Not so well, but there is a reasonable context for studies of collected material in the laboratory. Are there smells? No. Sounds? Some is recorded by the video recorder. Weather? Distant hints.

Is there enough to stimulate the imagination, generate interest, and leave the viewer with some sense of what it is actually like to be amongst mangroves? More questionnaires to answer this will be carried out, but I like to think that we are more than half way between a set of static photos and a real visit. I hope that students will obtain a feel for the mangrove community shown, and that there is some degree of exploration given by the choice of which detail to examine and in which order.

The combination with laboratory investigations in the home university department also has its merits. If we were to do the same projects in Sydney or Singapore, it would involve collecting and returning to the laboratory. So the only difference (admittedly a major one) is that I had the chance of visiting and did the collecting the samples and the students didn't.

Advantages of a virtual field trip

First of all, there is no substitute for a real visit. It would be dishonest to say otherwise. Second, a responsible teacher of mangrove biology should attempt to visit a mangrove community, and deserves support from their university for such a trip.

That said, the advantages of a virtual field trip can readily be listed. The ecosystem is not trodden under foot, handled or otherwise disturbed. Any collecting is done expeditiously and minimally by one person. All can participate, there is no limitation due to lack of mobility. There are no safety issues. Most importantly, time and cost are the widest barriers to Northern European students visiting mangroves while a virtual field trip can be made at no cost to students and no additional cost to staff in money or time. This is a big plus.

However, when dealing in the UK with salt marsh vegetation one can not justify substituting a virtual field trip for a day's outing. There is no substitute for the real thing.

References

Cram, W.J., Torr, P.G. and Rose, D.A. (2002) Salt allocation during leaf development and leaf fall in mangroves. *Trees*, **16**, 112-119.