Molecular Systematics: applying genetic tools to studies of Pacific biodiversity

by Richard Winkworth, Linton Winder, and Peter Lockhart

Mention DNA and many people think of the movie Jurassic Park where ancient genetic material is used to recreate *Tyrannosaurus*, *Velociraptor* and other scary creatures. Although bringing extinct animals to life remains in the realm of science fiction, DNA technology already has significant impacts on our lives. Perhaps best known and most controversial is 'genetic modification' for the purpose of changing an organism's physical characteristics – often this is done for food production or medical purposes. But there are other applications of DNA technology that can be extremely helpful for documenting, understanding, and conserving biodiversity. Central to our story is the use of genetic technologies as sensitive, rapid, and cost effective tools for understanding the genetic blueprint for biodiversity. These tools form the kit bag of "molecular systematics," a discipline that is concerned with investigating the genetic differences between organisms and the processes that might explain their distribution and diversity – why do animals, plants and microbes have so many different forms and why do they occur where they do?

The sensitivity of DNA technology has led to molecular systematics becoming the foundation for many studies of biological diversity. In many parts of the world, the tools of molecular systematics are being used for biodiversity assessment – to better understand what organisms are present in different environments, to understand the population dynamics of endangered plants and animals, and to catalogue the diversity of important agricultural species. These tools are also being used to investigate issues of wider environmental interest. For example, they are being applied to biomonitoring of ecosystem health and to biosecurity and biocontrol programs that track the spread of invasive pests. Finally, molecular systematics is being used for bioprospecting where it helps identify plants and microbes that contain chemicals of value to the pharmaceutical industry. To date, this type of science has not been widely applied in the Pacific region. However, informing people in the Pacific of its relevance and developing the skills necessary to utilize these tools would benefit the region. Developing regional capacity in molecular systematics has the potential to help improve the effectiveness of natural resource management, conservation, health, and food and crop sustainability in the Pacific. It can inform local and regional policy development, and enable Pacific Island nations to participate more fully in regional and international dialogue on issues associated with biological diversity, biopiracy and bioethics.

Over the last five years scientists at the University of the South Pacific (USP) and the Allan Wilson Centre in New Zealand have been pursuing an initiative to develop capacity and expertise in molecular systematics at USP. In 2007 this collaboration resulted in the establishment of a specialized laboratory and a postgraduate research program in molecular systematics in the university's Faculty of Science, Technology and Environment. This initiative has been supported by several agencies, including NZAid, USP, Birdlife International, the UK's Darwin Initiative, and the Oceania Development Network. Now at a fledgling stage, the lab supports postgraduate students conducting a range of research projects. Students in the laboratory are enrolled in either masters or doctorate study programs at USP and are co-supervised by USP and New Zealand scientists. These projects provide an illustration of just some of the many questions that can be addressed using molecular systematics.

BIOLOGICAL DIVERSITY

Globally we remain a long way from a sound understanding of biological diversity. This presents a significant problem – without knowing what biological diversity is around us, it is difficult to effectively conserve or manage it. This is particularly true for the Pacific region, where there remains a need to better understand and document the diversity both of native biotas and domesticated species. Improving our understanding of biological diversity will have local and regional benefits, especially with human induced and environmental changes threatening so much of the region.

We can learn much about the world around us by direct observation. However, molecular systematic studies can give us insights that are hidden from the naked eye. For example, in one ongoing project in the USP lab, a suspected cryptic species of Fijian groundfrog has been identified – that is, a genetically distinct species unrecognizable by morphology alone. This study is helping to identify genetically distinct populations that could be the focus of future conservation efforts. Beyond identifying what species are present, molecular systematics can help us understand where they came from and how individual species arose. For island biotas it is interesting to ask whether native species originated as independent immigrants or they evolved in situ. Members of the USP lab are studying the origins of the Fijian biota using several groups of organisms – including honeyeaters and the fern flora – using molecular evidence. To date these studies tend to favour the view that there have been multiple colonizations of Fiji.

BIOSECURITY AND MONITORING OF INVASIVE SPECIES

The introduction of non-native species can have devastating impacts on the local environment. They may threaten the survival of native species or alternatively attack crops and livestock. Ultimately this impacts upon the local economy through lost tourism or productivity. The increasing ease of international travel and transport has greatly increased the potential for noxious pests to move between countries with many now having strict controls in place to limit the entry of new, potentially dangerous organisms. Nowhere are the problems associated with invasive species more acute than on islands. Responding appropriately to potential threats requires vigilance and the ability to rapidly identify problem species. Molecular systematics provides rapid and sensitive tools for identifying and pinpointing the source of invasive organisms, even when local authorities cannot identify them from morphology alone.

Bird photograph by Phil Bender

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One study in the USP is looking at the diversity of root-knot nematodes (RKN). These small worms infect plant roots causing crop loses worth an estimated US$157 billion worldwide annually. Given that many Pacific countries rely heavily on local agriculture, understanding RKN distribution and diversity has important implications for maintaining regional food security. The USP study suggests that three cosmopolitan species, as well as at least one novel form, are present in Fiji. Although the genetic picture is still emerging it seems that there are complex distribution patterns with mixed populations in at least some locations. A second project is investigating the small but aggressive invasive ant, *Tapinoma melanocephalum*. It had been widely assumed that all Fijian colonies were descended from a single introduction. However, the observation that members of different colonies act aggressively towards one another suggests that there may have been multiple introductions. Genetic studies are being used to test these alternative hypotheses for the origins of the Fijian populations.

BIOPROSPECTING FOR NATURAL PRODUCTS

Many of the pharmaceuticals we use today were originally derived from natural sources and identifying new bioactive compounds is an important direction for research. We still need to identify treatments for the many diseases that modern medicine still cannot cure as well as "next-generation" treatments to combat diseases which are now resistant to commonly used treatments. One way of finding new pharmaceuticals is to search for organisms that are closely related to those we already know produce bioactive compounds. The idea being that related species would also contain compounds with similar, or perhaps modified activities.

One project in the USP lab is focused on natural products. It involves a molecular analysis of relationships among *Cribrochalina* sponges from across the Pacific. These sponges contain compounds such as cribrostatins that have been shown to inhibit cancer cell growth, as well as having antibacterial and antifungal activity. It is hoped that by better understanding the relationships between the species it may be easier to identify other active compounds. However, studying these sponges is more difficult than it sounds, they have relatively few morphological differences and they often play host to other organisms. We are developing specific DNA protocols so that we can be sure that the DNA studied belongs to the sponge and not organisms associated with it.

THE FUTURE

As outlined the USP molecular systematics laboratory currently supports a range of projects. But we have others in the works and we hope these will further expand expertise in the region.

One area of growing importance is the diversity of local crop species such as coconut and taro. Climate change will bring changes in patterns of land availability and use. What varieties are threatened by these changes? Which will be best suited to the new conditions? Collaborative studies with the Secretariat of the Pacific Community have recently begun and these aim to identify genetically distinct varieties that may be of potential importance in conservation and breeding programs. Another new direction involves documenting and monitoring microbial communities as these can impact on human health, agriculture, and environmental management. New DNA technologies allow the genetic signature of entire communities to be determined. One new project involves developing protocols for the routine biomonitoring of aquatic microbial communities with these technologies. If successful, such tools would be widely applicable both in the Pacific region and globally.

However, the future of the laboratory is not really about developing and implementing technology, it is about people. The benefit of the USP laboratory is that it provides the tools to study questions important to the Pacific within the Pacific. The goal is to develop expertise and grow capacity here in the Pacific, ultimately making it possible for locally trained researchers to answer the questions that are important to Pacific peoples.

If you would like more information about the USP molecular systematics laboratory please email Richard Winkworth (winkworth_r@usp.ac.fj).

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