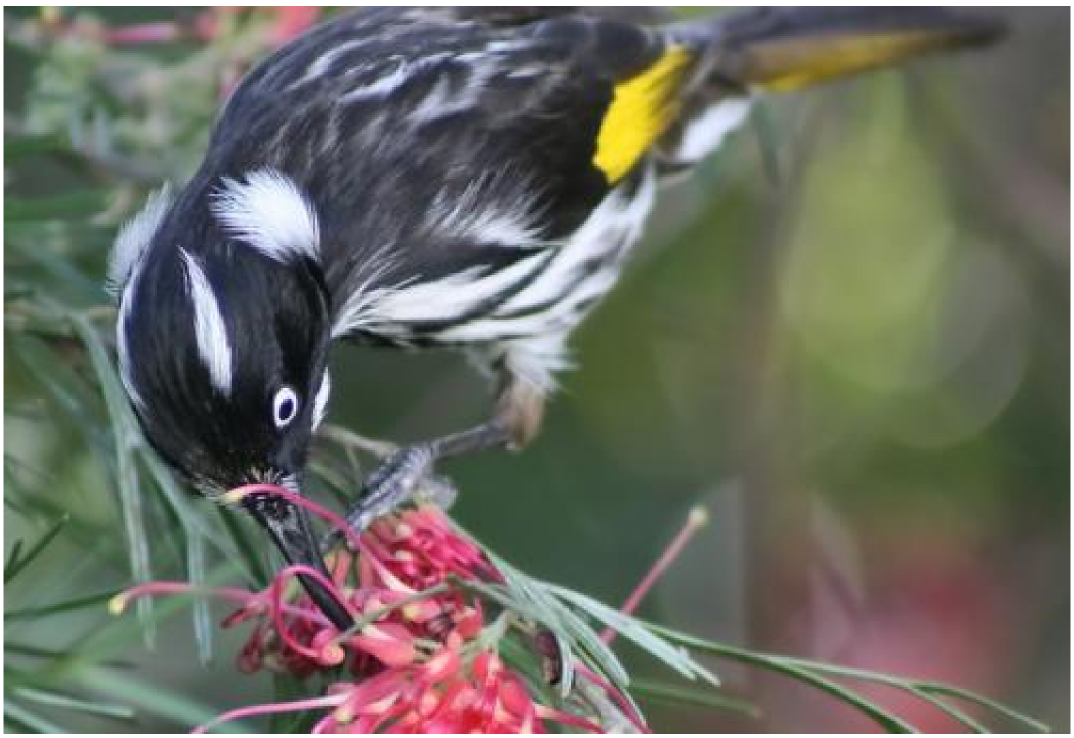
How birds' visual perception influences flower evolution

February 26 2014, by Martin Burd



Australian flowers and their pollinators have evolved a specific way of communicating – all based upon colour. Credit: aussiegall/Flickr

In Australia, honeyeaters are far and away the most abundant and important nectar-feeding birds, so also the most important avian pollinators of flowers.

What effect has their visual perception had on the evolution of colour among the flowers they visit?

Today, a team of biologists from Monash (including me) and RMIT universities in Melbourne and Bucknell University in the US published the most quantitative and rigorous investigation of this question to date.

We used mathematical models of bird vision to represent the colours of Australian flowers as birds are likely to see them.

Reading colours

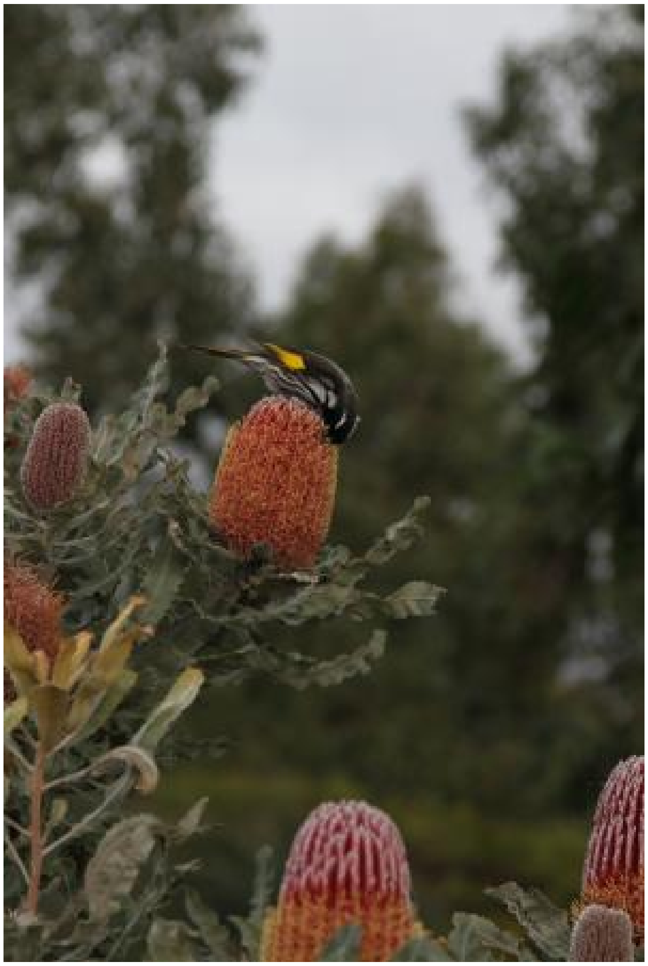
Birds and flowers provide much of the colour that we see in the natural world, but we are accidental eavesdroppers on the visual conversations in which they are engaged:

- colourful birds signal not to us but to potential mates
- colourful flowers also try to find mates, but they do so by communicating first to animal pollinators, including many birds.

Biologists have long wished to know how visual communication between flowers and their pollinators works, but it's not an easy task as animals perceive colours quite differently from us.

We humans have three types of colour receptors in our retinas, sensitive to blue, green, and red light.

Birds have four types of receptors, and see more complexity in colours than we do. Some birds, including the honeyeaters, have violet-sensitive receptors along with blue, green and red receptors. Other birds use receptors sensitive to ultraviolet rather violet light.



A New Holland honeyeater (Phylidonyris novaehollandiae) visiting flowers of Banksia menziesii (Proteaceae). Mani Shrestha

In our study, we examined the reflectance profiles (patterns of how an object reflects light of different wavelengths) of the flowers of 234 native Australian species.

We measured these profiles across the ultraviolet and visual wavelengths of light, and these profiles were then translated into single points in a "colour space" based on the sensitivities of birds' four classes of colour receptors. (A colour space is a way of positioning reflectance profiles within a four-dimensional grid so that colours lying near each other would appear similar to a bird.)

Of the 234 plant species we looked at, 154 were pollinated by insects and 80 by birds. The insect-pollinated flowers had a colour range that we see as violet and blue to yellow. Although birds don't pollinate these flowers, birds would also see them as having a broad range of colours.

The flowers that *were* bird-pollinated formed a more interesting pattern. About half the species overlapped with the colour space arc of insect-pollinated flowers. As bird pollination usually evolves from insect-pollinated ancestors, this similarity in colours is not surprising.

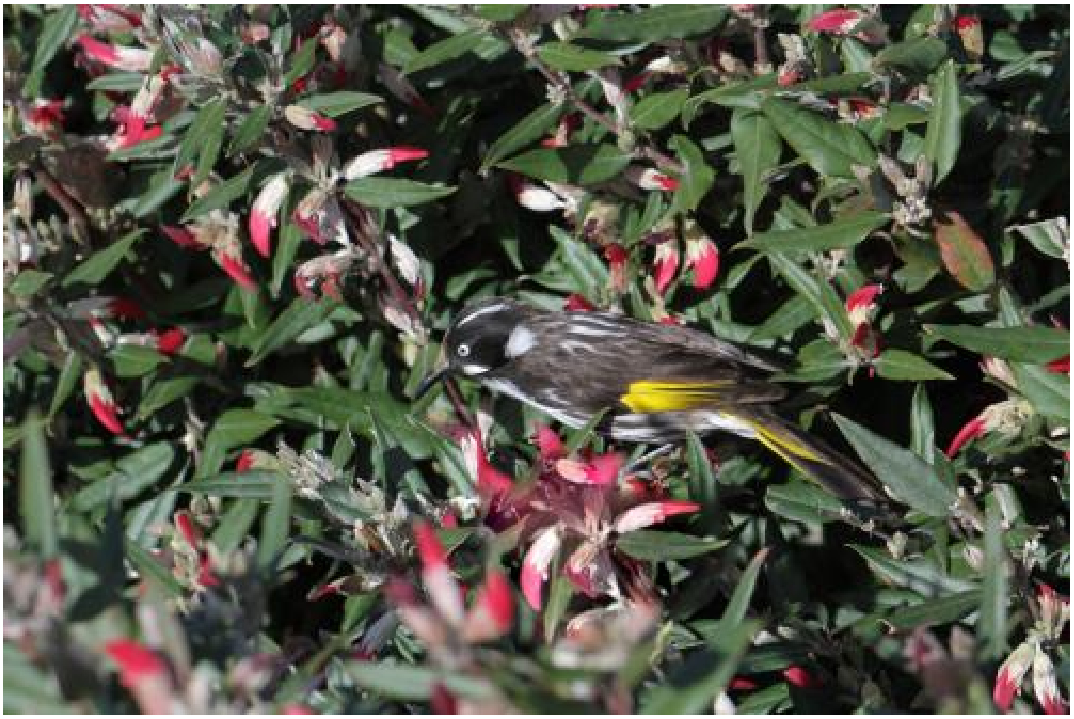
The other half of bird-pollinated species, however, were crowded in a narrow and separate stretch that occupied just 1% of the total volume of the colour space. These flowers appear red to humans, and we named this cluster the "red arm". Their reflectance profiles would also strongly stimulate the red receptors in bird eyes.

It appeared that many flowering species had evolved to "talk" to birds using a very particular set of colour "words". In particular, the distinctiveness of the "red arm" appeared only when the colour space was based on the visual system of honeyeaters.

Models of the other visual system in birds with ultraviolet receptors, common in parrots and songbirds, did not reveal a distinctive red arm of floral colours.

'Language' evolution

Evolution could produce this shared use of a special colour language in two ways. Plants that evolved a red-arm colour might speciate more frequently, perhaps because of their special appeal to honeyeaters, thus creating a "radiation" of lineages that use the distinctive colours, somewhat like a family that occasionally uses their own special words rather than standard English.



A New Holland honeyeater (Phylidonyris novaehollandiae) visiting flowers of Eremophila maculata (Scrophulariaceae). Credit: Mani Shrestha

Alternatively, many unrelated lineages may get in on the act by independently evolving the red-arm colours. Because evolutionary relationships among plant species are now fairly well understood thanks to DNA sequence evidence, we were able to test these alternatives.

Using new statistical techniques developed at Bucknell University, we showed that the distinctive red-arm colours had probably evolved on 31 separate occasions.

We could also show that had floral colours evolved as a random walk through the colour space, the red arm colours would have evolved, on average, only five or six times.

This is strong quantitative evidence of convergent evolution, the repeated appearance of the same or similar traits among unrelated lineages.

The same patterns may have evolved on an intercontinental scale. Hummingbirds, which have been exclusively in the Americas for millions of years, have a visual system with violet-sensitive receptors similar to that of honeyeaters in Australia.

In contrast, sunbirds, which are major pollinators in Africa and southern Asia, have the visual system with ultra-violet receptors.

The evolutionary convergence that shaped the red arm among Australian floral colours should, then, also appear among American plants visited by hummingbirds, but not among Asian and African species.

So is this the case? It's a question we hope to answer next.

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