The false allure of robotic facsimiles of pollinating animals

A critique of 'materially engineered artificial pollinators' and the championing of preserving real pollinating organisms

Kit Prendergast, Forrest Scholar and PhD researcher on Australia's native bee assemblages

A recent paper titled "Materially Engineered Artificial Pollinators" has had the media in a frenzy of excitement. Across my Facebook Newsfeed and on popular 'science' websites have been posts and articles clamouring about the exciting development of 'robo-bees': tiny robotic drones coated with specially-engineered sticky hairs, which apparently can perform pollination. As touted by *WiredScience* "Robo-bees covered in sticky horsehair could one day help pollinate crops," with the byline "Tiny drones powered by artificial intelligence could help us keep up with global crop demands, Japanese chemists suggest"... I very much doubt so. As an ecologist, conservation scientist, and bee researcher, I don't share the hype. Instead, I have cause to be very critical of the claims that these robotic bees can save humankind from the impending "pollination crisis." Moreover, the notion promulgated by such websites gives me grave cause for concern for they imply that if robotic bees can do the job, then why spend the time and effort on trying to disentangle the various factors threatening real living pollinators. Why put money and effort into the long, arduous, mundane, and, by various stakeholders, undesirable practices into restoring habitat, limiting pesticide use, and preventing further land-clearing? For some, a 'techno-fix' is a lot more 'cool' than ecological restoration.

The artificial pollinators were created by attaching a patch of ionic liquid gel-coated animal hairs, which the researchers demonstrated to be capable of adsorbing and depositing pollen, to the back of an unmanned aerial vehicle (AUV), and as a demonstration of their pollinating prowess, were directed to visit lilies. The accompanying article titled "Sticky Solution Provides Grip for the First Robotic Pollinator" starts with the statement: "Bees, move over. A lily has been pollinated by a remote-controlled flying robot"... I think not!

Above: A *Megachile* bee foraging on *Salvia.* Note the pollen located on the underside of her abdomen, where her scopae are located. This makes megachilid bees very effective pollinators in that they readily collect and deposit pollen when flying from flower to flower. Photo: Kit Prendergast

A drone created to function as an artificial pollinator.

It is clear that the artificial pollinator's creators are not ecologists, let alone pollinator ecologists. Pollination is not so simple. Many plants exhibit a huge diversity of structures that have evolved such that only specific pollinators that have the right match in morphology or behaviour can pollinate them.

In the co-evolution between plants and pollinators, plants have evolved traits (scent, colour, shape, rewards, floral guides) and pollinators have evolved behaviours, which increase the chance that a bee visitor will pick up pollen, which will adhere to its body as it travels to another flower of the same species, and deposit it on the stigma (the receptive part of a female flower). Whereas bees perform this task through innate behaviours and learning, even programmed drones are unlikely to be able to 'forage' in such a way that the right amount and quality of pollen is collected and subsequently deposited on the stigma. Moreover, flowers do not release viable pollen indefinitely, nor are stigmas receptive indefinitely: whilst bees use sensory cues to determine this, how on earth can a robo-bee 'know' when the anthers (male reproductive structures) of a given flower are releasing pollen, and tell when the stigma is receptive so that fertilisation can occur?

Some flora have long corollas that can only be legitimately accessed by pollinators with matching glossa (tongue) lengths. The 'textbook' example is the orchid *Angraecum sesquipedale* which has a very long nectary (up to 30cm long); Charles Darwin who developed the theory of evolution by natural selection predicted that this orchid would have co-evolved with a moth with a tongue long enough to pollinate it; 20 years after Darwin's death this moth was finally discovered and named *Xanthopan morganii*

A pollen-covered *Megachile* bee foraging on the inflorescence of a bottlebrush, *Callistemon viminalis.* Photo: Kit Prendergast *pradedicta* and finally, in 1992, 130 years after Darwin's prediction, the moth was confirmed to visit and transfer pollen between the orchids.

Various flowers have a complex 'tripping' mechanism (including the economically important crop lucerne); only bees that handle the flowers in a particular way can properly gain access to the pollen and effectively perform pollination services. Some complicated programming would be needed to get the robo-bees to perform this behaviour that comes innately to some bees.

Then there are the many flora that requires sonification or 'buzz pollination'; this includes both native flora (e.g. *Hibbertia*) as well as horticulturally important species like tomatoes, peppers, pumpkin, cucumber, and squash. Such flowers requiring sonification have what are known as poricidal anthers that will only release pollen when vibrated at a specific frequency. This form of pollination evolved independently in multiple plant lineages and is achieved by a range of bees (over fifty genera distributed across all seven bee families, but is not performed by the dominant domesticated bee pollinator, the honeybee *Apis mellifera*). Poricidal anthers requiring sonification for pollen release are believed to have evolved to control the rate of pollen release and thereby limit pollen loss and promote pollen dispersion, as well as exclude illegitimate pollen thieves.

And then there are various 'sexually deceptive' orchids that, by mimicking the scent, shape, and colour of a female bee or wasp, dupe the males of the corresponding species into attempting to mate with the flower and in the act, end up ensuring the 'mating' of the flower!

Plants also exhibit different mating strategies: some require pollen from other plant individuals that are genetically different; the extreme is self-incompatible plants, where pollen from the same genetic individual will fail to germinate on the stigma, yet other forms of inbreeding depression occur when pollen from plants that are too genetically similar to the female flower fertilise the ova, and can result in fruit abortion, poor fruit development, poor seeding germination, and poor seedling performance. Plants that benefit from 'outcrossed' pollen require pollinators forage between plants in different populations, achieved by large-bodied long-distance foragers like birds. On the other hand, pollen that is too genetically dissimilar can be detrimental and can disrupt local adaptation. Can drones be programmed to 'forage' in ways to maximise these? For most flora, we don't even know their 'ideal' outcrossing scenario, but fortunately, a range of species visiting them and exhibiting variation in foraging behaviour ensures at least some pollen is deposited that maximises fruit and seed set.

Lasioglossum (Parasphecodes) hilactum (family Halictidae) foraging for pollen on the native plant *Hardenbergia violacea*. This plant, as in other species in the family Fabaceae (pea plants), has papilionaceous flowers which require bees to apply pressure in order for pollen to be released. Note the large pollen loads on the bee's hindlegs, especially the femur where the primary scopae (pollen-collecting hairs) are located for this genus. Photo: Kit Prendergast

Likewise, although not all floral visitors are effective (and some are even 'thieves' that steal pollen or obtain nectar without performing pollination), a diverse community of floral visitors usually ensures effective pollination. We are only beginning to unravel the complexities of pollination, and certainly, do not know enough to design robo-bees that can provide full pollination services to the myriad flora.

Bees and other pollinating animals do not exist 'for' humans. While their pollination services, of course, are

A European honeybee (*Apis mellifera*) foraging on a marigold. Note the pollen packaged in corbicula, also known as 'pollen baskets': a cavity surrounded by a fringe of hairs on the tibia of the hindlegs in honeybees as well as some other bee species in the family Apidae. Photo: Kit Prendergast

critical to ensuring pollination (75 percent of crop species benefit from animal-mediated pollination, and up to 94 percent of all flowering plants rely to some extent on animal-mediated pollination), bees themselves have intrinsic value; their loss represents a loss of natural heritage. Bees and other pollinating animals are part of the intrinsic co-evolutionary web of ecological relationships and provide us with insights into the fascinating aspects of evolution, and of mutualistic – and even antagonistic – relationships that play out in the grand epic of life. A little army of metal drones buzzing around the skies is a poor substitute for the diverse, beautiful, intricate, glossy to fuzzy, cute to bizarre bees that, through their daily quests to provide resources for their offspring, enable the fertilisation of plants to the benefit of entire ecological communities, of which we are just one member.

A closer look at the video supplied by the authors and shared widely by the PR press and news outlets already point to flaws in the robo-bees. In fact, in the process of what essentially amounts to the drone dive-bombing the lily, the drone bee actually can be seen to bruise the flower! Damage to floral structures like petals can impair the attraction of flowers to 'real pollinators', and if the stigma is damaged, can leave it prone to infection by pathogenic bacteria and fungi, or even prevent pollen germination. These clumsy prototypes seem to be no substitute for real bees.

The flowers used – the lily (*Lilium japonicum*) – to demonstrate the robo-bees pollination ability also makes me question the ability of these robo-bees to provide pollination to the majority of flora: lilies are far larger than the majority of flowers and have receptive surfaces and pollen that are far more exposed than most. Even for such an 'easy' pollination target, the video of the robo-bee makes me cringe at the clumsy attempt to mimic pollination.

Three foragers of the eusocial honey-producing native 'stingless bee' species *Tetragonula carbonaria* (family Apidae) foraging on thistle at a bamboo property in the Northern Rivers Region, New South Wales, owned by Mark Donald. Photo: Kit Prendergast

Any claim that robo-bees can replace or compensate for bee and other pollinator declines expresses a woeful ignorance of pollination biology, as well as a disregard for the value of bees irrespective of their pollination services.

Not only is the idea dangerous regarding the fate of bees, but it is also ridiculous and underscores the lack of understanding of engineers when it comes to the real, messy world of nature outside of the technological institutions they work in. Should dollars be spent on gizmos and gadgets to replace pollinators, or spent on restoring habitat to protect the pollination services that living bees and other floral visitors provide for free, with the added beauty of these 'service providers' being living organisms of which we are connected to both ecologically, and evolutionarily?

Sure, the robo-bees do have some pros; for, as living organisms, bees are vulnerable to disturbances, they do suffer from habitat destruction, and are threatened by the inappropriate use of herbicides and pesticides. A major worry I and anyone who cares for the environment should have is the risk that, allured by the promises of this new technology, it leaves farmers to feel secure to apply pesticides and herbicides without restraint: a robotic bee can't die from pesticide exposure, but the remaining bees and myriad invertebrate biota can!

In theory, an army of drones, each designed to maximise pollination for a specific plant might be possible... but in practice? The time and money spent on manufacturing the hardware involved in the creation each robo-bee, programming it, and making it function would end up being prohibitive, and these technological feats are more a show demonstrating engineering feats, rather than being realistically deployable in the real world. An estimate by bee researcher David Goulson calculated that to build the 3.2 trillion units required to even partially replace those of a single species – the honeybee *Apis mellifera* – during a foraging season, complete with power and control devices, under the (absurdly optimistic) cost of one penny each, this would cost 32 billion pounds per year. At present, each drone costs about US$100!

This futuristic scenario of tiny flying robots pollinating our food supply is no match, in efficiency or cost, for real

A little *Leioproctus* bee (family Colletidae) foraging on the small flowers of the native plant *Conostylis candicans.* Note the pollen on the femur of the hindleg where the primary scopa are located for this species. Photo: Kit Prendergast

bees. Unlike this new invention, bees have been on this planet, and, through their activities to obtain pollen and/or nectar, coincidentally pollinating flora, and promoting biodiversity for about 120 million years: a very long time for natural selection to tune them to be very good at it. And this is largely performed for free.

And once set out in the field, the fate of these cyborg insects is unknown: some would become lost, it is inevitable some would malfunction, others become damaged by wind, rain, heat and other environmental vicissitudes, and I'm sure many a bird, robber fly, spider or praying mantis would try and make a quick meal of these flying creatures that lack the sensory perceptions and instinct of real bees to avoid predation. Not only does this represent a loss of investment in these robo-bees, but this also underscores that living bees cannot be replaced by robotic facsimiles. Not only are real bees capable of escaping predation, but those that do not play an important part in providing food for other organisms – bits of metal hardly can be benign on the stomach of those animals that mistakenly ingest the robotic bees, and robo-bees certainly provide no nutritional value!

A *Lipotriches flavoviridis* bee (family Halictidae) on *Corymbia ficifolia.* Photo: Kit Prendergast

If we assume (generously) a lifespan of one year, what would happen to all the defunct robo-bees? Would we be littering the land with more trash in the form of deceased robotic pollinator machines? And what about the environmental costs of manufacturing these bees? What rare metals would need to be mined, how much carbon pollution would be involved in their manufacture?

Real bees have no environmental cost and provided their foraging and nesting resources are met; they readily replenish themselves and power themselves.

So, rather than being a savour designed by tech-savvy 'scientists' as hailed by the media, robotic bees may indirectly result in adverse consequences for the fate of nature's originals. Acknowledged by one of the designers as "just a proof-of-concept," they likely will stay as such, but of course, the press needs to sell a story, and hyperbolic claims are nothing new.

This technological machismo should be interpreted as a cute bit of engineering, perhaps a point of intellectual interest, but certainly not an alternative to the 'wicked' problems of biodiversity decline. We need to use science, not technology, to protect and conserve living, breathing bees and the pollination services they perform for free to the benefit of humans and non-humans alike.

Spins on projects like these might seem innocuous, but they can have dangerous consequences by endorsing an attitude that we can tolerate dwindling bee populations since we have technological back-ups. More repulsive, and most damaging, is that they promote the idea that we should only care to protect biota if they have utilitarian uses, and that their existence is justified by what goods and services they can perform to humanity. And if such services can be replaced or better serviced by technology, then there is no reason to conserve biota just for the pure reason that they have evolved and exist on this planet.

Rather than look to a quick techno-fix, we should solve the problems humans have created that threaten food supplies and food security. The solution is there in nature: we just need to protect the wonderful diversity of bee assemblages. Their decline is symptomatic of larger environmental issues (inappropriate pesticide use, habitat destruction largely for livestock agriculture, and increasingly, climate change, also largely driven by livestock agriculture as well as excessive fossil fuel use). Unlike deploying robotic bees, directly addressing bee declines and restoring pollinator populations will go towards addressing and reversing the problems facing the natural world on which we depend on and are a part of at large.

Website - http://www.wired.co.uk/article/robotic-bee-pollinates-flowers

Video produced by Kit Prendergast of a Blue-banded bee (*Amegilla*) pollinating the Australian native flora *Hibbertia scandens*:

https://www.facebook.com/Kit.Prendergast/videos/g.1041684025880609/10154928886084273/?type=2&theater

A resin bee *Megachile aurifrons* foraging on bottlebrush *Callistemon viminalis*. Bees in the family Megachilidae are very effective pollinators owing to having scopae (pollen-carrying hairs) on the underside of their abdomens.