PHANTOM LIMB PAIN

Could augmented reality, 3D printing and the genius of termites work together to keep Australia's rarest hunters in the city?

WORDS BY IVY SHIH
PHOTOGRAPHY BY MATT WRIGHT

Dr Beth Mott saw her first powerful owl (*Ninox strenua*) five years ago. She had been listening to the loud chorus made by a trio of boobook owls that gathered on her street like clockwork to engage in a ritual of territorial debate.

"One evening, all of a sudden, they went deadly silent," says Beth.

Then two deep hoots punctuated the air.

Beth looked up and saw a powerful owl perched above her, with bold chevrons on its breast and massive yellow feet.

"Powerful owls have this magnificent presence and this real sense of calm that you don't see in most backyard birds," says Beth, who is a community ecologist and project officer of Birdlife Australia's Powerful Owl Project, which empowers citizens scientists to track urban powerful owls. This data is then used to monitor the health of populations and formulate effective conservation measures.

"When you find an animal that has some weaponry, often you will find that real gentleness. They tend not to be so worried about the fact that they are going to be eaten – they have the confidence of a top predator."

The powerful owl, Australia's largest owl, is a keystone predator that roosts at the top of the food chain. A wingspan of 140 centimetres blots out the field of view of a possum or small bird before the owl's 1.45-kilogram bulk slams down, talons grasping – and the prey's carcass is lifted effortlessly onto a branch. They eat up to 350 possums a year, keeping the ecosystem in check.

But it's becoming increasingly harder for powerful owls to find space for themselves. Large bushland areas that serve as crucial hunting habitats are now mostly fragmented by urban spaces, roads and suburbs. In the urban landscape, powerful owls settle at the borders of green habitat that adjoin suburbs. In these areas, the large old trees the owls rely on for hollows are disappearing, selectively removed as they are considered dangerous to humans and property.

There may be only around 5000 powerful owls in Australia, half of which are in the state of New South Wales, a state that cleared 663,000 hectares between 2010 and 2018. Developing artificial hollows is crucial to support the population of urban powerful owls.

LIKE A LOST LIMB, TECHNOLOGY CAN MIMIC THE NATURAL THING IT'S REPLACING TO THE BEST OF ITS ABILITY, BUT PHANTOM LIMB PAIN FELT BY WILDLIFE FROM LOSING THE ORIGINAL NATURAL HABITATS IS AN IMPACT THAT WILL ACHE THROUGH GENERATIONS.

While we're losing natural tree hollows rapidly, we're not replacing them in urban spaces. Natural tree hollows take centuries to form, sculpted in large old trees as the wood decays and natural elements gradually carve out the tree's centre to create an opening. A hollow suitable for powerful owls takes at least 150 to 200 years to develop. Even one suitable for smaller animals, such as sugar gliders, takes about 80 years to form.

Prosthetic habitats are increasingly being explored as an option to replace damaged environments with artificial replacements.

"This idea of developing artificial habitat becomes much more important if we want to be able to preserve this species," says Beth.

However, prosthetic habitats are not an aesthetic solution – it's not about simply replicating the appearance of the lost habitat. Ideally, it also needs to fulfil a similar ecological function as the original – a far more complicated challenge.

University of Melbourne architecture student and PhD candidate Dan Parker has a different type of client than most of his colleagues. In some parts of Melbourne you can spot his immense pixelated sculptures up a Sydney blue gum or swamp gum, slotted neatly between the crook of two branches.

They are prototypes of artificial nests, sculpted using augmented reality and designed to attract breeding pairs. Dan decided to design a prosthetic habitat for powerful owls as part of his Masters of Architecture degree. The idea came when he heard Judith Alcorn, former Biodiversity Coordinator at the UoM, wistfully remark on how amazing it would be to see powerful owls on campus.

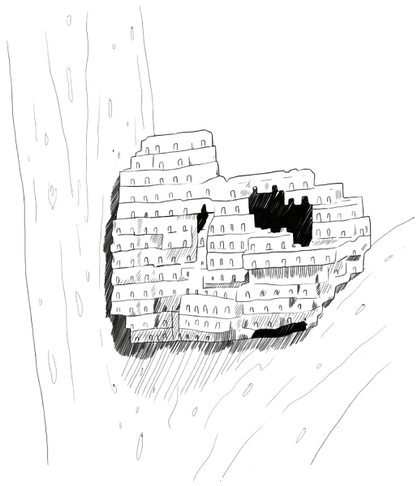
It is not enough to simply create space that will fit powerful owls the prosthetic hollow needs to be designed so that the owls will stay. There has only been one official record of a pair of power owls nesting in a location outside of natural tree hollows – an artificial nest box constructed from plywood.

The artificial nest needs to mimic a similar thermal microclimate to tree hollows, which standard nest boxes fail to achieve. BirdLife Australia have found that standard timber nest boxes had an internal temperature significantly hotter than a natural hollow, which could lead to heat stress for brooding owl mums and eggs failing to hatch.

Beth says the biggest difficulty in replicating a natural tree hollow is also replacing the existing dynamic microcosm of organisms in the 'mud guts' of a tree hollow. The 'mud guts' is the earth-like material in the tree centre, often created by termite activity absent in an artificial nest box. The microcosm of fungi and bacteria in the 'mud guts' are so efficient in recycling the remnants of prey in active owl hollows that by the time the owl chick has left the nest, the hollow is remarkably clean, save for a stray eggshell or bone.

Dan consulted several conservationists and ecologists, including Beth, to understand powerful owl behaviour. Then he came across a photo taken by Sydney photographer Ofer Levy of powerful owls nesting in a termite mound up a tree. After hearing similar stories of the owls nesting in termite mounds from Beth, Dan had a starting point: reconstructing the organic shape of the termite mound, inside and out.

"We wanted to take inspiration from the natural formations and processes from the termite nest and natural hollows – the material and geometries that would really support



Sketch of an 3D-printed nest

these favourable internal microclimates," says Dan. "In natural tree hollows, microorganisms like to eat into the heartwood at the areas where branches have fallen off. This creates a rounded edge for owl talons to latch onto when they are landing, and space to feed the young. They also have a roughened surface, which allows the young to scratch, climb and safely exit the nest."

Dan chose to install the artificial nests in areas favoured by owls, which have a high prey density of birds and tree-dwelling mammals such as possums, sugar gliders and flying-foxes. Owls also prefer a south-east aspect and a hollow height of about 15 metres.

Dan began by 3D scanning a tree and its surroundings with lasers. He assembled the nest design using augmented reality headsets, stacking together holographic digital models of 'parts' that resembled the craggy parts of a termite mound.

One of the benefits of the design is that the different modules could be stacked together in AR, like building blocks, to precisely fit a chosen tree. Dan says using AR offers flexibility and a more sustainable method to experiment with different configurations that would otherwise waste materials.

Dan made prototypes from 3D printed wood and hemp concrete. It was hemp concrete

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that hit the ‘goldilocks zone’ for optimal owl usage. Hemp concrete is not only lighter than a dense block of wood, but durable and allows for ventilation and drainage. Most importantly, over time, the nest can degrade naturally into organic waste.

When Dan and the team did a final quality check on the artificial nests, fitting them with temperature and humidity data loggers, they found hemp-concrete nests had relatively stable temperatures that most closely resembled the natural tree hollows.

Months later, Dan peered up as his prosthetic nest prototype was hoisted into the air and placed with ease by the arborist in the tree canopy. It was a perfect fit. The 15-kilogram prototype had been easy to install, taking only 20 minutes, compared to carved hollows which weighed 270 kilogram apiece and needed a huge truck to lift them up.

The final hurdle had been cleared – they’d proved that the artificial nest wasn’t just user friendly for powerful owls, it could easily be installed by humans and adapted into the urban landscape.

“Honestly, it was a relief to see everything come into fruition. To see that our 3D scan was accurate, our digital model was accurate, and that the product was so easily hoisted into the tree,” says Dan. “It really made us realise what we are doing is worthwhile.”

Prosthetic habitats are the result of engineers and ecologists collaborating to restore habitats for displaced wildlife. Projects have been installed on both land and sea, including latticed sea wall tiles that mimic the nooks and crevices of a rock formation, and intricate 3D-printed, coral-inspired structures and reefs that dot the ocean floor to attract sea life.

But questions arise. Does creating one prosthetic habitat accidentally exclude other wildlife species? How can prosthetic habitats be designed to integrate seamlessly into the environment with no side effects?

Like a prosthetic leg, technology can mimic the natural thing it’s replacing to the best of its ability, but phantom limb pain from losing the original natural habitats will be felt by the impacted wildlife, an ache that will echo for generations. Prosthetic habitats are not a conservation strategy that should exist in isolation, but instead should be integrated into the urban planning process.

Powerful owls are an apex predator and a key indicator species that play an important role in maintaining ecosystem health. Conserving powerful owls and helping them flourish in an area means you are automatically also protecting an entire suite of elements that are crucial for a wide variety of fauna.

The Powerful Owl Project is now monitoring over 90 breeding pairs in Sydney and 62 in Brisbane. In Melbourne, Dan’s prosthetic prototypes are still there, two nests installed among the branches of large eucalyptus trees east of Melbourne. Dan says possums and lorikeets have visited the nest – but no powerful owls just yet.

According to Beth, the day powerful owls successfully breed in those hollows will be an emotional one. The sound of chirping powerful owl chicks is bittersweet – a recent report showed that 15 percent of powerful owl chicks didn’t survive a week past fledging.

“You know what, when I hear a chick trilling, and I know that an owl family has been successful in actually fledging that chick, I still cry.”