The dilemma of bringing the Passenger Pigeon, *Ectopistes Migratorius*, back from extinction

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Once the most abundant bird species in North-America (Kasperbauer, 2017; Murray et al., 2017; Roberts et al., 2017), and probably in the whole world, passenger pigeon, *Ectopistes Migratorius*, was driven to extinction in approximately half a century. With an estimated population of 3 to 5 billion individuals before European settlement (Blockstein, 2002), passenger pigeon was subject to intensive and indiscriminate hunting, habitat loss and nest disturbance (Halliday, 1980) especially during the latter part of the 19th century, and Martha, the last recorded individual in captivity died in the Cincinnati Zoo in 1914.

Despite conservationists' efforts in the late 1800s and early 1900s, economical and political barriers proved to be obstacles too difficult to overcome and ended up sealing the fate of the passenger pigeon and its descend into extinction (Jackson & Jackson, 2007). Due to its previously enormous population and the extraordinary fast declining process, from billions to none in barely 40 years, passenger pigeon stands as one of the most stunning anthropocenic extinctions ever witnessed.

In the last hundred years much has been written and discussed in the scientific community about the passenger pigeon and its fate as a species, its effects on ecosystems as a keystone species, population trends and genetic diversity among others. But in recent decades and in light of new advances in the biotechnology and genome engineering fields, a new question has been brought up in regards to the passenger pigeon: would it be possible to bring the species back from extinction, and if so, should it be attempted?

Scientists like Novak (2013) are convinced the passenger pigeon deserves to be resurrected and consequently are working towards to make it happen. As a part of Revive and Restore (2012), Novak and his team are working with some of the most advanced gene editing and synthesis techniques. Their ultimate goal? To have a flock of passenger pigeons roam the forests of eastern North America by the year 2032 (Preston, 2017; Novak, 2013; Preston, 2017). The project is known as "The Great Passenger Pigeon Comeback" and it is one of the main exponents of an idea currently known as *de-extinction* or bringing a species long gone back to life.

But bringing a species back from extinction is definitely not only about genetics, genome engineering or biotechnology development. In 2016 the International Union for Conservation of Nature, through their Species Survival Commission network, published a set of considerations and guidelines to consider for projects such as the passenger pigeon de-extinction (IUCN SSC, 2016). Ecological considerations, socio-economic factors, associated risks and ethical limitations are some of the topics covered by this publication and should be carefully considered in the case of the passenger pigeon or any other de-extinction programme.

In the new geological era we are currently living in, commonly referred to as Anthropocene (Crutzen, 2006), human activities are responsible for the deep degradational changes happening within the Earth's core processes, and are known to have brought the ecological resources humanity depends on to the brink of collapse (Raudsepp-Hearne et al., 2010). All types of industrial activity such as mining, agriculture, fishing etc. have had a massive negative domino effect throughout all levels of our environment. As an outcome of these severe impacts, the rates of species becoming extinct are believed "to be several orders of magnitude above baseline rate" (Sandler, 2017) with some estimates stating that current rate is hundreds, potentially thousands, times higher than the natural background rate (De Vos et al., 2015). Studies also suggest that up to 50% of bird species, 32% coral species and 44% amphibian species are likely to be vulnerable to the effects of climate change (Foden et al., 2013), which leads to believe that, unless serious mitigation measures are put in place, extinction rates are only going to keep on increasing.

Considering the gravity of the situation, it seems rather difficult to envision the feasibility of de-extinction initiatives, such as the passenger pigeon, when there is already so much that needs to be done. Diverging scientific efforts and dividing the rather light conservation funds in order to pursue what is often labeled as a fantasy, is considered by many as an act of irresponsibility (Blockstein, 2017).

Usually labeled as a conservation effort, de-extinction faces as much opposition as support from the scientific community and the public in general (Minteer, 2014). How can de-extinction be a conservation practice if it is not even about conserving an existing species (Sandler, 2017; Meine 2017), is one of the first arguments put forward by those who are against. This seems to be a valid point when referring to a long gone species, such as the wooly mammoth (Nicholls, 2008; Church, 2013; Revive and Restore, 2012), when the link between extinction and human intervention is weak or non-existent, but can be challenged in the case of the passenger pigeon, as its fate was clearly driven by human activities. If human intervention was the main factor that led this species into extinction why should not human intervention be allowed into their restoration? (Haught, 2017) After all, willingly or not, human intervention is the centerpiece to what everything in the age of the Anthropocene orbitates around (Ackermann, 2014; Donlan et al., 2006).

In spite of not being a conservation act but rather a restoration act, the de-extinction of the passenger pigeon could help restore missing ecological links and processes and bring some megafauna balance back at a large scale (Novak, 2013). It is often argued by those in favour that bringing back the passenger pigeon would be a slightly more complex type of relocation. Relocations and translocations are one of the most common techniques in the field of conservation and management of both endangered and non-endangered species (Griffith et al., 1989; Seddon et al., 2014). In fact, one of the IUCN guidelines for reintroduction best practices is to treat de-extinctions as translocations (IUCN SSC, 2016; Seddon, 2014).

However, the release of resurrected species entails an impact on other species and ecosystems that might have evolved since the extinct species' disappearance (Sandler, 2017) and it is one of the most common points argued against the de-extinction of the passenger pigeon. Sandler (2017) and others have expressed their concerns about the current situation of suitable habitats, and their doubts seem to be reasonably sustained. The original habitat of the passenger pigeon is known to be large hardwood forests capable of providing the right amount of space for their massive flocks to breed as well as enough food to satisfy such a constant and high-volume demand (Smithsonian Institution, 2001). It is estimated that by early 1920s at least half of the south-eastern forests that used to support the passenger pigeon did not exist anymore, as they were lost to intensive agricultural development, logging and fossil-fuel exploitation (Biello, 2010). The situation slightly improved after the 1920s but worsened again during the 1970s (American Institute of Biological Sciences, 2010), with approximately 4 million hectares of forested area lost to human activities (Biello, 2010; Drummond & Loveland, 2010).

Despite of all the history of passenger pigeon habitat loss, there seems to be hope. Novak (2013) suggests that ongoing reforestation efforts are helping to slowly recover passenger pigeon habitat, while recent studies point to an increase of passenger pigeon suitable habitat in the next few decades as a direct consequence of climate change (Peers et al., 2016). But are the forested areas going to be able to support large flocks of passenger pigeon?

In the past, the pigeons were known not to live in isolation but within their ecosystems, relying on their massive numbers to defend themselves against predators and other threats (Blockstein, 2017; Blockstein & Evans, 2014). There is some evidence suggesting that passenger pigeons were able to successfully breed only in large colonies, and their reproductive rates started to considerably decrease when their populations began to shrink due to excessive hunting (Hung et al., 2014; Kasperbauer, 2017; Neumann, 1985; Halliday, 1980). Without their original flocks size and the large forests to support them, their survival as a species in the wild, and therefore their restoration, might not be viable (Blockstein, 2017).

Assuming Novak and his team would be able to successfully bring a whole flock of passenger pigeons into the wild, where would the species go (Kasperbauer, 2017)? Passenger pigeon flocks used to forage agricultural land when it was adjacent to the forests they used to roam (Peers et al., 2016; Blockstein, 2002). This made them look like pest species to the eyes of farmers (Kasperbauer, 2017) and it seems plausible to think that the same could happen again after their de-extinction, even if protective measures were to be put in place. As previously stated, if climate change effects are going to help expand the boundaries of the passenger pigeon traditional habitat, the species could potentially be able to reach new regions. These regions would then experience new impacts that could be negative to both human activities and ecological systems. Knowing unregulated hunting played a key role in their decimation, it seems reasonable to think that when facing another human-wildlife conflict, the passenger pigeon could suffer the same fate all over.

If the intention of the passenger pigeon de-extinction is to restore missing ecological links and processes through seeds dispersion and soil fertilisation (Novak, 2013), using an existing species to act as a substitute of the passenger pigeon seems like an easier and much affordable alternative (Bennett et al., 2017; Sandler, 2017). A good candidate would be the band-tailed pigeon, one of the closest species to the passenger pigeon. This species endured an almost similar story as it was also a victim of indiscriminate hunting and land loss, leading environmentalists to believe it could suffer the same fate as its close relative (Keppie & Braun, 2000). The excessive hunting stopped long ago but they are still being legally hunted in six states of the US, as their status in the IUCN Red List of Threatened Species classifies them as least concern (BirdLife International, 2016). Ironically, this might change in the future. Since the mid 1990s regular surveys are showing a steady decrease in the numbers of band-tailed pigeons, approximately 3% each year (Keppie and Braun, 2000). Using the band-tailed pigeon to re-populate the hardwood forests left could be a good opportunity to stop its decline while at the same time helps restore a long time altered ecosystem.

But those involved in the resurrection of the passenger pigeon have another role in mind for the band-tailed pigeon. As its extinction happened relatively recently, there are multiple physical remains of the passenger pigeon in good condition, including hundreds of stuffed specimens (both males and females) and preserved eggs spread across museums and public and private collections. This has allowed Novak and his team to successfully map multiple DNA fragments and compare them with the band-tailed pigeon, which they intend to use to fill the gaps in a gene sequence (Revive and Restore, 2012). The results are expected to be close approximations of the passenger pigeon's germ cells, which would then be inserted into band-tailed pigeon embryos (Revive and Restore, 2012; Preston, 2017). Using band-tailed pigeons as surrogate parents, Novak and his team expect to be able to bring back an *Ectopistes Migratorius* individual back to life as a first step to the comeback of the species (Revive and Restore, 2012; Preston, 2017).

Even if they succeed, is their creation going to be a passenger pigeon as such? Probably not. Many refuse this hypothesis as they consider the newly created species to be a result of a hybridization process (Preston, 2017) more likely to produce a new biological creature that would become closer to a band-tailed pigeon but with some passenger pigeon features (Blockstein, 2017; Temple & Blockstein, 2014). Even if a perfect clone of the original species could be engineered, an animal species is much more than just a pile of genetic material. There are a lot of unknowns on how genes are linked to behavioural peculiarities needed to ensure survival in a natural environment (Blockstein, 2017). There are recorded cases of loss and modification of behavior of previously captive specimens having been released into the wild, becoming a serious issue for their survival and welfare (McPhee, 2004). Novak (2013) pretends to use band-tailed pigeons disguised as passenger pigeons as decoys to help bring back those lost behaviors, but the feasibility of his idea remains unknown.

Ethics experts like Kasperbauer (2017) have expressed their concerns about the suffering inflicted upon individuals taking part in the de-extincion initiatives. A whole debate between ethicists and scientists has arisen around this, not only concerning the passenger pigeon, but in relation to any de-extinction attempt (Blockstein, 2017). Cloning and related methodologies are known to bring a whole set of issues such as aborted fetuses, physical deformities and other health deficiencies (Campbell et al., 1996; Hwang 2013).

Some experts argue that individuals are usually put below the greater good of the species and might experience harmful events for the good of their species as a whole (Rolston 1986; Rolston 1994). But the well-being of a species and its individuals is a very thin line and it is difficult to separate one from the other (Palmer, 2009; Palmer 2011). Kasperbauer (2017) advocates for a deeper study to understand how the needs of the first re-created individuals would be met during the de-extinction process, or to at least prove that future specimens would benefit from their ancestors' suffering and are not going to experience their same misery and pain (Kasperbauer, 2017).

Let's not forget that the first "successful" attempt to bring a lost species back to life ended after seven minutes of agony. In 2003, in Spain, a baby pyrenean ibex, *Capra pyrenaica pyrenaica*, was born from a surrogate domestic goat mother that scientists impregnated with a sample of the last known pyrenean ibex specimen (Folch et al., 2009). The baby only lived for seven minutes due to a lung condition that suffocated her to death (Folch et al., 2009). Although scientists believe conditions will improve over time there is an ethical responsibility to avoid cases like the baby ibex in the future.

Conservation efforts for other species could definitely benefit from the advances in the field of genome engineering (Kasperbauer, 2017) obtained through initiatives such as the passenger pigeon de-extinction. There seems to be less of an ethical debate over using genome sequencing for conservation purposes only. In New Zealand, one of the most notorious cases of genome sequencing is the kakapo, *Strigops habroptilus*, a critically endangered (IUCN, 2016) parrot species that went through a major bottleneck when only 60 individuals were left (Powlesland et al., 2006). After having recovered from their lowest numbers, signs of inbreeding and fertility issues are seriously endangering the species (White, 2012). Scientists are trying to sequence all 125 individuals left in order to apply artificial insemination and planned matings to ensure the viability of the kakapo as a species (Bergner et al., 2014).

Overall, the theory for bringing back the passenger pigeon seems to be well supported and it would suppose an incredible technological milestone. But it does not seem to be a solid way to ensure the viability of the species in the long term as there are many unresolved questions around it. Unknown impacts on other species, lack of suitable habitat, socio-economical effects and well-founded ethical doubts appear to be obstacles too big to overcome, at least for now.

It can not be ignored that even if a century has gone by since the extinction of the passenger pigeon, the circumstances that led to it are still unresolved. Our world is still suffering from human-driven activities such as habitat loss, degradation, poaching and intense pollution, sending thousands of species down the same path the passenger pigeon once went. It seems rather naive to think that bringing the passenger pigeon back to life is achievable without first solving all the issues previously mentioned.

No one can deny the advantages and potential that synthetic genomics bring to the table. From helping critically endangered species to help decrease or eliminate populations of invasive species through gene drives (Sandler, 2017), conservation genomics are definitely here to stay. But they should not be perceived as a magic wand capable of solving all issues in the conservation field. As long as the main causes are not addressed, conservation efforts are just a mere way to gain time while the extinction clock keeps ticking.

Rather than spending time and effort on debates such as the de-extinction of the passenger pigeon, the scientific community should focus on pushing society to embrace sustainability management at a global scale as soon as possible, as recommended by Nobel-prize winning atmospheric chemist Crutzen (2002), in order to start decreasing the negative impacts of humans on Earth.

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