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Successful Citizen or Voracious Vermin?

What we know, what we don't know, and what we need to know to address the Pied Crow conundrum in South Africa

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Summary

BirdLife South Africa receives regular enquiries from its membership and the broader general public about the increasing spread of Pied Crows *Corvus albus* into new habitats in South Africa. A common perception is that this phenomenon may be both ecologically damaging and financially costly and should be actively managed to mitigate these impacts.

For BirdLife South Africa to develop a properly informed policy on this issue, *AVISENSE* Consulting was contracted to (i) compile an objective review of what is known from other areas about the expansion of corvid populations into new environments, including the direct and indirect effects of such expansions on local biodiversity and the efficacy of various measures used to control or eradicate invasive crows around the world, (ii) assess what is known about Pied Crow biology, about changes in the species' distribution in South Africa, and about the biodiversity impacts of such changes, and (iii) identify important gaps in the knowledge required to formulate a rational, defensible, ethical and effective approach to addressing this problem (if, indeed, one is required).

A virtual workshop, attended by a range of stakeholders, including academics, conservationists, people in industry and members of the public, was held on 25 June 2020 (Figure 1). The workshop built on the knowledge base informing this review and discussed sensible and viable actions required to better understand and respond to the expansion of Pied Crows in South Africa. This review is intended to inform BirdLife South Africa's position on and future involvement in the management of this issue.

There is a wealth of published research on the biology of the world's crows, much of it focused on the role they play in local ecosystems and the implications for biodiversity of crow populations increasing and spreading, as they are doing virtually across the globe. A recent review of corvid impacts on bird populations suggests that in many cases they are minimal. However, a significant number of credible studies provide clear evidence that under some circumstances, and particularly where they are invading completely foreign environments, a proliferation of crows can cause significant loss of biodiversity. In response to such impacts, many crow control or eradication programmes have been instituted and are detailed in the published literature, and many include a variety of lethal and non-lethal methods used to limit crow numbers. While some of these programmes demonstrate considerable success, a common conclusion is that determining and controlling the anthropogenic drivers of crow population growth, rather than the crows themselves, is a more efficient way of achieving the targeted outcome.

The Pied Crow is a common, generalist forager, scavenger and predator that occurs across much of sub-Saharan Africa. A recent analysis of bird atlas data shows a distinct shift in the South African population of this species from northeast to southwest, and an increase in abundance of up to 30% in some areas. While this shift is correlated with climate change and with the spread of linear infrastructure (power lines, roads, fences) into the Karoo, we still have no definitive understanding of what has driven this significant change in Pied Crow distribution. Similarly, while there is suggestive evidence of detrimental effects on tortoises, little credible scientific research has been done to properly document and quantify significant impacts of expanding Pied Crow populations on local biodiversity.

The Pied Crow population has certainly expanded into urban areas and into new environments in the southwest of South Africa in the last 20 years. This expansion has likely been driven by one or a combination of anthropogenic factors (including the spread of linear infrastructure, poor waste management, persecution of competing species and, perhaps ultimately, climate change). Pied Crows in these new habitats may be causing significant loss of locally indigenous biodiversity – either directly through predation, competition and disturbance, or indirectly through the collateral damage caused by landowners initiating ill-advised and possibly illegal crow control or eradication campaigns to reduce costly crop and stock losses attributed to 'invasive' Pied Crows. The current situation is untenable and warrants urgent attention. However, before formulating and promoting any kind of response, it is imperative that BirdLife South Africa ensure that such a response is based on a full understanding of the causes of the Pied Crow expansion, the actual ecological and economic consequences of the expansion, and the need for and possible consequences of any kind of practical management of crow numbers. This understanding must stem from rigorous and defensible science, and any future intervention must be bound by the precautionary principle and strictly adhere to the global best-practice protocols of animal ethics.

We recommend that BirdLife South Africa's position statement on this issue includes all of the points made above, and that any subsequent course of action which the organisation takes, collaborates in, supports or facilitates, be congruent with the research and management priorities compiled a an outcome of this review.

Figure 1. Attendees of the BirdLife South Africa Pied Crow workshop held virtually on 25 June 2020.

What we know, what we don't know, and what we need to know to address the Pied Crow conundrum in South Africa

INTRODUCTION

The Pied Crow *Corvus albus* is an indigenous, medium-large bird found across much of sub-Saharan Africa (Dean 2005, Anjos et al. 2009). In South Africa, it is closely affiliated with urban and rural settlements, and recent evidence indicates that its numbers are increasing and its range expanding steadily across parts of the country (Cunningham et al. 2016). Southern African Bird Atlas Project 2 (SABAP2) data show increased reporting rates in the south-western region of South Africa over the last decade, with landowners reporting large flocks of Pied Crows as regular occurrences in areas of the Northern and Western Cape. Human population growth and expansion, climate change, an expanding electricity grid, increasing access to human waste, and a sophisticated road network have all been identified as potential drivers of this apparently growing and spreading population (Cunningham et al. 2016, Joseph et al. 2017, Dean et al. 2018).

Pied Crows are generalist predators and opportunistic scavengers (Dean 2005). Small-stock farmers report that they regularly kill and feed on new-born lambs and that increasing crow numbers is making sheep farming unsustainable. Perhaps understandably, landowner attitudes towards Pied Crows are increasingly negative, and localised attempts have been made to exterminate the offending birds. Unfortunately, most of the available control methods operate indiscriminately, and these attempts often cause wider environmental damage, even leading to the death of endangered, non-target animals. The general public also harbour negative sentiments towards burgeoning crow numbers, which are perceived to be detrimental to reptile, small bird and even raptor populations (Simmons & Barnard 2011, Fincham & Lambrechts 2014, Loehr 2017, Johnson & Murn 2019, Kopij 2019). As a result, BirdLife South Africa receives several enquiries a month requesting a solution to this problem.

To address these growing concerns, BirdLife South Africa has recognised the need for a review document that synthesises and summarises what is and isn't currently known about the biology of the Pied Crow, its impacts on biodiversity, and the possible need for and suitability of various crow population control methods. This document should provide BirdLife South Africa and the broader conservation community with robust and well-balanced arguments about the present Pied Crow predicament. It should also clearly list important information deficiencies and research priorities, and work towards developing a preliminary action plan for a practical, ethical, defensible and environmentally sustainable way forward. *AVISENSE* Consulting was contracted by BirdLife South Africa to compile this review in May 2020.

METHODS

The review process contributing to this draft was based largely on a simple search of the published literature using the Web of Science academic literature database and

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Pied Crows are high social birds and will often spend time together within their territories.

science citation index, which includes over 8500 mostly peer-reviewed journals, spanning the period 1900 to the present day. The search focused on literature dealing with any aspect of Pied Crow biology, anything to do with corvid impacts on biodiversity, and any aspect of biocontrol involving crow species. Information on the basic biology of the Pied Crow was mostly gleaned from a relatively recent species account summarising known information for the Pied Crow in southern Africa (Dean 2005 and references therein).

The following questions were deemed central to the objectives of the review, and the answers to these questions are intended to inform the action plan that is the end product of this process, to be refined and ultimately applied by BirdLife South Africa and its partners.

1. In any similar situations from around the world where corvid populations have been implicated in damaging local biodiversity, what kinds of evidence have been deemed sufficient or insufficient to justify intervention, what levels of biological and demographic knowledge were required of both the crow species involved and the worst affected taxa to build and substantiate that evidence, and to develop and apply an effective remedial plan?
2. What do we know about Pied Crow biology, with emphasis on those aspects most relevant to how the species might increase in numbers and/or expand its distribution into new environments, and how it might adversely affect biodiversity? And what don't we know about Pied Crow biology that we need to know in order to assess and respond to this matter responsibly and effectively?
3. What evidence is there that the Pied Crow population has increased and/or that it has expanded its range in South Africa? And what evidence don't we have that we need in order to assess and respond to this matter responsibly and effectively?
4. What evidence is there that Pied Crows are causing unsustainable damage to South Africa's biodiversity? And what evidence don't we have that we need in order to assess and respond to this matter responsibly and effectively?

The review is broadly structured in accordance with this sequence of questions, followed by a summary of important knowledge gaps and the research required to fill those gaps.

Once an initial draft of this review had been completed, a virtual workshop was held on 25 June 2020, hosted and facilitated by BirdLife South Africa and attended by representatives of other conservation NGOs, academics with experience of or interest in crow research, provincial conservation officers ultimately responsible for implementing invasive or problem animal management, representatives of industries implicated or affected by expanding crow populations, and interested and knowledgeable members of the public. The workshop included a series of presentations (on the content of the draft review, the outcomes of new, unpublished research, crow population management techniques, and the perceived impact of crows on small-stock farming in the Karoo), followed by short, breakaway discussion groups tasked with addressing research, landscape management and infrastructure issues pertaining to Pied Crows in South Africa. The workshop was run over six hours and culminated in a period of open discussion on the way forward.

RESULTS & DISCUSSION

CROW POPULATIONS, IMPACTS AND MANAGEMENT AROUND THE WORLD

The Corvidae is a well-studied family of birds with a wide range of published research detailing many aspects of crow biology, including life history, population dynamics, social structure, cognitive abilities and physiology. Studies from other parts of the world on related species have the potential to provide useful supporting information for broadening our understanding of crows generally and increasing our capacity to effectively manage South Africa's perceived Pied Crow problem.

Crow populations

The increase and expansion of corvid populations appears to be a global phenomenon, generally linked with beneficial forms of environmental change. Common Raven *Corvus corax* and American Crow *Corvus brachyrhynchos* have increased in abundance and colonised effectively new habitats in urban and agricultural landscapes throughout North America (Hackworth et al. 2019), and the same applies to Hooded Crow *Corvus cornix*, Carrion Crow *Corvus corone*, Rook *Corvus frugilegus* and Eurasian Magpie *Pica pica* in many parts of Europe and the United Kingdom (Marchant & Gregory 1999, Olea & Baglione 2008, Köver et al. 2015, Krüger et al. 2020), Torresian Crow *Corvus orru* in Australia (Everding & Jones 2006), Pied Crow in Africa and South America (Cunningham et al. 2016), and House Crow *Corvus splendens* in Asia and Africa (Lim et al. 2003). Many of the studies documenting corvid population increases and range expansions are qualitative and anecdotal, but some recent publications adopt a more quantitative approach and provide a far better guide to the data requirements of fully understanding the ecological drivers and population dynamics involved. These include using multivariate models to predict where numerical and range size responses of invasive crows are most likely to manifest (e.g. Fraser et al. 2015 for House Crow in New Zealand, Adelino et al. 2017 for Pied Crow in eastern Brazil, Shivambu et al. 2020 for House Crow globally), how corvid predation risk is distributed in the environment (Kristin & Boarman 2003 for Common Raven in the Mojave Desert), and to estimate the effort needed to control crow numbers (e.g. Brook et al. 2003 for House Crow in Singapore).

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The inquisitive nature of Pied Crows has allowed them to take advantage of the novel foraging opportunities in urban environments.

Reasons put forward to explain crow population expansions include exploitation of escalating quantities of human waste (especially in urban areas – Vuorisalo et al. 2003, Olea & Baglione 2008, Campbell 2009, Wilson et al. 2015), the spread of intensive agriculture (Korovin 2019), and growing networks of utility structures (Steenhof et al. 1993, De Gregorio et al. 2014, Howe et al. 2014) and alien trees (Lauro & Tanacredi 2003) as nesting substrates in otherwise treeless habitats.

Overall, published studies suggest that to build a comprehensive understanding of how, why and where crow populations may be growing and expanding, and to be able to predict impact risk and patterns of future change, accurate data detailing life history and demographic parameters are needed, such as the size of the corvid population, nesting activity and success in that population over time, and productivity in relation to pertinent measures of diet and environmental conditions.

Crow impacts on biodiversity

There is wealth of published literature on the role of corvids as predators (particularly of birds and their nests), some of it qualitative, some of it correlative and some of it experimental. Most were motivated by concerns over inflated numbers of crows in a given habitat, but the conclusions reached about the ecological significance of crow predation are as varied as the nature of the studies themselves.

A recent, comprehensive review of crow impacts on bird populations globally (Madden et al. 2015), based on 42 correlative or experimental studies, concluded that:

a) Corvids had no negative impact on 81% of the avian biodiversity indices assessed.
b) Negative impacts of crows affected the productivity (46%) of bird prey species far more than it affected their abundance (10%).
c) In predator removal experiments, corvids accounted for only 16% of negative impacts on birds, whereas other predators accounted for 44%.

d) Different groups of birds (waders, game birds, passerines) were not affected in different ways.
e) Ground-nesting birds were not more or less affected than those that nested on other substrates.
f) Different species of corvids (e.g. crows versus magpies) had markedly different impacts on the avian biodiversity of the affected environment.

This review paper tends to downplay the importance of crow impacts on targeted prey populations. Specific examples of such limited effects include an experimental study of Common Eider *Somateria mollissima* nest predation by Hooded Crows, which found that when crows were removed from the environment breeding success increased marginally in one affected colony and remained the same in another (Stien et al. 2010). Also, despite public concern, the recovering population of Common Ravens in Britain was found to have little to no spatial or temporal impact on numbers of sympatric, ground-nesting birds (Amar et al. 2010).

In contrast, numerous published studies have found detectable and possibly significant impacts of crows on their prey. For example, desert tortoise *Gopherus agassizii* predation in the Mojave Desert, California was high near successful Common Raven nests (hyperpredation), and away from successful nests where large numbers of non-breeding ravens were present (spillover predation, Kristan & Boarman 2003, Daly et al. 2019). This study found that a raven population boosted by access to anthropogenic resources could indirectly bring about the suppression, decline, or even extinction of the desert tortoise population. In southern England, removal of Carrion Crows *Corvus corone* and Eurasian Magpies resulted in a 10-16% increase in hedgerow songbird nest success (Sage & Aebischer 2017). A study of nest predation of ground-nesting birds in southern Finland found that Hooded Crows and Magpies accounted for nearly 50% of recorded predation (Krüger et al. 2018). Similar impacts of the Common Raven have been mapped against Greater Sage-Grouse *Centrocercus urophasianus* populations in the Great Basin in the USA, highlighting areas needing greater conservation effort due to the high probability of raven predation on nesting sage-grouse (Coates et al. 2020). Common Ravens in southern California depressed breeding success of Pelagic Cormorants *Phalacrocorax pelagicus*, removing an average of 3.3 eggs per nest (Carle et al. 2017), and in Australia Little Raven *Corvus mellori* has been found to raid 61% of monitored Little Penguin *Eudyptula minor* nests (Ekanayake et al. 2015a), and accounted for nearly 79% of predation at the nests of Red-capped Plover *Charadrius ruficapillus* (Ekanayake et al. 2015b).

Some experimental studies have used decoy bird nests to study crow predation rates. One such experiment found that predation of artificial duck nests was higher close to the nest sites of breeding crows (60%) than further away and outside of the home range of nesting crows (20-40%; Sullivan & Dinsmore 1990). Another such study found that American Crows living in urban (novel) environments were more likely to attempt to raid dummy Common Nighthawk *Chordeiles minor* nests than the same dummy nests in rural environments (Latta & Latta 2015). In a Swedish study, predation of dummy nests by Hooded Crows increased as crow populations increased in response to fragmentation of forest habitats caused by agriculture (Andren 1992).

Apart from predation, crows can also affect biodiversity by displacing or outcompeting indigenous species, and kleptoparasitising or mobbing other predators (Amar & Redpath 2002, Peh 2010, Simmons & Barnard 2011, Yosef et al. 2012). In addition to such direct impacts on biodiversity, crows also have the potential to detrimentally affect livestock and crops, spread disease (Nxele & Shivambu 2018), spread alien plants (e.g. Dean & Milton 2000) and form large roosts in urban areas with associated noise and fouling (Everding & Jones 2006, Köver et al. 2018) – all of which can result in the implementation of poorly conceived and even illegal crow control or eradication efforts that may ultimately adversely affect biodiversity. For example, legal sport-hunting of crows in Spain has encouraged illegal shooting of Jackdaws *Coleus monedula* and Red-billed Choughs *Pyrrhocorax pyrrhocorax*, the latter being a threatened species (Blanco et al. 2019).

While the sum of the evidence presented on the capacity for corvids to affect local biodiversity may be equivocal, the majority of the experimental studies documented in the literature recorded significant increases in the productivity of prey populations when crows were removed. In addition, accounts of less direct behavioural and ecosocial impacts are persuasive, if generally lacking in hard data and analyses (e.g. Köver et al. 2018, Preininger et al. 2019). Overall it seems safe to assume that under circumstances of significant increase and spread of indigenous crows into new environments, or invasive spread of exotic crow species, there is a likelihood that direct impacts (related to predation or competition), or indirect impacts (such as from human attempts to control crow populations), or a complex combination of the two, will have an adverse effect on local, indigenous biodiversity.

Crow management

There are numerous examples of corvid eradication programmes around the world, generally instituted because a perceived increase and/or spread of crows into new areas was deemed to be either environmentally detrimental or to pose some level of health risk or inconvenience to people. At this stage it is probably appropriate to consider the control of indigenous crow species separately from measures taken to eradicate alien, invasive crows.

The former have been instituted in some European countries to reduce the impacts of Hooded Crow and other indigenous corvid species on hunted, ground-nesting birds, songbirds in urban environments, and to reduce noise, pollution, dispersal of waste and hygiene issues associated with large aggregations of crows in urban areas (e.g. Köver et al. 2018). However, such measures are not easy to execute successfully and not without resistance from the general public. For example, public support was considered key in eradicating House Crow from the Netherlands (Vane 2016), while in Slovenia a third of the interviewed general public opposed a Hooded Crow control program and rather advocated softer, people-centric measures such as environmental education and better waste management (Spur et al. 2016).

After 25 years of increasing the intensity of hunting of Hooded and Carrion Crows in the Rhine Valley, Austria, numbers of both species were still increasing, with access to

waste disposal suggested as the main driver of this population growth (Preininger et al. 2019). This study concluded that the only way to reduce crow numbers in the area was to change the way that waste products were processed. A study of the efficacy of crow hunting in Cyprus has revealed that Hooded Crow and Eurasian Magpie populations, having endured over 30 years of seasonal culling, have adapted their breeding strategies to accommodate biased mortality of males, and continue to proliferate regardless (Betz Heinemann et al. 2020). Control methods used have also included aversive conditioning, in which dummy eggs of threatened bird species being subject to nest predation by crows were laced with toxin, effectively teaching the corvids to avoid these eggs as a food source. Successful examples include suppression of Common Raven predation of Least Tern *Sternula antillarum* nests (Avery et al. 1995), and Steller's Jay *Cyanocitta stelleri* predation of Marbled Murrelet *Brachyramphus marmoratus* (Gabriel & Golightly 2014). However, in other instances, this method has proven to be ineffective (Catry & Granadeiro 2006). Similarly, the use of predator exclosures have reduced predation rates at the nests of some species but can also result in inflated adult mortality of the targeted species (Isaksson et al. 2007, Baker et al. 2010).

Collectively, these studies emphasise that for a culling programme to be successful, it has to be designed appropriately (e.g. Redpath et al. 2012) and requires local community buy-in. Another important issue to consider is the cost of such efforts: the cities of Mombetsu and Hirosaki in Japan spend around $300,000 and $70,000 respectively each year on controlling populations of Carrion Crow and Large-billed Crow *Corvus macrorhynchos* (Yoda 2019).

Most exotic crow control initiatives have been developed to combat House Crow range expansions into new areas of Asia and Africa. An effective House Crow control program (that achieved a 75% to 95% reduction in crows) was implemented in Kenya and Tanzania (on Zanzibar Island) but a subsequent lack of funding, coordination and follow up, resulted in these birds becoming re-established in some areas (Archer 2001). The programme was started because the crows were thought to be detrimental to indigenous birdlife through both predation and displacement, presenting human health risks, damaging power infrastructure and causing damage to crops. Another eradication programme for this species was recently started in Tanzania, and again included destroying nests, eggs and chicks, shooting and trapping, a bounty system and poisoning (Shimba & Jonah 2017). There is no clear indication yet that this scheme has been effective.

More localised, efforts to control House Crows in East Africa include a project in Mombasa, Kenya, where they apparently raid restaurants and prey on domestic poultry, and a project in Malindi, Kenya, where Starlicide was used to reduce crow numbers. Since this use of poison was discontinued by government, the crows have increased again. Some poultry keepers in East Africa dye their chickens to prevent the crows from taking them (*www.bbc.com/news/world-africa-301782661, accessed June 2020*).

In Malaysia an effective short-term management plan was put in place to control invasive House Crows (Wilson et al. 2015). Once again, this plan included a wide range of activities, including shooting and trapping, egg removal and replacement with fake eggs, poisoning, and pruning and blasting of roost trees. The study concluded that since the birds were attracted to urban waste, an improved waste management system would be a better, longer-term solution.

A House Crow control programme launched in Cape Town in 2009 (under the Biodiversity Management Act 10 of 2004 – Category 1a invasive species) reduced the population of this invasive species from 10 000 birds to 300 birds in just a few years. Since 2015, the remaining crows have been monitored but no further eradication has been deemed necessary (*www.capetowninvasives.org.za/house-crows*, accessed June 2020).

In review, while there are multiple examples of successful campaigns to decimate invasive populations of an alien crow species, lethal control of indigenous crow populations seems to be more effective in reducing productivity of the offending population than actually reducing numbers (Madden et al. 2015). Furthermore, eradication programmes are controversial and possibly socially unacceptable, as well as time-consuming, expensive, and likely to only have short-term benefits.

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Pied Crows have adapted well to the human-altered landscape and can make use of infrastructure for territory defense or breeding displays.

There can be ecological costs of crow removal too. A culling program on Cyprus has had negative effects on Long-eared Owl *Asio otus*, Cypriot Scops Owl *Otus cyprius* and Common Kestrel *Falco tinnunculus*, all of which breed in disused crow nests, and on Great Spotted Cuckoos *Clamator glandarius* that parasitise the crows (Hadjisterkotis 2003). There are also studies showing that corvids are useful in seed dispersal (Bai 2017). In predator control programs, potential cascading effects on other competing predators should be considered. For example, when Hooded Crows were culled on Rathlin Island in the UK, the Common Raven population expanded with an associated increase in damaging predation (Body et al. 2009). Crows have also been shown to provide useful ecosystem services as scavengers in urban environments, where they remove carcasses from the streets in the UK (Inger et al. 2016).

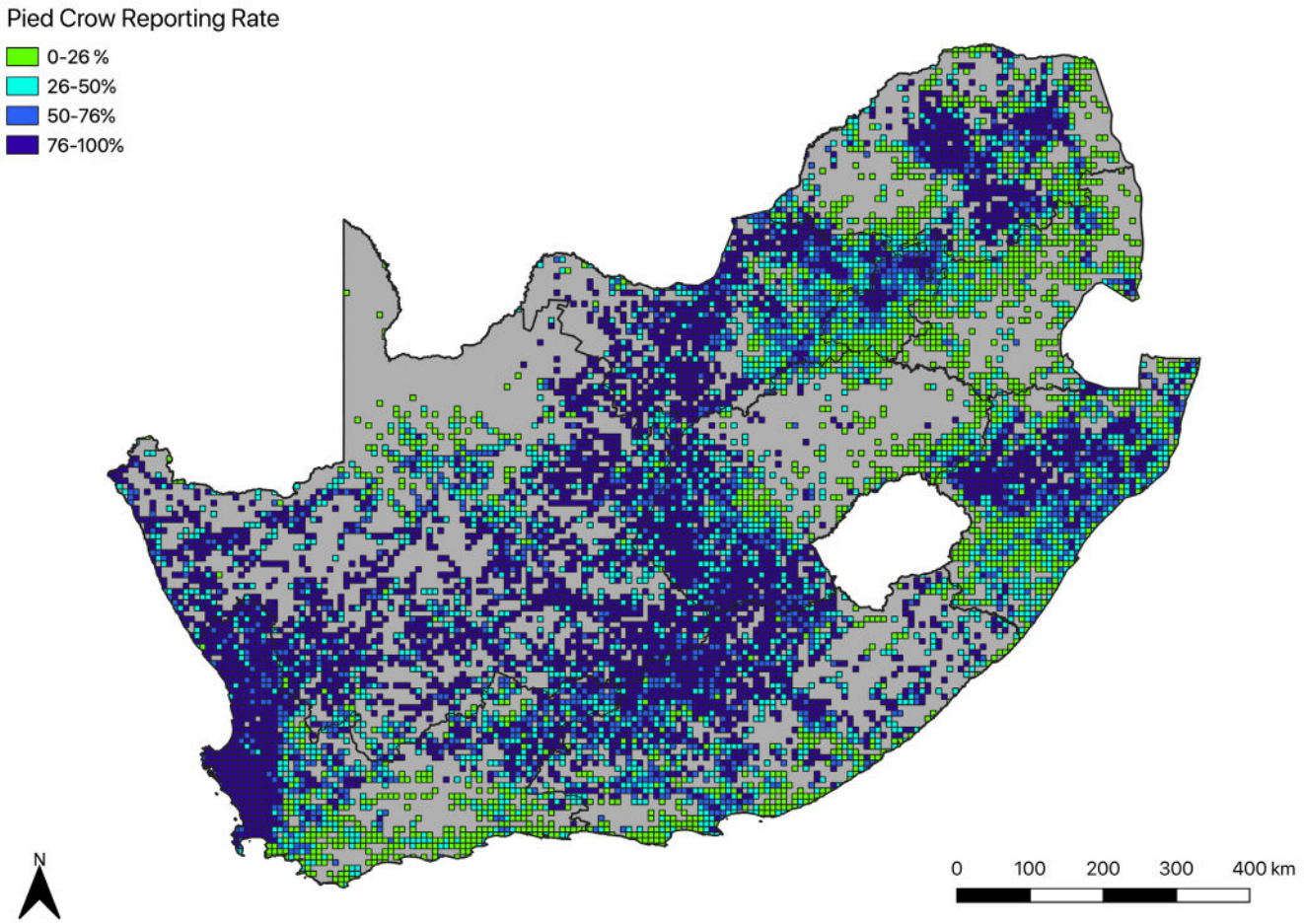

Figure 2. Pied Crow reporting rates across South Africa from 2007-2019. Southern African Bird Atlas Project (SABAP2) reporting rates are calculated as atlas cards including Pied Crow records expressed as a percentage of the total number of atlas cards submitted for each pentad.

PIED CROW BIOLOGY

The Pied Crow is a common to abundant, mainly resident species in sub-Saharan Africa, and is widespread in South Africa (Fig. 2). It is probably native to open savanna woodland and dwarf shrublands, but now occurs extensively in open Karoo ranchlands, cultivated lands, and suburban and urban habitats with a strong association with life stock farming and human settlements (Londei 2010). it usually occurs in pairs or small flocks, although flocks can number in the hundreds on occasion. It naturally roosts in trees, but where suitable trees are unavailable will use cliffs, quarries, utility poles and buildings. Roosts may contain up to several thousand birds (Dean 2005). There is little to suggest any kind of concerted, seasonal movement within the South African population. Ringing data are few (154 birds ringed, 15 recoveries, *http://safring.birdmap.africa/*), with the oldest recovered bird being 9.4 years old, and the longest movement from ringing site being a distance of 237 km.

Pied Crows mainly forage in open ground, in the intertidal zone along coastlines, along road verges, at rubbish dumps (e.g. Campbell 2009), and in association with veld fires. The species is omnivorous and eats mostly plant material, including alien prickly pears *Opuntia*, seeds, roots, maize and other grain crops. It also eats a diversity of animals, including insects and other invertebrates, fish, reptiles (including lizards, snakes and tortoises), birds, birds' eggs, small mammals and carrion. It is quite capable of catching live, free-flying birds (Wanless & Jupiter 2009) but apparently does so infrequently. Pied Crows often feed on roadkill while sympatric Cape Crows *Corvus capensis* are attracted more to road verges (Dean, Milton & Anderson 2006). There may be some competition between the two species, as Cape Crows feed more frequently on carrion where Pied Crows are absent. Pied Crows are known to be dispersers of the seeds of invasive prickly pears. Individuals and flocks frequently mob and possibly kleptoparasitise birds of prey, but the population-level effects of this behaviour on raptors are not known (Simmons & Barnard 2011).

The Pied Crow is monogamous and territorial, but nests are sometimes built <200m apart (Dean 2005). Both birds of the pair build the nest over a period of 11-12 days. The structure is a large bowl of sticks,wire and/or baling twine (about 50 cm in diameter and 30 cm deep), lined with fur, wool and dry dung, usually placed in a tree (often an alien eucalypt, pine or palm) at least 3 m off the ground, but also on a utility structure, building or quarry or cliff ledge. One to seven eggs are laid from July to January and incubated (mostly by the female) for 18-19 days. Hatching is synchronous, the nestlings' eyes open at 11-12 days old, they are well-feathered by 20 days, and fledge in 35-43 days (Mundy & Cook 1977). They are fed by both adults, with deliveries occurring at about 2-4 times per hour depending on the age and size of the brood. The only productivity data are from Nigeria where 0.89 young are fledged per pair. About 13% of nests in South Africa are parasitised by Great Spotted Cuckoo. Old nests may be taken over by other species such as Lanner Falcon *Falco biarmicus*, Red-necked Falcon *Falco chicquera* and particularly Greater Kestrel *Falco rupicoloides* (Hockey et al. 2005), while the latter species and Pied Crow sometimes breed in close proximity (Malan 2010).

Overall, our knowledge of some of the key aspects of Pied Crow biology relevant to its potential to spread uncontrollably

into novel environments and cause significant loss of biodiversity is conspicuously lacking (Fincham et al. 2015, Fincham & Nupen 2016). A comparison of the volume of information on Pied Crows present in the published literature in relation to the same metric for other common corvids around the world (Fig. 3) clearly show how poorly known the species is. In particular, we have no quantitative idea of the diet or food requirements of individual birds or of nesting pairs, or of the importance of different elements of the Pied Crow's omnivorous diet on survival, nesting success or productivity. Similarly, we have no idea whether or not Pied Crows living in human transformed habitats achieve these same life history advantages. In fact we have only limited knowledge of basic breeding biology of the species and no reliable data on key life history parameters under any environmental conditions – no longevity or survival figures, no age of first breeding, and no substantive information on clutch size, hatching success, or breeding success. Without these basic data it is extremely difficult to understand how Pied Crow populations are currently responding to different environmental variables and affecting surrounding biodiversity, how they might do so in future with conditions continuing to change, and how they might respond to any population control methods that might be applied.

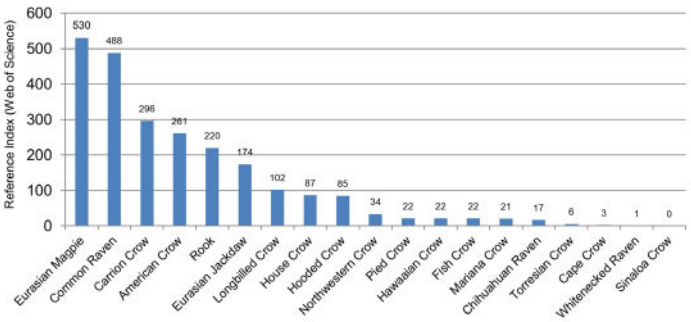

Figure 3. Number of published studies listed by "Web of Science" for each of a sample of corvids from around the world.

CHANGES IN PIED CROW NUMBERS AND DISTRIBUTION IN SOUTH AFRICA

There is copious anecdotal evidence to suggest that the distribution of the Pied Crow in South Africa has recently undergone significant change, but is there empirical evidence to support this impression? Analysis of Southern African Bird Atlas (SABAP 1 & 2) data clearly shows that the Pied Crow has increased in the south-western region of South Africa and decreased in the north-eastern region in the last 20-30 years (Cunningham et al. 2016, Fincham & Nupen 2016, Craig & Hulley 2020; Fig. 4). This range modification is correlated with climate change-related warming of the shrubland biomes of south-western South Africa (Cunningham, et al.

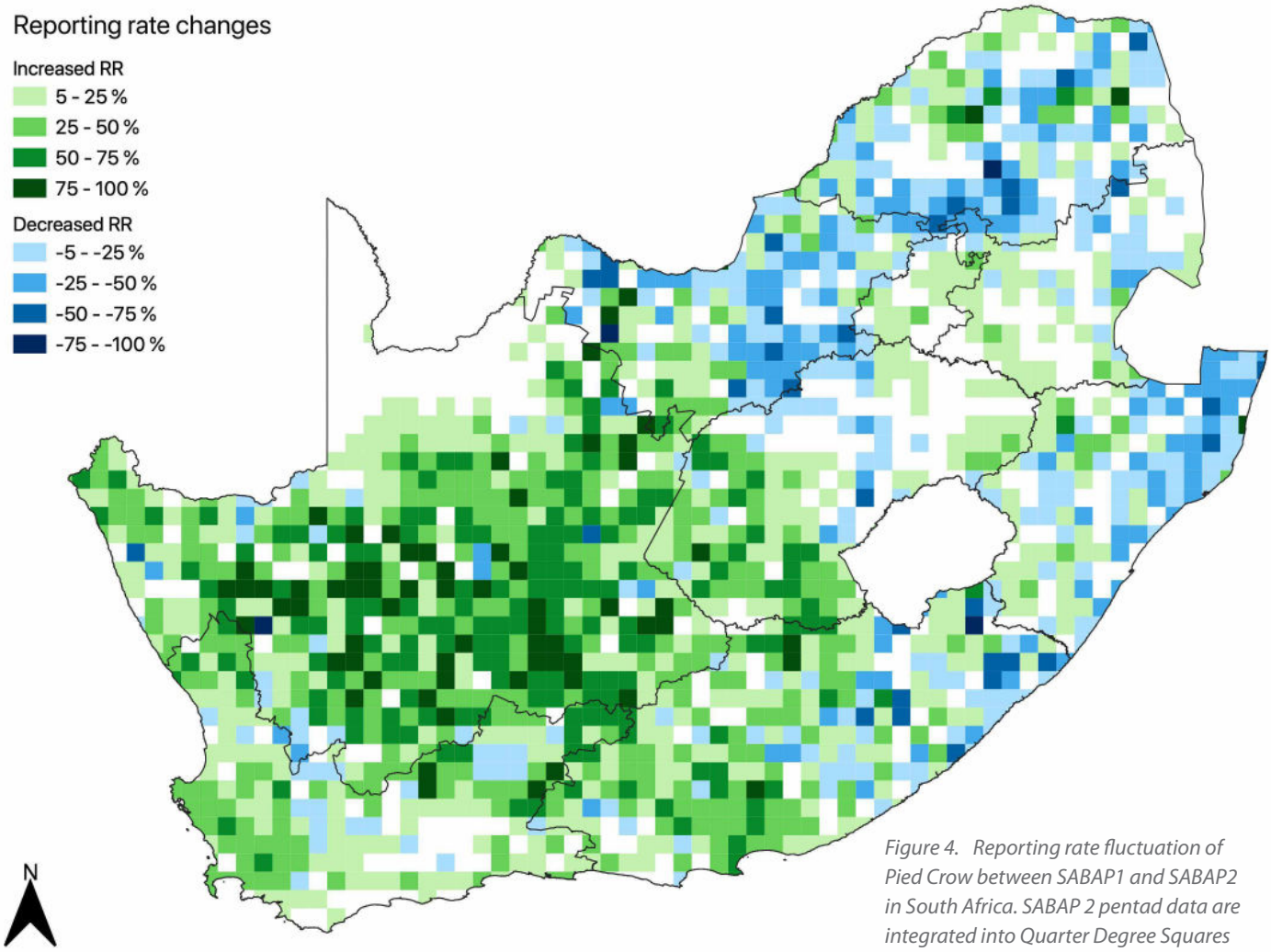

Figure 4. Reporting rate fluctuation of Pied Crow between SABAP1 and SABAP2 in South Africa. SABAP 2 pentad data are integrated into Quarter Degree Squares as per the SABAP1 protocol.

2016). Also, there is a strong correlation with the expansion of the country's powerline, road and fencing infrastructure (Dean et al. 2018). Pied Crow abundance – as indicated by SABAP reporting rates – increased by 13% averaged across all nine provinces in South Africa, and by up to 30% in the Northern Cape, with these increases correlated with the expansion of human settlements (Joseph et al. 2017), the spread of power and telephone infrastructure providing nesting opportunities in tree-less environments, and with the availability of animal fatalities from which to scavenge along road networks.

Hence the distribution of the Pied Crow in South Africa has significantly shifted over the last two decades, with strong correlative evidence to suggest that this shift has at least partly been in response to human-caused changes in climate and in the availability of nest and roost sites, and food. However, in the latter case no clear cause-and-effect relationship has been established, and a more nuanced understanding of the drivers of increase and range expansion, one that could inform a practical plan to limit these anthropogenic drivers and thereby slow, stop or even reverse the spread of the species, is still lacking (Cunninghamet al. 2016).

BIODIVERSITY IMPACTS OF PIED CROWS IN SOUTH AFRICA

Increasing numbers of Pied Crows are reputedly linked with unnatural and unsustainably high levels of predation of small animals, especially small birds and reptiles, and with an overly high incidence of mobbing and kleptoparasitism of birds of prey that may even constrain foraging and breeding success in affected species (Fincham et al. 2015). Larger than normal flocks of Pied Crows are also associated with crop damage and persecution or even predation of small livestock (Fincham et al. 2015, Fincham & Nupen 2016). However, the empirical evidence for these various effects is limited (although there are numerous complaints posted on social media about Pied Crow impacts, and landowners in parts of the country have already instituted localised campaigns to eradicate Pied Crows – e.g. *http://africanpredator.com/crowarticle.html*).

Perhaps the best, quantitative study of Pied Crow impacts on biodiversity is of predation on Speckled Tortoise *Homopus signatus* hatchlings in the Springbok area of the Northern Cape. A modelling study found that hatchling predation by Pied Crows, which in terms of atlas data had become nine times more abundant in the area over the eight years of the study, was probably responsible for a sharp decrease in Speckled Tortoise numbers (Loehr 2017). This kind of effect on tortoise populations is likely to apply more widely, given that Pied Crows often perch on fence-poles and tortoises on the move often patrol along fence-lines looking for an opening (Dean et al. 2018). Further evidence of tortoise predation by Pied Crows as a possible problem is provided by the discovery of 27 Angulate Tortoise *Chersina angulata* carapaces at a nest near Lambert's Bay (Riley & Baxter-Gilbert 2019). Another count of small tortoise carapaces recovered under an active nest in the Ceres area over two breeding seasons, revealed that a single pair of crows and their two broods of young accounted for at least 465 tortoises over that time (Fincham and Lamprecht 2014). However, a more in-depth study of the distribution of tortoise predation suggested that it is a localised phenomenon, possibly restricted to Pied Crow sites in Namaqualand and the West Coast and far less frequent at nests in the Nama Karoo (Dura 2016).

Suitably quantitative studies of Pied Crow predation on birds and birds' nests are extremely limited. An isolated population on Aldabra Atoll regularly hunts and kills turtle doves (Wanless & Jupiter 2002), confirming that the species is quite capable of operating as an effective predator of adult birds. Also, they appeared to feed on the eggs of White-backed Vultures *Gyps africanus* at a nesting colony in the Northern Cape, but while they mobbed incubating birds they weren't able to displace them and only fed on deserted eggs (Johnson & Murn 2019). Pied Crow was also found to be an important predator of Kittlitz Plover *Charadrius pecuarius* eggs (Ferguson 2016) along the Berg River Estuary, with Conditioned Food Aversion (CFA) found to be an effective, non-lethal means to lower predation rates.

KNOWLEDGE GAPS & RESEARCH QUESTIONS

In order to properly make the case that Pied Crows, as they occur in inflated numbers and new environments in South Africa, are either directly or indirectly causing damage to locally indigenous biodiversity, and thereafter to determine the most defensible, effective and ethical way to mitigate this unnatural and unsustainable source of environmental damage; the following information is currently unavailable and, we suggest, urgently required:

1. Accurate quantitative information, supported by representative sample sizes and ideally spread over a range of habitats, on basic aspects of Pied Crow biology – breeding season, nest spacing, clutch size, nesting success, diet, foraging range, habitat selection, age of first breeding, longevity, survival, dispersal of juveniles and predation threats.
2. A deeper understanding of the causal drivers of recent changes in the distribution of Pied Crows in South Africa.
3. Accurate quantitative information, supported by representative sample sizes and ideally spread over a range of habitats, on how Pied Crows may have a direct, negative impact on biodiversity when operating in newly colonised environments.
4. Accurate quantitative information, supported by representative sample sizes and ideally spread over a range of habitats, on how expanding Pied Crow populations may have an indirect, negative impact on biodiversity.

WAY FORWARD

Apparently, there is a groundswell of support in the public domain to control Pied Crow numbers in South Africa and thereby reduce the negative effects these indigenous invaders may be having on our biodiversity (Fincham et al. 2015). However, this review found insufficient reliable evidence in the published literature to either verify these perceived impacts or to justify the institution of any kind of control programme. This is not to say that such evidence does not exist, just that it has not been formally researched and documented.

The workshop organised as part of this review process was primarily intended to pool national interests and expertise in the field to help BirdLife South Africa and partners plan a way forward in dealing with this issue. The attendees and direct outcomes of the workshop are listed and collated in Appendix

1 and many of the accumulated comments, suggestions, edits and additions resulting from the workshop have been integrated into this document, which is an expanded and improved version of the original draft. The three break-away group discussions yielded lists of research or knowledge requirements or practical interventions considered to be immediate or longer-term priorities by each of the groups, clustered under the headings "Landscape management", "Research" and "Linear infrastructure". These priorities have been re-worded, refined, expanded on and re-ordered here to generate discrete action points, to which are allocated suggested responsible agencies, targeted outcomes, suggested funding sources and realistic timelines (Appendix 2).

Action points include elements of practical management that can ethically and responsibly be implemented in the short-term (and in the absence of related research outputs), short-duration, applied research that can be completed in the short- to medium-term to address more easily filled knowledge gaps, and longer-duration, academic research projects that ultimately will yield empirically tested answers to the more fundamental shortfalls in our understanding of Pied Crow ecology (Appendix 1). The former can probably be handled in-house by the suggested responsible agencies, begun almost immediately and completed within a year, while the required research could be started within 6-18 months, be conducted in terms of collaborations between government, industry, and the conservation and academic communities, and be undertaken by university post-graduate students. There are certainly opportunities to dovetail or integrate some of these action points into single initiatives, which should result in some compression of schedules and reduction in costs.

In addition to these action points, some important, general points came out of the workshop that should have a bearing on how this matter is handled going forward. These included:

1. Existing and ongoing efforts by farmers to control or eradicate Pied Crows – in many cases illegally and with little or no regard for collateral damage to threatened species and sensitive ecosystems – should be addressed directly and as a matter of urgency.
2. While the human-wildlife conflict referred to above, which is driven primarily by the perceived economic costs to landowners of expanding Pied Crow populations, does not fall within the central conservation mandate of BirdLife South Africa, the potentially serious indirect impacts on biodiversity of the resulting mismanagement requires that this situation be addressed as a priority. Also, while BirdLife South Africa will always favour biodiversity conservation-related research and interventions, the human-wildlife conflict aspect of the Pied Crow conundrum should not be ignored.
3. If Pied Crows are responsible for significant and damaging levels of biodiversity loss, this is likely to be happening on a habitat, location or even site-specific basis. Such localised impacts are likely to be the result of unique conditions and thus require bespoke solutions. There may well be little need or justification for wholesale, landscape-scale management of Pied Crows.
4. Whatever management actions are ultimately recommended by this initiative, the precautionary principle will be a default position throughout, and the strict adherence to the highest possible ethical protocols and standards will be a constant requirement. The latter are well described in the literature (Redpath et al. 2012, Dubois et al. 2017), requiring (among other things) that decision-making involves all affected parties and is done transparently and in terms of the best available scientific evidence, management of animals is only considered when options for managing people have been exhausted, and that lethal control measures are employed as sparingly as possible, and only when non-lethal options have been exhausted.

CONCLUSION

The Pied Crow population has certainly expanded into urban areas and into new environments in the southwest of South Africa in the last 20 years. This expansion has likely been driven by one or a combination of anthropogenic factors (including the spread of linear infrastructure, poor waste management, persecution of competing species and, perhaps ultimately, climate change). Pied Crows in these new habitats may be causing significant loss of locally indigenous biodiversity – either directly through predation, competition and disturbance, or indirectly through the collateral damage caused by landowners initiating ill-advised and possibly illegal crow control or eradication campaigns to reduce costly crop and stock losses attributed to Pied Crows. The current situation is untenable and warrants urgent attention. However, before formulating and promoting any kind of response, it is imperative that BirdLife South Africa ensure that such a response is based on a full understanding of the causes of the Pied Crow expansion, the actual ecological and economic consequences of the expansion, and the need for and possible consequences of any kind of practical management of crow numbers. This understanding must stem from the rigorous and defensible science, and any future intervention must be bound by the precautionary principle and strictly adhere to the global best-practice protocols of animal ethics. We recommend that BirdLife South Africa's position statement on this issue include all of the points made above, and that any subsequent course of action which the organisation takes, collaborates in, supports or facilitates be a subset of the actions and priorities listed here (Appendix 2).

ACKNOWLEDGEMENTS

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REFERENCES

Adelino, J.R.P., dos Anjos, L. & Lima, M.R. 2017. Invasive potential of the Pied Crow (*Corvus albus*) in eastern Brazil: best to eradicate before it spreads. *Perspectives in Ecology and Conservation* 15: 227-233.

Amar, A. & Redpath, S.M. 2002. Determining the cause of the Hen Harrier decline on the Orkney Islands: an experimental test of two hypotheses. *Animal Conservation* 5: 21-28.

Amar, A., Redpath, S., Sim, I. & Buchanan, G. 2010. Spatial and temporal associations between recovering populations of Common Raven *Corvus corax* and British upland wader populations. *Journal of Applied Ecology* 47: 253-262.

Andren, H. 1992. Corvid density and nest predation in relation to forest fragmentation: a landscape perspective. *Ecology* 73: 794-804.

Anjos, L., Debus, S.J.S., Madge, S.C. & Marzluff, J. 2009. Family Corvidae (Crows). In: del Hoyo, J., *et al.* (Eds.), Handbook of the birds of the world. Bush-shrikes to old world sparrows, vol. 14. Lynx Edicions, Barcelona, pp. 494-640.

Archer, A.L. 2001. Control of the Indian House Crow (*Corvus splendens*) in eastern Africa. *Ostrich Supplement* 15: 147-152.

Avery, M.L., Pavelka, M.A., Bergman, D.L., Decker, D.G., Edward, C. & Linz, G.M. 1995. Aversive conditioning to reduce raven predation on California Least Tern eggs. *Colonial Waterbirds* 18: 131-138.

Bai, B., Li, N., Li, X. & Lu, C. 2017. Bulbuls and crows provide complementary seed dispersal for China's endangered trees. *Avian Research* 8: 31.

Barber, C., Nowak, A., Tulk, K. & Thomas. L. 2010. Predator exclosures enhance reproductive success but increase adult mortality of Piping Plovers (*Charadrius melodus*). *Avian Conservation and Ecology* 5: 6.

Betz Heinemann, K.A., Betmezoglu, M., Ergoren, M.C. & Fuller, W.J. 2020. A murder of crows: culling corvids in Northern Cyprus. *Human Ecology* https://doi.org/10.1007/s10745-020-00154-4.

Blanco, G., Cuevas, J. A., Frias, O. & del Barrio, J.L.G. 2019. A shot in the dark: sport hunting of declining corvids promotes the inadvertent shooting of threatened red-billed choughs. *Journal of Nature Conservation* 52: 125739.

Body, T.W., McDonald, R.A. & Bearhop, S. 2009. Mesopredators constrain a top predator: competitive release of ravens after culling crows. *Biology Letters* 5: 617-620.

Brook, B.W., Sodhi, N.S., Soh, M.C.K. & Lim, H.C. 2003. Abundance and projected control of invasive House Crows in Singapore. *Journal of Wildlife Management* 67: 808-817.

Campbell, M. 2009. Factors for the presence of avian scavengers in Accra and Kumasi, Ghana. *Area* 41: 341-349.

Carle, R.D., Calleri, D.M., Beck, J.N., Halbert, P. & Hester, M.M. 2017. Egg depredation by Common Ravens *Corvus corax* negatively affects Pelagic Cormorant *Phalacrocorax pelagicus* reproduction in central California. *Marine Ornithology* 45: 149-157.

Catry, T. & Granadeiro, J.P. 2006. Failure of methiocarb to produce conditioned taste aversion in Carrion Crows consuming Little Tern eggs. *Waterbirds* 29: 211-214.

Coates, P.S., O'Neil, S.T., Brussee, B.E., Ricca, M.A., Jackson, P.J., Dinkins, J.B., Howe, K.B., Moser, A.M., Foster, L.J. & Delehanty, D.J. 2020. Broad-scale impacts of an invasive native predator on a sensitive native prey species within the shifting avian community of the North American Great Basin. *Biological Conservation* 243: 108409.

Craig, A.F.K. & Hulley, P.E. 2020. Pied Crows in the Eastern Cape: what bird club records reveal. *Ostrich* DOI: 10.2989/00306525.2020.1782498.

Cunningham, S.J., Madden, C.F., Barnard, P. & Amar, A. 2016. Electric crows: powerlines, climate change and the emergence of a native invader. *Diversity and Distribution* 22: 17-29.

Daly, J.A., Buhlmann, K.A., Todd, B.D., Moore, C.T., Peaden, J.M & Tuberville, T.D. 2019. Survival and movements of head-started Mojave Desert Tortoises. *Journal of Wildlife Research* 83: 1700-1710.

Dean, W.R.J. 2005. Pied Crow. In: Hockey, P.A.R., Dean, W.R.J., Ryan, P.G. (Eds). Roberts – Birds of Southern Africa, VIIth edition. The Trustees of the John Voelcker Bird Book Fund, Cape Town.

Dean, W.R.J. & Milton, S.J. 2000. Directed dispersal of *Opuntia* species in the Karoo, South Africa: are crows the responsible agents? *Journal of Arid Environments* 45: 305-314.

Dean, W.R.J., Milton, S.J. & Anderson, M.D. 2006. Use of road kills and roadside vegetation by Pied and Cape Crows in semi-arid South Africa. *Ostrich* 77: 102-104.

Dean, W.R.J., Seymour, C.L. & Joseph, G.S. 2018. Linear structures in the Karoo, South Africa, and their impacts on biota. *African Journal of Range & Forage Science* 35: 223-232.

De Gregorio, B.A., Weatherhead, P.J. & Sperry, J.H. 2014. Power lines, roads, and avian nest survival: effects on predator identity and predation intensity. *Ecology and Evolution* 4: 1589-1600.

Dubois, S., Fenwich, N., Ryan, E.A., Baker, S.E., Beausoleil, N.J., Carter, S., Cartwright, B., Costa, F., Draper, C., Griffin, J., Grogan, A., Howald, G. Jones, B., Littin, K.E., Lombard, A.T., Mellopr, D.j., Ramp, D., Schuppli, C.A. & Fraser, D. 2017. International consensus principles for ethical wildlife control. *Conservation Biology* 31: 753-760.

Durá, C. 2017. Quantifying the level of predation on tortoises by Pied Crows in south western South Africa. Unpublished Conservation Biology MSc mini-thesis. University of Cape Town, Cape Town.

Ekanayake, K.B., Sutherland, D.R., Dann, P. & Weston, M.A. 2015a. Out of sight but not out of mind: corvids prey extensively on eggs of burrow-nesting penguins. *Wildlife Research* 42: 509-517.

Ekanayake, K.B., Whisson, D.A., Tan, L.X.L. & Weston, M.A. 2015b. Intense predation of non-colonial, ground-nesting bird eggs by corvid and mammalian predators. *Wildlife Research* 42: 518-528.

Everding, S.E. & Jones, D.N. 2006. Communal roosting in a suburban population of Torresian Crows (*Corvus Orru*). *Landscape and Urban Planning* 74: 21-33.

Ferguson, A. 2016. Using Conditioned Food Aversion (CFA) to reduce Pied Crow (*Corvus albus*) predation of plover nests. Unpublished Conservation Biology MSc thesis, University of Cape Town, Cape Town.

Fincham, J. & Lambrechts, N. 2014. How many tortoises do a pair of Pied Crows *Corvus alba* need to kill to feed their chicks? *Ornithological Observations* 5: 135-138.

Fincham, J.E., Visagie, R., Underhill, L.G., Brooks, M., & Markus, M.B. 2015. The impacts of Pied Crow *Corvus albus* on other species need to be determined. *Ornithological Observations* 6: 232-239.

Fincham, J.E. & Nupen, P. 2016. A Pied Crow *Corvus albus* survey covering 4 000km^2 of the Karoo: Autumn 2015. *Biodiversity Observations* 7: 1-4.

Fraser, D.L., Aguilar, G., Nagle, W., Galbraith, M. & Ryall, C. 2015. The House Crow (*Corvus splendens*): a threat to New Zealand? *ISPRS International Journal of Geo-Information* 4: 725-740.

Gabriel, P.O. & Golightly, R.T. 2014. Aversive conditioning of Steller's Jays to improve Marbled Murrelet nest survival. *Journal of Wildlife Management* 78: 894-903.

Hackworth, Z.J., Cox, J.J., Felch, M.F. & Weegman, M.D. 2019. A growing conspiracy: recolonization of Common Raven (*Corvus corax*) in Central and southern Appalachia, USA. *Southeastern Naturalist* 18: 281-296.

Hadjisterkotis, N. 2003. The effect of corvid shooting on the populations of owls, kestrels and cuckoos in Cyprus, with notes on corvid diet. *Zeitschrift fur Jagdwissenschaft* 49: 50-60.

Howe, K.B., Coates, P.S. & Delehanty, D.J. 2014. Selection of anthropogenic features and vegetation characteristics by nesting Common Ravens in the sagebrush ecosystem. *Condor* 116: 35-49.

Inger, R., Cox, D.T.C., Per, E., Norton, B.A. & Gaston, K.J. 2016. Ecological role of vertebrate scavengers in urban ecosystems in the UK. *Ecology and Evolution* 6: 7015-7023.

Isaksson, D., J. Wallander, and M. Larsson. 2007. Managing predation on ground-nesting birds: the effectiveness of nest exclosures. *Biological Conservation* 136: 136-142.

Joseph, G.S., Seymour, C.L. & Foord, S.H. 2017. The effect of infrastructure on the invasion of a generalist predator: Pied Crows in southern Africa as a case-study. *Biological Conservation* 205: 11-15.

Johnson, T.F. & Murn, C. 2019. Interactions between Pied Crows *Corvus albus* and breeding White-backed Vultures *Gyps africanus*. *Ethology Ecology & Evolution* 31: 240-248.

Korovin, V.A. 2019. Tendencies in the dynamics of bird communities in agricultural landscapes of the Steppe Trans-Urals at the turn of the century. *Biology Bulletin* 46: 1325-1332.

Kristan, W.B. & Boarman, W.I. 2003. Spatial pattern of risk of Common Raven predation on Desert Tortoises. *Ecology* 84: 2432–2443.

Köver, L., Gyure, P., Balogh, P., Huettmann, F., Lengyel, S. & Juhasz, L. 2015. Recent colonization and nest site selection of the Hooded Crow (*Corvus corone cornix* L.) in an urban environment. *Landscape and Urban Planning* 133: 78-86.

Köver, L., Tóth, N., Lengyel, S. & Juhász, L. 2018. Corvid control in urban environments: a comparison of trap types. *North-Western Journal of Zoology* 14: 85-90.

Krüger, H., Vaananen, V-M., Holopainen, S. & Nummi, P. 2018. The new faces of nest predation in agricultural landscapes – a wildlife camera survey with artificial nests. *European Journal of Wildlife Research* 64: 76.

Krüger, T., Heckenroth, H., Prior, N., Seitz, J. & Zang, H. 2020. Persecution and statutory protection have driven Rook *Corvus frugilegus* population dynamics over the past 120 years in NW-Germany. *Journal of Ornithology* 161: 569-584.

Latta, S.C. & Latta, K.N. 2015. Do urban American Crows (*Corvus brachyrhynchos*) contribute to population declines of the Common Nighthawk (*Chordeiles minor*)? *Wilson Journal of Ornithology* 127: 528-533.

Lauro, B. & Tanacredi, J. 2003. Habitat use of sympatrically nesting Fish Crows and American Crows. *Wilson Bulletin* 115: 382-387.

Lim, H.C., Sodhi, N.S., Brook, B.W. & Soh, M.C.K. 2003. Undesirable aliens: factors determining the distribution of three invasive bird species in Singapore. *Journal of Tropical Ecology* 19: 685-695.

Loehr, V.J.T. 2017. Unexpected decline in a population of Speckled Tortoises. *Journal of Wildlife Management* 81: 479-476.

Londei, T. 2010. How the most widespread African crow, the Pied Crow *Corvus albus*, depends on man. *Ostrich* 81: 243-246.

Madden, C., Arroyo, B. and Amar, A. 2015. A review of the impacts of corvids on bird productivity and abundance. *Ibis* 157: 1-16.

Malan, G. 2010. Distribution of nests of the Pied Crow *Corvus albus* on telephone poles in the upper Karoo. *Ostrich* 65: 44-47.

Marchant, J.H. & Gregory, R.D. 1999. Numbers of nesting Rooks *Corvus frugilegus* in the United Kingdom in 1996. *Bird Study* 46: 258-273.

Maslo, B., and J. L. Lockwood. 2009. Evidence-based decisions on the use of predator exclosures in shorebird conservation. *Biological Conservation* 142:3213–3218.

Mundy, P.J. & Cook, A.W. 1977, Observation on the breeding of the Pied Crow and Great Spotted Cuckoo in Northern Nigeria. *Ostrich* 48: 72-84.

Nxele, B.J. & Shivambu, C.T. 2018. House Crow (*Corvus splendens*) eradication measures from eThekwini Municipality, KwaZulu-Natal, South Africa. *Journal of Biodiversity Management and Forestry* 7:2.

Olea, P.P. & Baglione, V. 2008. Population trends of Rooks *Corvus frugilegus* in Spain and the importance of refuse tips. *Ibis* 150: 98-109.

Peh, K.S.-H., 2010. Invasive species in Southeast Asia: the knowledge so far. *Biodiversity and Conservation* 19: 1083-1099.

Preininger, D., Schoas, B., Kramer, D. & Boeckle, M. 2019. Waste disposal sites as all-you-can-eat buffets for Carrion Crows (*Corvus corone*). *Animals* 9: 215.

Redpath, S.M., Young, J., Evely, A., Adams, W.M., Sutherland, W.J., Whitehouse, A., Amar, A., Lambert, R.A., Linnell, J.D.C., Watt, A. & Gutierrez, R.J. 2012. Understanding and managing conservation conflicts. *Trends in Ecology and Evolution* 28: 100-110.

Riley, J.L. & Baxter-Gilbert, J. 2019. *Cordylus macropholis* (Large-scaled Girdled Lizard). Avian Predation. *Herpetological Review* 50: 371-372.

Sage, R.B. & Aebischer, N.J. 2017. Does best-practice crow *Corvus corone* and magpie *Pica pica* control on UK farmland improve nest success in hedgerow-nesting songbirds? a field experiment. *Wildlife Biology* 2107: 1-10.

Shimba, M.J. & Jonah, F.E. 2017. Nest success of the Indian House Crow *Corvus splendens*: an urban invasive bird species in Dar es Salaam, Tanzania. *Ostrich* 88: 27-31.

Shivambu, T.C., Shivambu, N. & Downs, C.L. 2020. Impact assessment of seven alien invasive bird species already introduced to South Africa. *Biological Invasions* 22: 1829-1847.

Simmons, R. & Barnard, P. 2011. Pied pirates: crow threat to raptors? *Africa – Birds & Birding* October/November, 51-54.

Spur, N., Pokorny, B. & Sorgo, A. 2016. Attitudes toward and acceptability of management strategies for a population of Hooded Crows (*Corvus cornix*) in Slovenia. *Anthrozoos* 29: 669-682.

Steenhof, K., Kochert, M.N. & Roppe, J.A. 1993. Nesting by raptors and Common Ravens on electrical transmission towers. *Journal of Wildlife Management* 57: 271-281.

Stien, J., Yoccoz, N.G. & Ims, R.A. 2010. Nest predation in declining populations of Common Eiders *Somateria mollissima*: an experimental evaluation of the role of Hooded Crows *Corvus cornix. Wildlife Biology* 16: 123-134.

Sullivan, B.D. & Dinsmore, J.J. 1990. Factors affecting egg predation by American crows. *Journal of Wildlife Management* 54: 433-437.

Vane, M. & Runhaar, H.A.C. 2016. Public support for invasive alien species eradication programs: insights from the Netherlands. *Restoration Ecology* 24: 743-748.

Vuorisalo, T., Andersson, H., Hugg, T., Lahtinen, R., Kaajsibebm H, & Lehikoinen, E. 2003. Urban development from an avian perspective: causes of Hooded Crow (*Corvus corone cornix*) urbanisation in two Finnish cities. *Landscape and Urban Planning* 62: 69-87.

Wanless, R.M. & Jupiter, T.A. 2009. Predation on doves by Pied Crows, *Corvus albus*, on Aldabra Atoll. *Ostrich* 73: 73-73.

Wilson, R.F., Sarim, D. & Rahman, S. 2015. Factors influencing the distribution of the invasive House Crow (*Corvus splendens*) in rural and urban landscapes. *Urban Ecosystems* 18: 1389-1400.

Yoda, T. 2019. Managing urban crow populations in Japan. *Human-Wildlife Interactions* 13: 439-446.

Yosef, R., Zvuloni, A. & Nufar, Y-S. 2012. House Crow (*Corvus splendens*) attempt to cooperatively kleptoparasitize Western Osprey (*Pandion haliaetus*). *Wilson Journal of Ornithology* 124: 406-408.

APPENDIX 1

List of delegates and their respective organisations which attended the online Pied Crow workshop on 25 June 2020.

DELEGATES	ORGANISATION
Andrè Wepener	Bakwena N1N4 Toll Concession
Andrew Jenkins	AVISENSE Consulting
Angela Furguson	FitzPatrick Institute of African Ornithology
Anthony van Zyl	AVISENSE Consulting
Arjun Amar	FitzPatrick Institute of African Ornithology
Beate Holscher	Private (SAOEN and Friends of Nylsvlei)
Brent Coverdale	Ezemvelo KZN Wildlife
Carles Durà	FitzPatrick Institute of African Ornithology
Charmaine van Wyk	Bakwena N1N4 toll Concession
Craig Whittington-Jones	Gauteng Department: Agricultural and Rural Development
Chrissie Parry	Molecular and Cell Biology: University of Cape Town
Gareth Tate	Endangered Wildlife Trust
James Baxter-Gilbert	Centre for Invasion Biology – Stellenbosch University
Julia Riley	Centre for Invasion Biology – Stellenbosch University
Hanneline Smit-Robinson	BirdLife South Africa
Kevin Shaw	Cape Nature
Kishaylin Chetty	Environmental Management Department – Eskom
Kyle Walker	BirdLife South Africa
Liam Clarke	Bakwena N1N4 Toll Concession
Linda van den Heever	BirdLife South Africa
Lourens Leeuwner	Endangered Wildlife Trust
Mark Anderson	BirdLife South Africa
Melissa Howes-Whitecross	BirdLife South Africa
Nkabeng Mzileni	SANParks
Robert Thomson	FitzPatrick Institute of African Ornithology
Rona van der Merwe	FitzPatrick Institute of African Ornithology
Ronelle Visagie	Endangered Wildlife Trust
Sharon Thompson	SANParks
Siya Aggrey	Centre for Invasion Biology – Stellenbosch University
Susan Cunningham	FitzPatrick Institute of African Ornithology

APPENDIX 2

Action points derived from an integration of the original draft of this review and the outcomes of the Pied Crow workshop on 25 June 2020.

ACTION POINT	RELEVANCE		SUGGESTED RESPONSIBLE AGENCY	SUGGESTED SOURCE OF FUNDING	SUGGESTED PARTNERS	ESTIMATES TIME LINES	
	FOCUS	OUTCOMES				START	FINISH
Investigate practicality and cost of widespread removal of crow nests from Eskom infrastructure	Human-wildlife conflict with knock-on implications for biodiversity	If practical and cost-effective, implement and reduce numbers of active, productive Pied Crow nests in areas of new distribution	Eskom	Eskom	Wildlife and Energy Programme (Endangered Wildlife Trust), BirdLife South Africa	Within 12 months	Short term
Investigate practicality and cost of using power infrastructure designs that discourage Pied Crows from building nests	Human-wildlife conflict with knock-on implications for biodiversity	If practical and cost-effective, implement and reduce numbers of Pied Crow nests on new infrastructure	Eskom	Eskom	Wildlife and Energy Programme (Endangered Wildlife Trust), BirdLife South Africa	Within 12 months	Short term
Monitor the colonisation of new power infrastructure by Pied Crows	Human-wildlife conflict and biodiversity impacts	Determine how quickly Pied Crows settle in new areas, using what infrastructure	Eskom	Eskom	Wildlife and Energy Programme (Endangered Wildlife Trust), BirdLife South Africa	Within 6 months	Medium term
Questionnaire study of landowner perceptions of crows, including whether or not Pied Crows do damage, if they do how, what it costs, and what if anything is currently being done to control Pied Crow numbers	Human-wildlife conflict with knock-on implications for biodiversity		Department of Agriculture, Land Reform and Rural Development	Department of Agriculture, Land Reform and Rural Development	BirdLife South Africa, Human Wildlife Solutions	Within 6 months	Short term
Review of legal and ethical aspects of the full range of Pied Crow control methods	Human-wildlife conflict with knock-on implications for biodiversity	Achieve clarity on what can and cannot be done legally and ethically to control Pied Crow numbers within each province and nationally	Department of Agriculture, Land Reform and Rural Development	Department of Agriculture, Land Reform and Rural Development	BirdLife South Africa, Human Wildlife Solutions	Within 6 months	Short term
Launch campaign to communicate to landowners that the Pied Crow issue is recognised, that research is underway and help at hand, and urging them not to start or persist with untested control or eradication methods that could cause significant harm to local biodiversity and may even exacerbate crow problems	Human-wildlife conflict with knock-on implications for biodiversity	Reduce the extent of existing collateral ecological damage caused by current efforts to control Pied Crow numbers	BirdLife South Africa, Endangered Wildlife Trust, Department of Agriculture, Land Reform and Rural Development	Department of Agriculture, Land Reform and Rural Development, agrochemical companies	Department of Agriculture, Land Reform and Rural Development, agrochemical companies	Within 6 months	Short term
Sample the diet of nesting Pied Crows in new areas of distribution	Biodiversity impacts	Establish potential to affect significant biodiversity damage across a range Karoo and Fynbos Biome habitats	Academic institutions (e.g. FitzPatrick Institute of African Ornithology)	Eskom, Telkom	Wildlife and Energy Programme (Endangered Wildlife Trust), BirdLife South Africa	Within 12 months	Short term

ACTION POINT	RELEVANCE		SUGGESTED RESPONSIBLE AGENCY	SUGGESTED SOURCE OF FUNDING	SUGGESTED PARTNERS	ESTIMATES TIME LINES	
	FOCUS	OUTCOMES				START	FINISH
Structured, experimental research on the relationship between Pied Crow expansions and local biodiversity, preferably by doing BACI-design surveys of Pied Crow diet and small animal diversity and density sampling across a range of nesting substrates, vegetation types and land uses. Ideally base this work on areas targeted for new power line installations and comparable control sites, otherwise perform crow removal experiments in existing areas of new colonisation	Biodiversity impacts	Empirically test for and quantify the impact of Pied Crow population expansion on biodiversity (also examine the biodiversity implications of either the installation of new power infrastructure, or of the removal of Pied Crows)	Academic institutions (e.g. FitzPatrick Institute of African Ornithology)	?	Eskom, Telkom, Wildlife and Energy Programme (Endangered Wildlife Trust), BirdLife South Africa	Within 12-18 months	Medium–long term
Structured, experimental research on the relationship between Pied Crow expansions and the presence/absence, density and breeding success of other corvids and raptors, preferably by doing BACI-design crow and raptor surveys in conjunction with the installation of new infrastructure, otherwise perform crow removal experiments in existing areas of new colonisation	Biodiversity impacts	Empirically test for and quantify the impact of Pied Crow population expansion on biodiversity	Academic institutions (e.g. FitzPatrick Institute of African Ornithology)	?	Eskom, Telkom, Wildlife and Energy Programme (Endangered Wildlife Trust), BirdLife South Africa	Within 12-18 months	Medium–long term
Structured, experimental research on the relationship between Pied Crow expansions and the management of waste along roadways and in association with human settlements, preferably by doing BACI-design crow surveys in conjunction experimental variation in waste management practices	Drivers of Pied Crow expansion	Empirically test for and quantify the response of Pied Crows to different forms of waste management	Academic institutions (e.g. FitzPatrick Institute of African Ornithology)	BAKWENA, SANRAL, SA government (Environment, Health, Transport, Sanitation)	Endangered Wildlife Trust, BirdLife South Africa, BAKWENA, SANRAL, SA government (Environment, Health, Transport, Sanitation)	Within 12-18 months	Medium–long term