The impact of two extreme weather events and other causes of death on Carnaby's Black Cockatoo: a promise of things to come for a threatened species?

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Carnaby's Black Cockatoo is an endangered species which has undergone a dramatic decline in range and abundance in southwestern Australia. Between October 2009 and March 2010 the species was subjected to a possible outbreak of disease in one of its major breeding areas and exposed to an extremely hot day and a severe localized hail storm. In addition, collisions with motor vehicles are becoming an increasing threat to the species. All of these stochastic events resulted in many fatalities. Species such as Carnaby's Black Cockatoo which form large flocks are particularly susceptible to localized events such as hail storms, contagious disease and collisions with motor vehicles. Extreme temperatures may have major impacts on both flocking and non-flocking species. Predictions of climate change in the southwest of Western Australia are that there will be an increased frequency of extreme weather events such as heat waves and severe hail storms. The implications of more events of this nature on Carnaby's Black Cockatoo are discussed.

Key words: Carnaby's Black Cockatoo, *Calyptorhynchus latirostris,* extreme heat, disease, hail damage, climate change, motor vehicle collisions

INTRODUCTION

CARNABY'S Black Cockatoo *Calyptorhynchus latirostris* has undergone a major decline in range and abundance over the past 50 years (Saunders 1990; Saunders and Ingram 1995, 1998). As a result, it is listed as endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* and as "Fauna that is rare or likely to become extinct" in Schedule 1 of the Western Australian *Wildlife Conservation Specially Protected Fauna) Notice 2010* under the *Wildlife Conservation Act 1950*. As a consequence of its endangered status it is the subject of a recovery plan (Cale 2003). Extensive removal and fragmentation of native vegetation for the development of broad-scale agriculture was the primary reason for its decline. While the rate of broad-scale clearing is now limited in the wheatbelt of Western Australia, urban and peri-urban development continues to result in loss of foraging habitat in areas used during the non-breeding season.

The species formerly occurred in the southwest corner of Western Australia in an area bounded roughly by a line between Kalbarri in the north to east of Esperance on the south coast (Saunders 1990) (Fig. 1). However, it has been extirpated from a considerable portion of the eastern and drier part of its former range (Saunders 1990). Most of the population breeds in hollows in eucalypt woodlands in what is now known as the wheatbelt. After breeding, the birds move closer to the coast where they forage in larger flocks than are seen in the breeding areas (Saunders 1980). These flocks consist of breeding adults and birds younger than four years of age (the age at which breeding commences) from a number of different breeding areas.

While the impact of clearing and fragmentation of vegetation on the species has been demonstrated, there is little information on the role of stochastic events in this or many other species. Species such as Carnaby's Black Cockatoo, which form large conspicuous flocks, may be subject to threats from some stochastic events that would not apply, or not be as obvious, in more dispersed and non-flocking species. A possible disease outbreak, a severe localized hail storm, a day of localized extreme temperature and collisions with motor vehicles provide four such examples. The possible disease outbreak was in a significant breeding colony located in one of the 74 designated Important Birds Areas (IBA) in Western Australia (Dutson *et al.* 2009). Koobabbie, the IBA where this event took place (Fig. 1) was designated on the basis of its importance as a breeding area for Carnaby's Black Cockatoo.

Possible disease outbreak

At Koobabbie, on 30th September 2009, an adult male Carnaby's Black Cockatoo was found on the ground, unable to walk. On advice from Department of Environment and Conservation (DEC) officers the bird was captured, euthanased and frozen for subsequent post mortem examination and pathology tests. The decision to freeze

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PACIFIC CONSERVATION BIOLOGY Vol.17: 141–148. Surrey Beatty & Sons, Sydney. 2011.

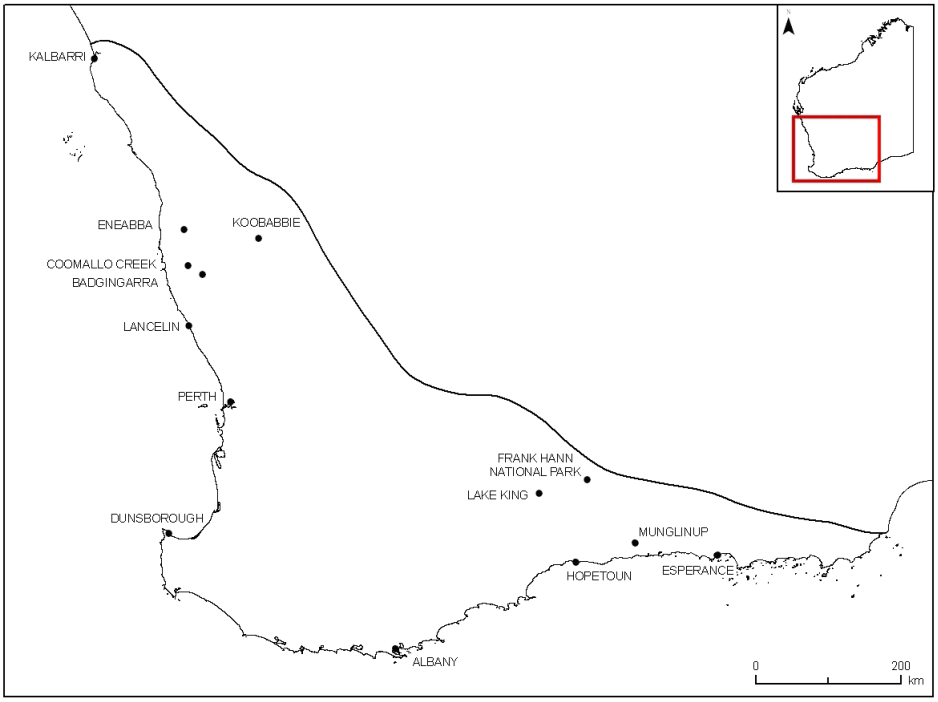

Fig. 1. Places named in the text and former distribution of Carnaby's Black Cockatoo shown by solid line stretching from Kalbarri to east of Esperance.

the carcase rather than to refrigerate it was made after taking into consideration the distance of the site from pathology services and advice from pathologists from the Department of Agriculture and Food Western Australia (DAFWA). The pathology report was unremarkable, in that aside from gross anatomical changes normally associated with freezing, there was no evidence of physical abnormality. Tests for organophosphates, organochlorines and heavy metal poisoning were unremarkable within the limits of the testing, and there was no evidence of chlamydiosis, avian influenza or Newcastle disease.

On 23rd October 2009, DEC received a report that 11 dead cockatoos (presumed to be breeding females) were found in nest hollows at Koobabbie. A further four dead birds were found on the ground nearby. Abandoned cockatoo eggs were found in another five nest hollows at the same site. Estimates are that as many as 23 female Carnaby's Black Cockatoo may have died at Koobabbie, which normally supports up to 30 nesting pairs and produces as many as 19 fledglings per year (PM and RD, unpublished data). The 15 birds had been dead for some weeks as some were reduced to dried tissue, bones and feathers. All affected birds were in a sitting position with heads slumped forward and showed no signs of struggle or interference (as might be expected from predators). Material from each carcase was collected, individually bagged and labelled, but no further analyses were possible.

Hail Stress

On the afternoon and early evening of 22nd March 2010, severe thunderstorms occurred over much of the southwest of Western Australia. The Perth metropolitan area was hit particularly hard between 1530 and 1800 hours with the largest hail stones (up to 6cm diameter) known to have fallen close to the central business district (http://www.bom.gov.au/wa/sevwx/perth_100322/perth_20100322.shtml and http://au.news.yahoo.com/thewest/full-coverage/storm/-/6972051/perths-storm-disaster/ accessed September 2010). This hail, associated heavy rain, and strong winds resulted in property damage estimated to be in excess of AUD $1 billion dollars.

Eighty-one Carnaby's Black Cockatoo were known to have been affected by the hail. Fifty-seven were killed and 24 were so badly injured with soft tissue and skeletal damage they were taken to wildlife rehabilitation centres. With such an influx of injured birds, priority was given to their care and no opportunity was available to carry out detailed post mortems to determine the age and sex of the affected birds.

The 81 birds were recovered from close to the centre of the city and areas to the north. Thirty-four of these birds were found in Kings Park, an area of native vegetation on the edge of the central business district. Twenty-six of the Kings Park birds were dead and eight were treated for injuries. In Kings Park, the hail was so severe that many trees in some areas of the park were

completely defoliated. There were so many leaves on the ground that some of the park's roads and tracks were completely obscured (RD pers. obs.). Witnesses to the storm in the area reported that the birds had been roosting in *Banksia* trees and lacked any protection from the hail. Eleven of the birds taken to rehabilitation centres were so badly injured they could not be released back to the wild.

Collison with motor vehicles

In 2009 and 2010, 264 injured or dead Carnaby's Black Cockatoo were taken to the Perth Zoo or the Black Cockatoo Rehabilitation Centre. Sixty-eight of these were as a result of the hail storm. Thirteen of the birds injured during the hail storm were successfully rehabilitated, individually marked with Australian Bird and Bat Banding scheme approved leg bands and released back into Kings Park on 7th April 2010. One of the birds (band #320-00881) released was subsequently recovered on 6th May 2010 (30 days post-release) when it was involved in a collision with a vehicle in the nearby suburb of Victoria Park (a distance of 5.9km from the release point). The bird was again taken into care, but its injuries were so severe it was euthanased the following day on advice from veterinarians at the Perth Zoo. A second bird (band #320-00883) from the same release event on 7th April was recovered dead (again due to collision with a vehicle) on the 8th August (122 days post-release) at Manning Lake (16km SSW from the release point). Within four months of release after rehabilitation, at least 15% of the rehabilitated and released birds had been killed in collisions with motor vehicles.

Analysis of data collected on Carnaby's Black Cockatoo received into care by DEC and treated at the Perth Zoo and Black Cockatoo Rehabilitation Centre during 2009–2010 indicates that injury or death due to collision with motor vehicles ranged from 6.3–10.0% (Table 1). These data are conservative estimates as a larger percentage of the birds examined had sustained bone fractures (14.3–38.5%), but there were inadequate data accompanying the specimens to know the cause of the damage. It is the personal experience of two of the authors (PM and RD) that the two most common causes of fractures in cockatoos are collisions with vehicles and shooting.

Heat stress

During the period from 6th to 8th January 2010, 145 Carnaby's Black Cockatoos were found dead in trees and on the fairways of the Hopetoun golf course on the south coast of Western Australia (Fig. 1). These deaths were widely reported in Australian news media with an article in *The West Australian* newspaper on 9th January 2010 under the title "DEC to probe why birds 'dropped dead from the sky'" being illustrative of this coverage (see http://www.watoday.com.au/wa-news/heat-kills-150-endangered-black-cockatoos-20100108-lyld.html accessed March 2011). Some articles were accompanied by a dramatic photograph of many of the dead birds laid out in front of a garage on the golf course.

Over the same period, 63 Carnaby's Black Cockatoo died while roosting in trees in a small Blue Gum *Eucalyptus globulus* plantation on the corner of Springdale and Doyle roads south of Munglinup and an adjacent property (Fig. 1), about 75 km east of Hopetoun. These deaths may have gone unnoticed, but for the fact that the DAFWA maintains a cage trap for Common Starling *Sturnus vulgaris* in the plantation. The dead cockatoos were seen and reported by a DAFWA officer tending the trap and collected by a DEC officer based in Albany. On 4th May 2010, one of us (DAS) visited the plantation and spoke to the owner of the farm on which the plantation was located. The owner knew of the mass deaths of the cockatoos at Hopetoun, but was unaware of the mass deaths on his property. He stated that he regularly sees flocks of at least 100 Carnaby's Black Cockatoo on his property, particularly when he has swathed canola (*Brassica napas* and *B. juncea*), on which the birds feed (Jackson 2009).

Eleven refrigerated (ten from Hopetoun and one from Munglinup) and ten frozen (all from Hopetoun) cockatoo carcases were transported to Perth and submitted to the DAFWA pathology unit for examination. The full details of the post

Table 1. Veterinary diagnosis of the cause of injuries or death of Carnaby's Black Cockatoo (percentages in brackets) received into care by Perth Zoo and Black Cockatoo Rehabilitation Centre during 2009-10. Birds killed or injured in the hail storm on 22nd March 2010 have not been included.

Year	Fractures and internal injuries — collision with vehicles	Fractures — cause unknown	Shot	Other	Unknown	Total
2009	7 (10.0)	27 (38.5)	3 (4.3)	16 (22.9)	17 (24.3)	70
2010	8 (6.3)	18 (14.3)	1 (0.8)	19 (15.1)	80 (63.5)	126
Total	15 (7.7)	45 (23.0)	4 (2.0)	35 (17.8)	97 (49.5)	196

mortems and the results of the organochlorine, organophospate and heavy metal testing that were conducted at the Western Australian Chemistry Centre were posted on the DEC website on 18th May 2010 (see http://www.dec.wa.gov.au/content/category/43/854/1991/ accessed March 2011). The report confirms no underlying disease and no pesticide or heavy metal contamination that could explain the mass deaths. The pathologist's finding was that heat stress was the most likely cause of the deaths. The report stated that:

"*While there are no gross or microscopic lesions exclusive to heat stress both the absence of other disease processes and the consistent pathological changes of congestion, pulmonary oedema and haemorrhage support the provisional diagnosis . . . The only consistent findings between birds were the presence of mild to moderate pulmonary oedema and diffuse, severe congestions of all tissues . . . Pulmonary oedema may reflect compromise of vascular integrity (considered probable) or pulmonary hypertension (considered unlikely). Subcutaneous oedema in bird 21* [specimen from Munglinup] *and the small, multi-organ haemorrhages noted in multiple birds reflects a loss of vascular integrity. Diffuse congestion suggests systematic circulatory failure (shock). These changes can be induced by several processes including infection, sepsis, trauma, cardiac failure and heat stress. Evidence of infection, sepsis, primary cardiac disease or trauma was not found in these cases. These changes may occur in heat stress due to the high demand for blood flow to the skin/extremities for effective thermoregulation with concurrent demand for perfusion to the internal organs. This may lead to hypoperfusion of vital organs (liver, kidney, brain) leading to multiorgan failure and death.*"

DNA samples were taken from a further 78 birds, and the carcases were lodged with the Western Australian Museum. When the carcases were processed at the Western Australian Museum, the age and sex of 74 of these birds were determined (Table 2). A positive determination of age, sex or both was not always possible due to the extent of decomposition of the carcases. Ninety per cent of the 53 birds from Hopetoun and 80% of the 21 from Munglinup were adults.

One of the birds found dead south of Munglinup was banded (band #320-00736). It had been banded by RD south-east of Lake King as a nestling on 28th November 2008. It was recovered 103km from where it had fledged more than 13 months before.

DISCUSSION

Possible disease outbreak

In the spring of 2009 there were 23 breeding attempts by Carnaby's Black Cockatoo at Koobabbie. Of these, 11 failed with females dead in the nest hollows and another five failed on eggs. The reasons for these deaths are unclear. They could have been the result of contagious disease, poisoning or weather related. It was only possible to carry out a post mortem on one bird from the area and no evidence of toxic levels of organophosphates, organochlorines or heavy metals were found. Neither was there any evidence for chlamydiosis, avian influenza or Newcastle disease. Weather is unlikely to have been the cause of the deaths as other nearby breeding populations, monitored by us, exposed to the same climatic conditions as the Koobabbie birds did not suffer any deaths of breeding adults in, or around, nest sites.

The most likely cause was a contagious disease, although poison cannot be ruled out. What is known is that whatever was responsible for the deaths had a major impact on the Carnaby's Black Cockatoo population breeding in the area. There were 29 known breeding attempts at Koobabbie the previous breeding season (2008). During the breeding season of 2010 there were 10 known breeding attempts (J Laurie in litt.), a halving of the breeding population. This provides an example of the potential importance of contagious wildlife disease events and highlights how little we know of natural disease processes in wild native animal populations. Despite not obtaining any

Table 2. Age and sex of a sample of 74 Carnaby's Black Cockatoo recovered from Hopetoun and Munglinup after the extreme heat event of 6th January 2010.

Hopetoun Age\Sex	Male	Female	Unknown	Total
Adult	17	30	1	48
Juvenile	1	1	1	3
Unknown	0	0	2	2
Total	18	31	4	53
Munglinup Age\Sex	Male	Female	Unknown	Total
Adult	10	7	0	17
Juvenile	0	0	1	1
Unknown	0	2	1	3
Total	10	9	2	21

confirmed diagnosis from the one bird that was able to be subjected to detailed pathology, we have gathered valuable data on baseline pathology and external contaminant levels in wild Carnaby's Black Cockatoo.

Hail stress

Eighty-one Carnaby's Black Cockatoo were killed or injured in the hail storm in Perth on 22nd March 2010. Thirteen of the 24 which were taken into rehabilitation centres subsequently recovered and were released. Accordingly, 68 birds are known to have been lost to the wild population due to this one event. No one knows how many more were killed or maimed, but were not reported. How significant is this loss to the population frequenting the Perth region? One way to examine this is to look at what percentage of the species has been affected.

How many Carnaby's Black Cockatoo are there? Based on the distribution of birds during the breeding season, Saunders *et al*. (1985) estimated a total of 11 000 to 60 000. Johnstone, R. E., Johnstone, C. and Kirkby, T. (in litt.) reported that in 2005–2006 they believed that the population of Carnaby's Black Cockatoo on the Swan Coastal Plain between Lancelin and Dunsborough in the non-breeding season was between 10 000 and 15 000 with the majority of these in the area between Perth and Lancelin. These numbers consist of breeding adults with their offspring and young birds not yet of breeding age from areas ranging from the northeast to the southeast of Perth. Burnham, Barrett, Blythman and Scott (Great Cocky Count report 2010 see http://www.dec.wa.gov.au/content/view/6198/2308 accessed March 2011) estimated that 8 000–10 000 cockatoos used the area between Lancelin and Bunbury during summer-autumn of 2010. Finn, Stock and Valentine (in litt.) (see http://ro.ecu.edu.au/ecuworks/6210/ accessed March 2011) provide data on numbers on the Swan Coastal Plain to the north of Perth. Their total estimates from seven districts within this area for the first half of 2009 range from 2 672 to 3 329. The numbers reported now are considerably less than the flocks of 5 000–6 000 noted in Somerville pine plantation (now cleared for suburbs round Perth suburbs of Murdoch and Booragoon) in the 1940s (Perry 1948) and flocks of over 3,000 seen in Somerville and Collier (now cleared for urban development in South Perth) pine plantations in the late 1960s (Saunders 1980, DAS pers. obs.).

More locally, Berry and Owen (2010) reported flocks of up to 500 birds in an area close to the sites that bore the brunt of the March 22nd hail damage. Burnham, Barrett, Blythman and Scott (in litt.) reported the largest flock in this same area in 2010 as 604 birds. Using these figures, somewhere between 11 and 13% of the birds were lost to this local population as a result of that one storm. Using Burnham, Barrett, Blythman and Scott's (in litt.) estimates for the population between Lancelin and Bunbury, this represents from 0.7 to 0.9% of the total.

Collisions with motor vehicles

Worldwide, motor vehicles are a significant cause of bird deaths. In a review on bird mortality as a result of collisions, Erickson, Johnson and Young (in litt. 2005 USDA Forest Service Gen. Tech, Rep. PSW-GTR-191 see http://www.fs.fed.us/psw/publications/documents/psw_gtr191/Asilomar/pdfs/1029-1042.pdf accessed March 2011) estimated that around 80 million birds are killed annually by vehicles in USA. Saunders (1982) reported on known causes of deaths of 35 individually marked Carnaby's Black Cockatoo. Four (11%) of these were due to collisions with cars. Two of these were killed by the same car and resulted in the failure of two out of the 14 breeding attempts at Manmanning that year. The fact that in 2009 and 2010 up to 30.7% of Carnaby's Black Cockatoo taken to rehabilitation centres in the Perth metropolitan area and 15% of the rehabilitated birds released after the March hail storm were killed by cars within four months of release indicates that cars are still a potent threat to the species.

Unfortunately much remnant vegetation is distributed along road verges and black cockatoos often fly out into clear air space when leaving a feeding site. Along road verges, this often leads them straight into the path of traffic, often with fatal consequences. It is highly unlikely that the species can evolve an escape mechanism to avoid such fatalities.

Heat stress

There is little reason to doubt that the black cockatoos at Hopetoun and Munglinup died on the 6th January as a result of heat exhaustion, as did a number of other species. Bureau of Meteorology (http://www.bom.gov.au/wa/ accessed March 2011) (BOM) records show the minima and maxima for Hopetoun for the period 5th, 6th and 7th January 2010 were 17.8°C–26.4°C, 17.7°C–48.0°C and 19.1°C–24.3°C. The temperatures at Munglinup West weather station over the same period were 15.2°C–34.1°C, 14.7°C–47.6°C and 17.5°C–25.8°C. The relative humidity at 0900 and 1500 hours on each of those days at Munglinup West was 55%/50%, 20%/6% and 58%/85%.The relatively mild day on the 5th was followed by an extremely hot, dry day, then a return to cooler weather and more humid

conditions. To make conditions more extreme, there was a hot northerly wind of over 60km/hr blowing in the Hopetoun-Munglinup area for much of the 6th January (RD pers. ob.), with a maximum wind gust of 83km/hr from the north recorded. BOM records are taken in Stevenson screens which provide shade to the instrumentation, and hence understate the temperatures in the open. Residents in the Munglinup area reported temperatures on the 6th in the range of 53°–55°C. The combination of extreme heat, low relative humidity and strong north winds on that day was extraordinary.

At Hopetoun other affected species included two Galah *Cacatua roseicapilla*, six Regent Parrot *Polytelis anthopeplus*, three Australian Magpie Lark *Grallina cyanoleuca*, three Australian Raven *Corvus coronoides*, four Yellow-throated Miner *Manorina flavigula*, while an Australian Kestrel *Falco cenchroides* was also found dead at Munglinup. A commercial apiarist working at Frank Hahn National Park, 150km north of Hopetoun left the area at 1100 h on 6th January when the temperature reached 53°C. He reported to DEC staff that when he returned the following day to check on the welfare of his managed hives he found 50–60 dead birds, including Black Honeyeater *Certhionyx nigra*, Red Wattlebird *Anthocaera carunculata*, Mulga Parrot *Psephotus varius* Purple-crowned Lorikeet *Glossopsitta porphyrocephala* and Bronze-winged Pigeon *Phaps chalcoptera*.

The pathologist's report on those Carnaby's Black Cockatoos subjected to post mortem indicated heat stress as the most likely cause of death. The fact that a range of species with different diets and requirements for water died in the same location rules out poison as the reason for the deaths. This day of extreme heat was apparently confined to the southeast of the range of Carnaby's Black Cockatoo, as Esperance to the east was subjected to the same extreme heat on the 6th (maximum 46.4°C), while Albany to the west was not (maximum 26.7°C). The south-west of Western Australia is regularly subjected to the formation of heat lows along the lower west coast in the austral autumn which then slowly move in an easterly direction. Cool, moist conditions follow in behind the heat lows providing welcome relief to humans and wildlife alike.

Saunders (1982) noted that during very hot weather Carnaby's Black Cockatoo could not forage and sat in the foliage of trees out of the sun during the heat of the day. Very hot weather reduces the time available for foraging and drinking and can exacerbate the impacts of any food shortages. While the birds killed at Hopetoun and Munglinup were not subjected to food shortages (as determined by the presence of food in the crops of many of the cockatoos examined), the extreme heat may have limited their ability to obtain water. The deaths of these cockatoos (and other species) on the 6th January are potent examples of the impacts of extreme heat waves discussed by McKechnie and Wolf (2010). They describe how birds, because of their relatively small body size, predominately diurnal habits, limited use of thermally buffered micro-habitats, are vulnerable to extreme heat waves. They point out how under extreme heat, birds may lose up to 5% of their body mass per hour and rapidly reach their limits of dehydration tolerance. They present modelling of water requirements and survival times during the hottest times of the day, when rates of evaporative water loss are high, but drinking and foraging behaviours are reduced, if not impossible. They clearly show rapid dehydration and death occurring in such extreme heat and review a number of such cases, including Welbergen *et al*.'s (2008) documented case of the impacts of extremely hot days on several species of Australian flying-foxes.

Assuming that the 74 cockatoo carcases that were recovered, aged and sexed were a random sample of the 208 that were found dead, there appears to be a bias in favour of adults (Table 2). In the first week in January, Carnaby's Black Cockatoo breeding in areas close to the south coast may still have chicks in nest hollows (PM and RD, unpublished data). If so, the total impact on the Hopetoun and Munglinup cockatoo populations was not limited to the 208 birds recovered, but may have also affected many chicks as a result of their parents being killed, if the chicks were not killed by the extreme heat.

While the 208 birds found dead of heat stress on the 6th January is a significant loss for an endangered species, it may be indicative of a much greater loss affecting a major part of the southern portion of the population. These 208 birds were those found and reported to the conservation authorities from two small areas. The south coast, where the southern portion of Carnaby's Black Cockatoo population spends the non-breeding season, has a low human population density and it is highly likely that more cockatoos died over the entire extent of the heat wave, but were not discovered. There are no estimates of the size of the southern portion of the population, so no way of knowing the extent of the impact of these losses.

Movements of the south-eastern population of Carnaby's Black Cockatoo

Based on the recovery of banded birds and the sightings of tagged and banded individuals, Saunders (1980) demonstrated that the popula-

tions of Carnaby's Black Cockatoo occurring between Eneabba, in the north of the range and Tarwonga in centre of the range moved towards the coast (higher rainfall areas) at the end of the breeding season (from December on). The birds from Coomallo Creek in the northern part of the range moved towards the coast and foraged over an area from Badgingarra north to Eneabba and the coast. Birds from the central wheatbelt moved to the Swan Coastal Plain forming big flocks, feeding predominantly in large pine plantations in Perth and to the north of Perth. Birds from the southern part of the central wheatbelt also moved towards the coast and to the south of Perth.

No information was then available about the movements of the birds from the south-eastern part of their range. Speculation based on known movements of the birds to the north and observations of flocks in the non-breeding season, led to suggestions that this south-eastern population also moved towards the coast and higher rainfall areas, in this case to the south coast (Johnstone, R. E., Johnstone, C. and Kirkby, T. in litt.). The recovery of the banded juvenile (#320-00736) among the heat-stressed dead birds south of Munglinup is the first confirmation that the birds in the south-eastern part of the range do move towards the coast during the non-breeding season.

What of the future?

Climate change predictions are that south-western Australia is likely to experience more exceptionally hot years and more extreme temperatures (Hennessy *et al.* 2008), with an increase in the number and severity of hot days (CSIRO 2007).

The fact that Carnaby's Black Cockatoo forms large foraging flocks during the non-breeding season means that the birds are concentrated into a number of such flocks scattered over the higher rainfall portion of their range. As pointed out by Saunders (1980), the Swan Coastal Plain could host up to a quarter of the total population. These flocks may also give rise to the mistaken impression that the birds are common and under no threat. While they may in some areas be locally common, they are in fact under considerable threat and when concentrated into flocks, significant numbers of the species may be susceptible to extreme weather events such as extremely hot days and storms.

The distribution of Carnaby's Black Cockatoo in the southwest of Western Australia is bounded by the sea and the arid zone. Hence the species has no room to shift its distribution in order to move as a consequence of any adverse changes in climate. Should the predictions of more extreme weather events such as the extreme heat of the 6th January or the hail of 22nd March take place, then pressures on this endangered species will increase.

Carnaby's Black Cockatoo is already under considerable pressure and any increase in adverse stochastic events will only lead to greater pressure. The species cannot afford to lose such a large number of individuals, particularly breeding individuals, in such a short period. One of the unfortunate consequences of land clearing and habitat degradation is that the remaining birds are forced into smaller and smaller areas, with fewer flocks which represent increasingly larger proportions of the total population and so the effects of such stochastic events as occurred in 2009/2010 will be more severe for the species. With the increasing urbanization of much of the range of Carnaby's Black Cockatoo there is need to protect all remaining foraging and roosting habitat and for the creation of more such habitat.

The issue that can be least well explained in this study is the one relating to disease in wild cockatoo populations. To understand the nature of disease in wild cockatoo populations better, in November 2010 DEC commenced a collaborative research programme with the Perth Zoo and Murdoch University to collect baseline blood chemistry, endo- and gastro-intestinal parasite burdens, and exposure to *chlamydia psittaci*, psitticine circoviral disease and avian polyomavirus. This programme will test Carnaby's Black Cockatoo nestlings across a range of breeding sites along with as many birds as possible that are taken into care and rehabilitated. The programme is scheduled to run until July 2013, subject to securing ongoing funding.

ACKNOWLEDGEMENTS

We are grateful to: Jon Pridham, Chris Phoebe, Paul Cory, Greg Broomehall, Alex Bowlay and Matt Swan (DEC), Colin Parry (DAFWA), John Laurie (Birds Australia) and Alison Doley for assistance in the field; Ron Johnstone for providing the data on the demographics of the birds collected from Hopetoun and Munglinup; Anna Le Soeuf (Perth Zoo) and Glenn Dewhurst (Black Cockatoo Rehabilitation Centre) for data relating to birds taken into care; Amy Mutton for preparing Figure 1; and Lesley Hughes, Richard Hobbs, Harry Recher, Mike Calver, Penny Olsen and two anonymous referees for constructive criticism of earlier drafts of this manuscript.

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