How many bird extinctions have we prevented?

Stuart H.M. Butchart, Alison J. Stattersfield and Nigel J. Collar

Abstract Considerable resources and efforts have been directed at biodiversity conservation in recent years, but measures of the success of conservation programmes have been limited. Based on information on population sizes, trends, threatening processes and the nature and intensity of conservation actions implemented during 1994–2004, we assessed that 16 bird species would have probably become extinct during this period if conservation programmes for them had not been undertaken. The mean minimum population size of these 16 species increased from 34 to 147 breeding individuals during 1994–2004. In 1994, 63% of them had declining populations but by 2004, 81% were increasing. Most of these species (63%) are found on islands. The principal threats that led to their decline were habitat loss and degradation (88%), invasive species (50%) and exploitation (38%), a pattern similar to that for other threatened species, but with exploitation and invasive species being relatively more important. The principal actions carried out were habitat protection and management (75% of species), control of invasive species (50%), and captive breeding and release (33%). The 16 species represent only 8.9% of those currently classified as Critically Endangered, and 1.3% of those threatened with extinction. Many of these additional species slipped closer to extinction during 1994–2004, including 164 that deteriorated in status sufficiently to be uplisted to higher categories of extinction risk on the IUCN Red List (IUCN, 2006). Efforts need to be considerably scaled up to prevent many more extinctions in the coming decades. The knowledge and tools to achieve this are available, but we need to mobilize the resources and political will to apply them.

Keywords Conservation action, Critically Endangered, exploitation, extinction, invasive species, IUCN Red List.

Introduction

The world's biodiversity is being destroyed at ever-increasing rates (Jenkins *et al*., 2003), and recent extinction rates are 1,000–11,000 higher than background rates (Pimm & Brooks, 1999). This situation has prompted the nations of the world to pledge to reduce significantly the rate of biodiversity loss by 2010 (Secretariat of the Convention on Biological Diversity, 2003). Certainly, substantial resources have been spent on conserving biodiversity in recent years. For example, based on figures from the mid 1990s, James *et al*. (2001) estimated that USD 6 billion is spent annually on management of protected areas alone. The US Fish and Wildlife Service's budget alone in 2004 was almost USD 1.3 billion in 2004 (USFWS, 2004a), while in 2003 the combined state and federal spending totalled USD 16 million for bald eagle *Haliaeetus leucocephalus* and USD 12.4 million for red-cockaded woodpecker *Picoides borealis*, and six other species received more than USD 5 million each (Anon., 2005). In Australia, nearly USD 22 million was spent on the conservation of 78 threatened bird taxa during 1993–2000. This equated to USD 480,000 per Critically Endangered species and more than USD 5,500 per individual bird for these species over the same 8-year period (although it should be noted that conservation benefits often extend beyond the particular species targeted; Garnett *et al*., 2003).

Has this funding had any effect on extinction rates? Unfortunately, because extinctions are difficult to detect extinction rates are problematic to estimate (Diamond, 1987; Butchart *et al*., 2006). For a species to be listed as Extinct requires exhaustive surveys to have been undertaken in all known or likely habitat throughout its historic range, at appropriate times (diurnal, seasonal, annual) and over a time frame appropriate to its life cycle and life form (IUCN, 2001). Even among birds, the best known class of organisms, there are 16 species that are classified as Critically Endangered (Possibly Extinct) because their extinction is suspected but requires confirmation (Butchart *et al*., 2006). One of these probably went extinct in the wild during 1994–2004 (Spix's macaw *Cyanopsitta spixii* in 2001) and two other species are confirmed to have gone extinct during this period: nukupu'u *Hemignathus lucidus* disappeared in 1996 and Hawaiian crow *Corvus hawaiiensis* went extinct

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in the wild in 2002 (BirdLife International, 2004a; Butchart *et al*., 2006). Many other bird species slipped closer to extinction, showing reduced populations or increasing rates of decline, but not at a rate sufficient to cross thresholds for higher categories on the IUCN Red List.

One measure of whether conservation efforts have had any success in reducing these deteriorating trends is to determine if conservation programmes have managed to prevent any extinctions. In order to address this question we examined information on the population size and trends of the world's birds, the threats to them, and the conservation actions taken during the decade 1994–2004.

Methods

To identify those species for which conservation may have prevented extinction during 1994–2004 we drew up a list of candidates by examining information on all 168 species classified as Critically Endangered in 1994, plus 73 species that would have qualified had current information been available then. We identified 27 such candidate species that (a) are currently still recognized taxonomically as species, (b) had a known population during 1994–2004, (c) are believed on present knowledge to have still been extant in 1994 and remained extant in 2004, (d) had a minimum population estimated to be <100 individuals in 1994 or had a population that was estimated to be <200 individuals and estimated, inferred or suspected to be declining at a rate >80% over 10 years or three generations (whichever was longer, as specified in the IUCN Red List criteria; IUCN, 2001), and (e) received direct conservation interventions during 1994–2004 that significantly mitigated a key threat to the species. We chose the period 1994–2004 because the best information is available for this period: Collar *et al*. (1994) provided the first assessment of all the world's birds for the IUCN Red List using the explicitly quantitative Mace-Lande extinction risk criteria, and gave sufficient information to make comparisons with the status of these species as assessed in BirdLife International (2004a).

We then examined each of the 27 candidate species in greater detail to assess the likelihood that they would have failed to survive if conservation action for them had ceased in 1994. Insufficient data were available to carry out detailed population modelling to quantify their extinction probability in the absence of conservation action. Instead, we attempted to decide as objectively as possible, considering the population size, trends, severity of threats and intensity and effectiveness of conservation interventions, whether each species was likely to have gone extinct had conservation action ceased in 1994. We gathered such information from the accounts published in Collar *et al*. (1994) and BirdLife International (2000, 2001, 2004b), and from personal communication with species experts (see Acknowledgements). For each species we weighed up this evidence and estimated the probability that they would have gone extinct during the period as certain, very high, high, medium or low.

To compare species that avoided extinction with other threatened species, we categorized their threats according to the classification of IUCN (IUCN, 2006). For species that avoided extinction, we identified the most important threats that led to their population declines, and also the most important threats addressed by conservation action that led to recoveries or reduced declines. We compared these to 'high' and 'medium' impact threats for other threatened species (calculated from scores for timing, scope and severity: see BirdLife International, 2004b, for details).

The possibility exists that so-called charismatic species attract more conservation attention than others, and we tested for this by separating out large, conspicuous and/or colourful species as charismatic (hence including albatrosses, waterbirds, raptors, galliformes, pigeons, parrots, hummingbirds, hornbills and some brightly or strikingly patterned or coloured passerines).

Results

Of 27 possible candidates, we judged that 16 species would probably have gone extinct in the absence of conservation intervention from 1994 to 2004, based on assessments of their population sizes and trends, the threats affecting them and the conservation actions undertaken. This total includes one species that became extinct in the wild briefly during the period (California condor *Gymnogyps californianus*), nine species that we estimate had a very high likelihood they would have gone extinct, and six species with a high likelihood (Table 1). The remaining 11 species were judged likely to have been close to extinction during this period, but were estimated to have a low (10 species) or medium (one species) likelihood that they would have gone extinct in the absence of conservation action (Table 2).

The 16 species that were prevented from going extinct all had very small population sizes at the beginning of the period. Their mean minimum population size in 1994 was 34 individuals (range 8–118 breeding individuals, where these data are available), with only four known breeding pairs of Chatham Island taiko *Pterodroma magentae*, four surviving female Norfolk Island green parrots *Cyanoramphus cookii* and the entire (previously released) population of California

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Table 1 Species judged likely to have gone extinct during 1994–2004 if conservation action had not taken place (see also Fig. 1). Population estimates refer to birds in the wild. Sources are additional to BirdLife International (2004b).

Species	1994 population estimate	1994 trend	2004 population estimate	2004 trend	Threats	Conservation action taken	Extinction probability if action had ceased in 1994	Sources
Junín grebe *Podiceps taczanowskii*	50–205	Declining rapidly from *c.* 1,000 in 1960s, *c.* 250 in mid 1980s, to 100 in 1992	100–300	Declining	Water-level regulation by a mining company for a hydroelectric plant causes breeding failure when nesting & foraging areas dry out; pollution by mines	International & national pressure on mining company to control water-level more responsibly	High, given 10-fold decline in previous 30 years	J. Fjeldså, pers. comm., 2005; Fjeldså (2005)
Chatham Island taiko *Pterodroma magentae*	4 breeding pairs known, others probably undetected	Declining	120 (15 breeding pairs)	Increasing	Introduced pigs, cats, weka *Gallirallus australis* & rodents take eggs, chicks & adults, or compete for, destroy or cause desertion of burrows; loss of forest habitat	Control of predators (rats, cats, possums, wekas) around burrows	V. high, given v. small breeding population; perhaps only functionally extinct given long lifespan of species	Hilhorst (2000); Brooke (2004); G. Taylor, pers. comm., 2005
Zino's petrel *Pterodroma madeira*	20–30 breeding pairs	Stable	65–80 breeding pairs (incl. some on newly discovered breeding ledges)	Increasing	Predation by introduced black rats *Rattus rattus* & feral cats; nest-site habitat loss & disturbance by grazing goats & sheep; hunting of chicks for food	Control of rats & cats around breeding ledges; exclusion of grazing stock	V. high, perhaps only functionally extinct given long lifespan of species	Brooke (2004); F.I. Ramírez, pers. comm., 2005
Northern bald ibis *Geronticus eremita*	300 (59 breeding pairs)	Declining	106 breeding pairs	Increasing	Human persecution, especially hunting; habitat loss; pesticide poisoning; human disturbance; egg predation	Protection of nesting & breeding habitat; disturbance & loss of breeding habitat prevented	High, probably would be functionally extinct but with some old birds surviving	C. Bowden, pers. comm., 2005
Crested ibis *Nipponia nippon*	22	Increasing (from 4 adults in 1981)	360	Increasing	Loss of feeding habitat; agrochemicals; hunting	Emergency regulations to prohibit logging, use of agrochemicals in rice-fields & hunting; protection of nest-trees; management of rice fields	High (although question over accuracy of 1994 population estimate)	BirdLife International (2001); Ding Chang-qing, pers. comm., 2005
California condor *Gymnogyps californianus*	9	Declining	128 (44 adults)	Increasing	Persecution & accidental lead ingestion from shot carcasses; behavioural difficulties & collisions with powerlines by reintroduced birds	Intensive captive breeding & reintroduction programme	Certain, last 4 were taken back into captivity in Mar. 1994 before releases recommenced with 6 in Mar. 1995	Meretsky *et al.* (2000); Snyder & Schmitt (2002); L. Kiff, pers. comm., 2006

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Table 1 (*continued*)

Species	1994 population estimate	1994 trend	2004 population estimate	2004 trend	Threats	Conservation action taken	Extinction probability if action had ceased in 1994	Sources
Black stilt *Himantopus novaezelandiae*	5 breeding pairs	Declining	11 breeding pairs	Increasing	Predators, particularly introduced cats, ferrets, stoats *Mustella erminea*, hedgehogs *Erinaceus europaeus* & brown rat *Rattus norvegicus*, plus swamp harrier *Circus approximans* & kelp gull *Larus dominicanus*; nest destruction by drainage, hydroelectric development, weed growth & flood-control programmes	Release of substantial numbers of captive-bred birds; predator control	V. high, given v. small population size & trend	R. Maloney, pers. comm., 2005
Pink pigeon *Nesoenas mayeri*	70	Increasing (from 9–10 birds in 1990)	359	Increasing	Predation by introduced crab-eating macaque *Macaca fascicularis*, Javan mongoose *Herpestes javanicus*, rats & feral cats; habitat loss; cyclones; disease	Captive-breeding & reintroduction; habitat restoration; control of exotic predators; supplementary feeding; nest guarding; clutch & brood fostering	V. high. Swinnerton *et al.* (2004) noted: 'extrapolation of the historical decline indicates that the wild population would have become extinct by about the year 2002'	Swinnerton *et al.* (2004); C. Jones, pers. comm., 2005
Norfolk Island green parrot *Cyanoramphus cookii*	4 breeding females, 28–33 males	Declining	200–300	Increasing	Habitat loss; weed invasion; nest-site competition with introduced crimson rosella *Platycercus elegans*, common starling *Sturnus vulgaris* & feral honey bees; predation by introduced black rats & feral cats; disease	Nest site protection; predator & competitor control; predator-proof nesting hollows installed	V. high, given v. small & sex-biased population size	R. Ward, pers. comm., 2005
Mauritius parakeet *Psittacula eques*	5 pairs, 3 of which bred without success	Stable, but v. low breeding success since 1970s	55 pairs (280–300 birds in the wild, Feb. 2005)	Increasing	Habitat destruction & degradation owing to cyclones & introduced plants; introduced predators & food/nest-site competitors	Captive breeding & habitat management	V. high probability of functional extinction although some old birds may have survived	C. Jones, pers. comm., 2005

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Table 1 (*continued*)

Species	1994 population estimate	1994 trend	2004 population estimate	2004 trend	Threats	Conservation action taken	Extinction probability if action had ceased in 1994	Sources
Lear's macaw *Anodorhynchus leari*	50–100	Declining	400–500	Increasing	Trapping for cage-bird trade; habitat loss through livestock grazing; fire	Control of trade; guarding of nest sites; land management	High probability of functional extinction although some old birds may have survived	Y. Barros, pers. comm., 2005
Puerto Rican parrot *Amazona vittata*	41	Fluctuating (20–47 during 1975–2000)	30–35	Stable	Habitat loss; hunting for food & pest control; trapping for cage-bird trade; competition for nest-sites; loss of young to parasitic botflies; predation & natural disasters such as hurricanes	Artificial nest-sites; control of nest predators & competitors; captive breeding & reintroduction; protection of remaining habitat in protected area	High, given pressures on species & small population size	T. White, pers. comm., 2005; Engeman *et al.* (2006)
Seychelles magpie-robin *Copsychus sechellarum*	48	Increasing (from 12–15 in 1965)	136	Increasing	Predation by cats & other introduced predators & competitors; encroachment of dense cover following abandonment of plantations, pesticides, disease	Translocations; habitat creation, supplementary feeding; nest defence; provision of nest boxes; eradication of rats & cats	V. high, given v. small population & impact of threats	R. Bristol, pers. comm., 2005
Tahiti monarch *Pomarea nigra*	40–60	Declining	40–45	Increasing	Invasive plants; introduced predators & competitors	Control of invasive predators	High, given v. small population size & rate of decline	J.-C. Thibault, pers. comm., 2005; P. Raust, pers. comm., 2005
Pale-headed brush-finch *Atlapetes pallidiceps*	14	Declining	50 pairs	Increasing	Habitat degradation by intensive grazing & fire; brood parasitism by shiny cowbird *Molothrus bonariensis*	Purchase & fencing of remaining habitat; cowbird removal; habitat management	V. high, given v. small population size	P. Sornoza, pers. comm., 2005
Bali starling *Leucopsar rothschildi*	25 (5 breeding pairs)	Declining	24 (following further captive releases)	Declining	Unsustainable illegal trapping; habitat loss	Protection in national park; release of captive-bred birds	V. high, given trapping pressures & v. small population size	P. Wood, pers. comm., 2005

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Table 2 Species judged likely to have been close to extinction during 1994–2004, but which probably would have survived even if conservation action had not taken place. Population estimates refer to birds in the wild. Sources are additional to BirdLife International (2004b).

Species	1994 population estimate	1994 trend	2004 population estimate	2004 trend	Threats	Conservation action taken	Extinction probability if action had ceased in 1994	Sources
Amsterdam albatross *Diomedea amsterdamensis*	40 mature (11 pairs)	Increasing	80 mature (18–25 breeding pairs)	Increasing	Degradation of breeding sites by introduced cattle; human disturbance; predation by introduced feral cats; incidental mortality on longlines; disease	Protection of nesting sites from cattle by fences	Low, even if degradation of breeding sites had continued, partly owing to longevity of species	Weimerskirch *et al.* (1997); Brooke (2004); H. Weimerskirch, pers. comm., 2005
Bermuda petrel *Pterodroma cahow*	45 pairs	Increasing	250 (70 breeding pairs)	Increasing	Habitat loss, exploitation; predation; competition for nest sites from white-tailed tropicbird *Phaethon lepturus* for nest sites; light pollution	Periodic rat eradications; creation of artificial burrows; protection of burrows from white-tailed tropicbird	Low, but would certainly be close to extinction now	D. Wege, pers. comm., 2005; J. Madeiros, pers. comm., 2005
Christmas Island frigatebird *Fregata andrewsi*	1,400–2,000 pairs (interpolated from 1985 & 2003 estimates)	Declining	1,200–2,400 breeding pairs in 2003	Stable?	Predation on nestlings by invasive yellow crazy ants *Anoplolepis gracilipes* (also alter island's ecology by killing red crab *Gecaroidea natalis*), & scale insects which damage trees; ants had formed supercolonies over 25% of the island by 2002	Control of yellow crazy ants (2002)	Low, but ants would have been having increasingly severe impact	Stokes (1988); Hill & Lill (1998); S. Garnett, pers. comm., 2004; D. James, pers. comm., 2004, 2005
Christmas Island hawk-owl *Ninox natalis*	562 ± 105 pairs in 1995	Stable?	*c.* 1,000	Stable?				
Grenada dove *Leptotila wellsi*	75–85 estimated in 1989–1990, plus unknown no. of additional birds	Declining	*c.* 100	Declining	Habitat loss; introduced predators	Protection of habitat in two protected areas	Low, given species' ability to survive recent devastating hurricanes, but population would have declined further without habitat protection	D. Wege, pers. comm., 2006
Orange-bellied parrot *Neophema chrysogaster*	122	Declining	150	Declining?	Habitat fragmentation & degradation (from fire, grazing, agriculture & urban & industrial development), introduced predators, competition with introduced species for food & nest-holes	Fire management, removal of nest competitors, supplementary feeding & captive breeding & release	Low, but would be in v. precarious situation now	Garnett *et al.* (2003); S. Garnett, pers. comm., 2005; M. Holdsworth, pers. comm., 2005

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Table 2 (*continued*)

Species	1994 population estimate	1994 trend	2004 population estimate	2004 trend	Threats	Conservation action taken	Extinction probability if action had ceased in 1994	Sources
Taita apalis *Apalis fuscigularis*	50–250	Declining	50–250	Declining	Habitat loss for cultivation or plantations	Safeguarding of remaining 1.5 km^2 of habitat	Low, as remaining forest would have been further diminished & degraded, but probably not completely destroyed	L. Bennun, pers. comm., 2006; N. Burgess, pers. comm., 2006
Caerulean paradise-flycatcher *Eutrichomyias rowleyi*	19–135	Declining	19–135	Declining	Habitat loss to shifting cultivation	Conservation awareness to reduce pressures on remaining habitat	Low, as remaining birds in steep inaccessible valleys, but population would have probably declined further	J. Wardill, pers. comm., 2006
Rarotonga monarch *Pomarea dimidiata*	88	Increasing	289–300	Increasing	Cyclones, habitat degradation & predation by rats	Control of rats	Low, but pre-conservation declines of 12% per year would have led to a population of 20–30 (largely old) by 2004	H. Robertson, pers. comm., 2005
Cebu flowerpecker *Dicaeum quadricolor*	95–130	Declining	85–105	Declining	Habitat loss owing to illegal settlement, road construction; shifting cultivation; illicit logging; firewood collection & habitat clearance for mining	Protection of remaining habitat, which was continuing to reduce when species rediscovered in 1992	Low, as population in Nug-as forest (50–60, discovered in late 1990s) would probably have survived	L.M. Paguntalan, pers. comm., 2005
White-chested white-eye *Zosterops albogularis*	<50	Declining	<50	Declining	Predation by introduced predators, habitat loss	Trapping of rats & cats; habitat protection	Medium, given that rat-trapping is not island-wide, but difficult to judge given uncertainty about population size	S. Garnett, pers. comm., 2006; P. Olsen, pers. comm., 2006

Table 3 Population trends of species prevented from going extinct during 1994–2004 (figures give number of species for each type of trend; n = 16).

Trend	1994	2004
Increasing	3 (18.8%)	13 (81.3%)
Stable	2 (12.5%)	1 (6.3%)
Fluctuating	1 (6.3%)	0
Declining	10 (62.5%)	2 (12.5%)

condor being taken into captivity again in 1994. By 2004, these species' mean minimum population size had increased significantly to 147 individuals (range 22–400 breeding individuals, where these data are available; paired *t*-test: $t_{18} = -3.82$, P = 0.0017). Some species underwent very significant population increases. For example, the population of crested ibis *Nipponia nippon* increased 16-fold from 22 to 360 individuals (although there is some question over the accuracy of the earlier figures), Norfolk Island green parrot increased almost 10-fold from 32–37 individuals to 200–300 individuals, and Mauritius parakeet *Psittacula eques* increased 10-fold from five to 55 pairs.

Populations of 63% of these species were declining in 1994, with two being stable, one fluctuating, and three increasing in numbers owing to conservation measures already in place (crested ibis, pink pigeon *Nesoenas mayeri* and Seychelles magpie-robin *Copsychus sechellarum*; Table 3). By 2004 these figures had improved: only two were still declining (Junín grebe *Podiceps taczanowskii* and Bali starling *Leucopsar rothschildi*), one was stable and the remainder were increasing.

The majority of these species (63%, 10 species) are found on islands (Fig. 1), including breeding colonies of two seabirds (Chatham Island taiko and Zino's petrel *Pterodroma madeira*). This is a higher proportion than for other species that would have qualified as Critically Endangered in 1994 (58%, 93/160 species) or for other threatened species (45%, 518/1,199 species), although in neither case are the differences significant (extinction prevented vs other Critically Endangered species: $\chi^2 = 0.11$, P = 0.73; extinction prevented vs other threatened species: $\chi^2 = 1.79$, P = 0.18).

Multiple factors led to the declines in all of the 16 species whose extinction was prevented, but the principal threats were habitat loss and degradation (88% of species), invasive species (50%) and exploitation (38%). This is similar to the pattern for the 1,199 other species of threatened birds, but with exploitation and invasive species being relatively more important (Fig. 2). Pollution and persecution were more important threats

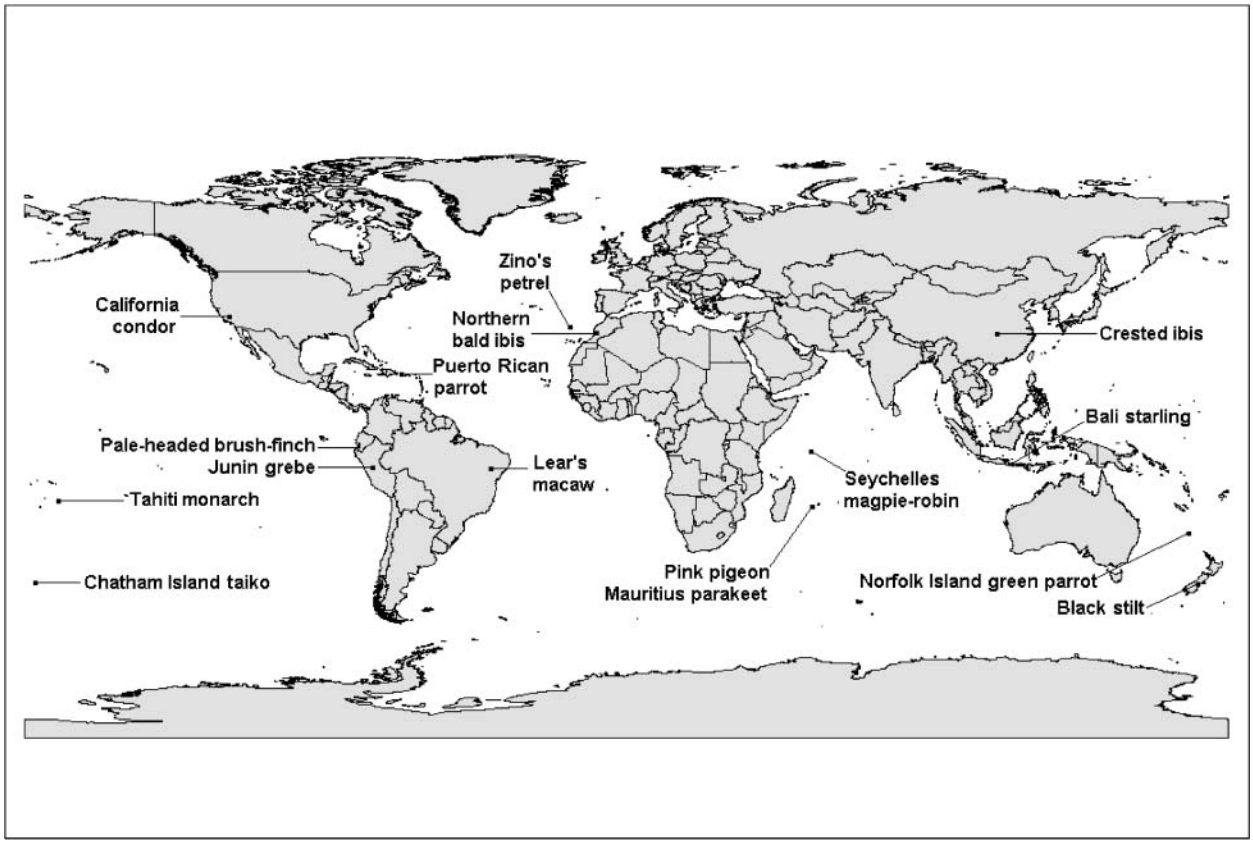


Fig. 1 Location of species whose extinction was prevented during 1994–2004.

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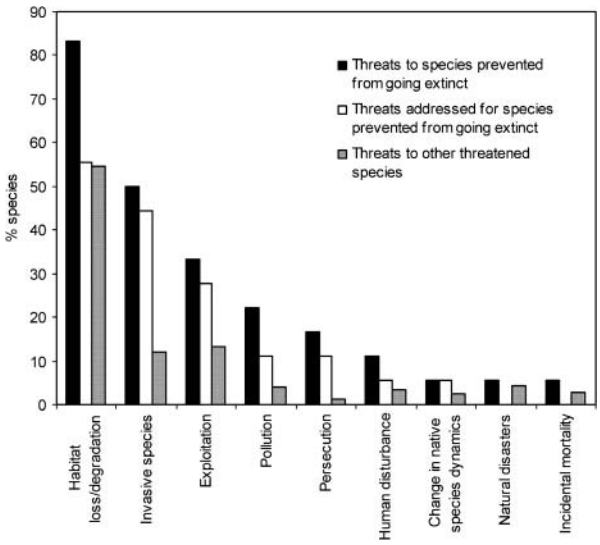


Fig. 2 Threats to species whose extinction was prevented during 1994–2004 (n = 16), the threats addressed by conservation actions for these species, and threats to other threatened species (n = 1,199).

to the species whose extinction was prevented than to other threatened species, affecting 19 and 25% of the 16 species respectively, compared to 3.9 and 1.1% of other threatened species. That invasive species were the most important threat to half of the species that avoided extinction is not surprising, given that the extinctions prevented were concentrated on islands, where native birds are often susceptible to the effects of introduced herbivores, competitors and, most importantly, predators.

The types of conservation action carried out for these species included habitat protection and management (12 species; 75%), control of invasive species (8; 50%), captive breeding and release (6; 33%), and translocation of individuals (1; 6%). The main threats that these actions successfully addressed to allow the species to recover (or at least slowed their rate of decline) were habitat degradation (50%), invasive species (50%), exploitation (31%) and, to a lesser extent, pollution (13%) and persecution (13%; Fig. 2).

Conservation actions were implemented through a mixture of both governmental and non-governmental agencies in the majority of cases (11 species, 69%), with governments alone being responsible in the other cases (5, 31%, in New Zealand, Australia, China and the USA). BirdLife International, the largest global alliance of national conservation organizations, contributed to the implementation of action for seven species (44%). One such national organization (Taporoporoanga Ipukarea Society in the Cook Islands) grew out of efforts to save the Rarotonga monarch *Pomarea dimidiata* from extinction.

Although public appeal is difficult to quantify, the 16 species include 12 (75%) that can be considered charismatic and popular, comprising four parrots, four waterbirds, one raptor, one pigeon and two attractive passerines. Among other species that qualified as Critically Endangered in 1994, only 48% were charismatic (77/160 species, $\chi^2 = 4.20$, P = 0.04), suggesting that public appeal is one parameter favouring successful conservation intervention. This may be because charismatic species capture conservationists' attention more easily, are easier to raise funds for, and/or are easier to change public opinion about (and hence the actions of hunters, farmers or landowners).

Discussion

We estimate that conservation efforts prevented at least 16 species from going extinct during 1994–2004. This estimate is based on consideration of the population size and trends of these species in 1994, the severity of threats, and the nature and intensity of conservation efforts carried out over the period. Ideally, sufficient data would have been available to run population viability analyses (Beissinger & McCullough, 2002) for each species in order to quantify their probability of extinction with and without conservation interventions. For Amsterdam albatross *Diomedea amsterdamensis* (a species we judge would have probably survived even if conservation action had ceased in 1994) Weimerskirch *et al*. (1997) modelled the projected population size if long-line fishing recommenced, and predicted a likely extinction around 2045. However, they did not model the effects on the population size if measures on the breeding island ceased (e.g. exclusion of cattle from breeding areas), which would have certainly hastened their projected extinction trajectory. Unfortunately, data were unavailable to carry out similarly detailed population modelling for the remaining 16 species.

In addition to the species that we judge survived in the wild only through implementation of conservation programmes, four species survived only in captive breeding programmes during 1994–2004 (and are classified as Extinct in the Wild): Alagoas curassow *Crax mitu* (survived in the wild until 1988), Guam rail *Gallirallus owstoni* (1987), Socorro dove *Zenaida graysoni* and Hawaiian crow (2002). Since 2001 Spix's macaw also probably survives only in captivity (being classified as Possibly Extinct in the Wild), with the last known wild individual disappearing in 2001.

We examined this issue only at the species level. Conservation action is also likely to have prevented extinctions of some subspecific taxa during the period, e.g. the helmeted honeyeater subspecies of yellow-tufted honeyeater *Lichenostomus melanops cassidix* and the

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northern subspecies of eastern bristlebird *Dasyornis brachypterus monoides* (Garnett *et al*., 2003).

We also focused only on the decade 1994–2004, but at least 10 other species would very probably have gone extinct without conservation interventions prior to 1994, e.g. black robin *Petroica traversi* was reduced to five individuals in 1980, and Mauritius kestrel *Falco punctatus* fell to four individuals in the wild in 1974 (Table 4). This total is probably an underestimate as considerably less information is available prior to 1994.

These successes show that preventing extinctions is possible, given political will and concerted action. This is not a particularly surprising result, but it is instructive to examine the characteristics of each species. The majority (88% of species that avoided extinction prior to 1994 and 63% during 1994–2004 respectively) are restricted to islands, where invasive species are often one of the most important threats. Two thirds (67%) of threatened birds on oceanic islands suffer negative impacts from invasive species (BirdLife International, 2004a). In recent decades technological advances and intense research, particularly in New Zealand, mean that eradicating invasive species is now a practical and feasible conservation option, even on sizeable islands (Myers *et al*., 2000; Veitch & Clout, 2002). Furthermore, habitat management and restoration, and protection from exploitation, may be easier to implement on islands owing to the restricted scale at which action is required. This means that although island species tend to have greater inherent susceptibility to extinction from anthropogenic factors (owing to naiveté to mammalian predators, and naturally small populations), their conservation may be more practicable than for continental species that frequently require action to address broad-scale habitat loss and degradation. More than half (54%) of threatened birds are continental (BirdLife International, 2004a). Preventing extinctions among this suite of species will be an even greater challenge.

Most (81%) of the species whose extinctions were prevented also qualify as trigger species under the Alliance for Zero Extinction initiative (AZE, 2005), a programme to identify all sites worldwide holding the last remaining populations of any Critically Endangered or Endangered species of animal or plant (Ricketts *et al*., 2005). This means that in each case >95% of the global population of the species is believed to be confined to a single discrete site. The exceptions are more wide-ranging species (California condor and northern bald ibis *Geronticus eremita*), or species that have recovered so successfully that they have been downlisted to Vulnerable, and hence do not qualify under the Alliance's criteria (Mauritius parakeet).

While we believe that the 16 species would have gone extinct in the absence of conservation, they are by no means saved from the threat of extinction. Some can barely be seen as conservation successes: Bali starling maintains a population in the wild solely through the continued release of captive-bred birds, owing to the difficulty of preventing illegal trapping of the remaining birds, and the population of Junín grebe continues to decline owing to inappropriate water-level regulation at the sole lake where it is found. More intense action is needed to reverse the declines in these two species. Many of the other species still have very small populations and are reliant on continued conservation efforts to sustain or increase their current population.

Furthermore, the 16 species whose extinction was prevented by conservation action over the last decade represent only 8.9% of the 179 bird species classified in 2005 as Critically Endangered, and 1.3% of the 1,212 bird species currently threatened with extinction (BirdLife International, 2006). Another 203 Critically Endangered or Endangered species are each also now restricted to single discrete sites and hence highly susceptible to extinction (Ricketts *et al*., 2005).

Many other bird species have slipped closer to extinction over this same time period: a total of 164 deteriorated in status sufficiently to be uplisted to higher categories of extinction risk on the IUCN Red List during 1994–2004 (Butchart *et al*., 2004, 2005). In addition, many species showed reduced populations or increasing rates of decline, but not at a rate sufficient to cross thresholds for higher categories on the IUCN Red List. For example, at least 45% of threatened bird species were judged to have deteriorated in status between 2000 and 2004 alone (BirdLife International, 2004a).

Therefore, despite the apparent substantial resources spent on conserving some species, we need to scale up our efforts considerably to prevent wholesale biodiversity loss and many more extinctions in the coming decades. This will require a combination of actions including: (1) research on distribution, population size and trends, ecology and threats; (2) monitoring; (3) identification of a network of key sites (Important Bird Areas; Fishpool & Evans, 2001); (4) safeguarding and managing these sites under a range of governance mechanisms through legal protection in conjunction with local community initiatives; (5) intensive recovery programmes; (6) public awareness and education; (7) broad-scale habitat approaches; (9) policy interventions at multiple scales. For most species this will require coordinated efforts implemented through collaboration and partnerships between governments, non-governmental organizations, business and private individuals.

The examples we have highlighted show that we have the knowledge and tools to achieve this. To mobilize the resources and political will to apply them presents an enormous and urgent challenge to the

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Table 4 Species judged likely to have been saved from extinction prior to 1994. Sources are additional to BirdLife International (2004b).

Species	Minimum population reached (& year)	Current population	Threats	Conservation actions	Sources
Short-tailed albatross *Phoebastria albatrus*	23 adults (1955)	1,200	Historically: exploitation for feathers. Currently: incidental mortality in fisheries; soil erosion	Prevention of hunting; habitat management; establishment of new colony	S. Chan, pers. comm., 2005
Bermuda petrel *Pterodroma cahow*	18 pairs (1962)	250 (70 breeding pairs)	Habitat loss; exploitation; predation; competition for nest-sites from white-tailed tropicbird *Phaethon lepturus*; light pollution	Periodic rat eradications; creation of artificial burrows; protection of burrows from white-tailed tropicbird	J. Madeiros, pers. comm., 2005; D. Wege, pers. comm., 2005
Hawaiian goose *Branta sandvicensis*	17 (1950)	1,304	Habitat loss; introduced predators; hunting	Captive breeding & release	Elder & Woodside (1958); USFWS (2004c)
Laysan duck *Anas laysanensis*	7 (1912)	391–537	Introduced rabbits, ants & plants; food shortages in drought years; exploitation; parasitic nematode infections	Eradication of rabbits & introduced plants; habitat management	Bailey (1956); USFWS (2004d); Moulton & Marshall (1996)
Whooping crane *Grus americana*	14 adults (1938)	340 (289 adults)	Historically: over-hunting; habitat conversion; human disturbance. Currently: collision with powerlines; drought; pollution; boat traffic	Captive breeding & release; powerline markers	USFWS (2004b); Http://www.whoopingcrane.com
Mauritius kestrel *Falco punctatus*	4 in the wild (1974)	500–800	Historically: deforestation; pesticides. Currently: predation by introduced black rats, crab-eating macaques, mongooses & feral cats	Captive breeding & release; supplementary feeding, nest box provision; nest guarding; control of predators	Safford & Jones (1998)
Kakapo *Strigops habroptila*	62 (1999)	86	Introduced predators, in particular cats, which were killing >50% of monitored birds on Stewart Island each year before they were translocated	Translocation; supplementary feeding; rat eradication	M. Szabo, pers. comm., 2005
Black robin *Petroica traversi*	5 incl. 2 females (1980)	250–300	Introduced predators (black rats & feral cats); habitat loss	Nest protection; cross-fostering; supplementary feeding	Butler & Merton (1992); Aikman *et al.* (2001); Department of Conservation (2001)
Rodrigues warbler *Acrocephalus rodericanus*	8 pairs known but others likely (1979)	150	Habitat degradation by timber harvesting, subsistence farming & feral livestock; predation by introduced rats & cats; drought; cyclones	Habitat protection & reforestation	A. Cristinacce & C. Jones, pers. comm., 2005; R. Safford, pers. comm., 2005
Rodrigues fody *Foudia flavicans*	5–6 pairs (1968)	911–1,200	Historically: habitat destruction. Currently: competition with introduced Madagascar red fody *Foudia madagascariensis*; cyclones; drought; feral cats	Habitat protection & reforestation	C. Jones, pers. comm., 2000; Impey *et al.* (2002)

conservation community, but one we must rise to. Future generations will measure how well we meet this challenge by the number of extinctions we succeed or fail in preventing in the coming decades.

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