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Conservation actions benefit the most threatened species: A 13-year assessment of Alliance for Zero Extinction species

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Abstract

More species in the world are threatened with extinction today than at any other time in recent history. In 2005, the Alliance for Zero Extinction (AZE; https://zeroextinction.org/) released its first inventory of highly threatened species (i.e., those listed as Critically Endangered or Endangered on the IUCN Red List) that are effectively confined to a single site. Updates were released in 2010 and 2018. Here we identify the species removed from the list in these updates, determine the reasons for these removals, identify species that no longer qualify as AZE species as a result of conservation actions, and examine which conservation actions produced these recoveries. In total, 360 species that qualified as AZE species in 2005 no longer qualified by 2018 (45% of those listed in 2005) due to improved knowledge of distribution or taxonomy (83%), genuine improvements resulting in species being downlisted to lower categories of extinction risk (12%), genuine range expansion of species such that they are no longer restricted to single sites (4%), or deterioration to extinction (1%). Our results show that while protected areas and site management are important to the successful conservation of AZE species, other conservation actions, such as species-level management or improved laws and policies, are also essential to safeguard these species from extinction. Sixty-eight percent of the original 2005 AZE sites are now fully or partially covered by protected areas, an increase of almost 20% in 15 years. Yet today, only 64% of current (2018) AZE sites are fully or partially covered by protected areas, with 36% lacking any formal protection. Continued efforts to safeguard and manage AZE sites would benefit not only the 1,483 AZE species but also potentially another 1,359 Critically Endangered and Endangered amphibian, bird, and mammal species whose distributions overlap with AZE sites.

KEYWORDS

conservation, conservation action, extinction, protected area

1 | INTRODUCTION

Anthropogenic activities have increased the rate of species extinction to unprecedented levels in the modern era (Ceballos, Ehrlich, & Dirzo, 2017; Ceballos, Ehrlich, & Raven, 2020; De Vos, Joppa, Gittleman, Stephens, & Pimm, 2015; Díaz et al., 2019; Pimm et al., 2014). Conservation efforts, such as reforestation, captive breeding, invasive species control, and so on, attempt to slow or stop these extinctions. While these efforts have prevented extinctions (Bolam et al., 2020) and aided in the recovery of some species (Butchart, Stattersfield, & Collar, 2006; Hoffmann et al., 2015), many species remain at high risk of extinction (>37,000 documented; IUCN, 2021). Preventing species loss has become a global ambition within the Sustainable Development Goals and will very likely be similarly reflected in the post-2020 Global Biodiversity Framework (Funk, Conde, Lamoreux, & Fa, 2017).

To support efforts to prevent extinctions, the Alliance for Zero Extinction (AZE; https://zeroextinction.org/) is a global initiative of over 115 non-governmental biodiversity conservation organizations aiming to prevent extinctions by identifying and safeguarding sites that hold effectively the entire global population of one or more highly threatened species (Alliance for Zero Extinction, 2013; Ricketts et al., 2005). AZE sites are identified using three criteria: Endangerment, Irreplaceability, and Discreteness (Alliance for Zero Extinction, 2013). Endangerment means that the site supports a species classified as Endangered (EN) or Critically Endangered (CR) on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (hereafter IUCN Red List). Irreplaceability means that the site supports effectively the entire (>95%) global population of the species for at least one life history segment. Discreteness means that the boundary of the site is defined according to the most practical unit at which conservation can be applied. Such sites therefore by definition qualify as Key Biodiversity Areas (KBAs) under KBA Criterion A1e (IUCN, 2016). Pinpointing these locations helps governments, conservationists, donors, financial institutions, businesses, and investors to target conservation efforts and minimize destructive activities as a means to prevent global extinctions.

To maximize the effectiveness of efforts to prevent extinctions, it is important to identify when successes have been achieved and why, as well identifying failures and the reasons for these. We used data on AZE sites to explore these issues. The first global list of AZE sites was published in 2005 (595 sites containing 794 species in six taxonomic classes; Ricketts et al., 2005). It was updated in 2010 (585 sites for 919 species in six classes; AZE, 2013) and 2018 (853 sites for 1,483 species in 18 classes; AZE, 2018; https://zeroextinction.org/site-identification/2018-global-aze-map/). A number of species and sites were added to and removed from the list in both 2010 and 2018, for a variety of reasons. Here we focus on the species removed from the AZE list and the reasons for their removal to better understand the conditions under which conservation successes are achieved; ongoing work is examining those species added and the reasons for their addition to the AZE list.

In this paper we aim to understand removals from the AZE list and which conservation measures are associated with AZE species whose conservation status has improved. This information can be used to inform conservation efforts to prevent extinctions and safeguard threatened species around the world, and thereby contribute to global policy objectives. To this end, we ask three fundamental questions of value to conservation in general:

1. Which species were removed from the AZE list due to improved knowledge, genuine improvements in status, or extinction?
2. Which conservation actions were associated with species removed from the list of AZE species owing to genuine improvements in their status?
3. Is listing as an AZE species or site associated with increased protected area coverage or improved conservation outcomes compared with other Endangered and Critically Endangered species or KBAs?

2 | METHODS

2.1 | Which species were removed from the AZE list due to improved knowledge, genuine improvements in status, or extinction?

To answer this question, information on AZE sites and species were compiled from the AZE website (http://www.zeroextinction.org/) and IUCN Red List in March 2019. While we used the most up to date information possible, we acknowledge that some species have not been recently assessed by the IUCN and therefore these data might not reflect their current conservation status. These data were combined with unpublished data on the reasons for the de-listing of species and sites from American Bird Conservancy, BirdLife International and IUCN (coordinators of the AZE assessments in 2005, 2010, and 2018). We classified each AZE species removed from the list in 2010 or 2018 according to the reason for its removal (Tables 1 and S1).

TABLE 1 Reasons for the removal of species from the Alliance for Zero Extinction list in 2010 and 2018, and the relevant number and percentage of species

Reason for removal from AZE list		Explanation of the reason	Number and percentage of AZE species removed in 2010	Number and percentage of AZE species removed in 2018	Total number and percentage of AZE species removed in 2010 and 2018
Change in knowledge/ taxonomy	Reclassified as data deficient	The species has been recategorized on the IUCN Red List as "Data Deficient"	27 (13%)	13 (8%)	40 (11%)
	Reclassified as Extinct or no longer known from any site	The species has been recategorized on the IUCN Red List as either " Extinct" or "Extinct in the Wild", due to changes preceding 2005	18 (8%)	7 (4%)	25 (7%)
	Downlisted owing to better knowledge and/or revised taxonomy	The species has been recategorized on the IUCN Red List as Vulnerable, Near Threatened or Least Concern primarily owing to better knowledge or revised taxonomy	32 (15%)	16 (10%)	48 (13%)
	No longer considered restricted to a single site owing to better knowledge	The species is no longer considered effectively restricted to a single site owing to the discovery and documentation of additional populations of the species	106 (51%)	69 (45%)	175 (49%)
	No longer considered restricted to a single site owing to taxonomic revision	The species is no longer considered effectively restricted to a single site owing to its "lumping" with another taxon or otherwise being taxonomically rearranged	0 (0%)	13 (8%)	13 (4%)
Genuine improvement	Downlisted owing to genuine improvement in status	The species has been recategorized on the IUCN Red List as Vulnerable, Near Threatened or Least Concern primarily owing to a genuine reduction in the extinction risk faced by the species	14 (7%)	28 (18%)	42 (12%)

(Continues)

TABLE 1 (Continued)

Reason for removal from AZE list		Explanation of the reason	Number and percentage of AZE species removed in 2010	Number and percentage of AZE species removed in 2018	Total number and percentage of AZE species removed in 2010 and 2018
	No longer considered restricted to a single site owing to genuine range expansion	The species is no longer considered effectively restricted to a single site owing to establishment and/or expansion of populations of the species outside the former AZE site, though it remains classified as Critically Endangered or Endangered	9 (4%)	7 (5%)	16 (4%)

2.2 | Which conservation actions were associated with species removed from the list of AZE species owing to genuine improvements in their status?

This question focuses on genuine improvements in a species' status leading to downlisting to Vulnerable (VU), Near Threatened (NT), or Least Concern (LC) on the IUCN Red List (and hence no longer meeting the first of the three AZE criteria), or to genuine range expansions resulting in a species no longer being confined to a single site. We extracted data on implemented conservation actions for these species from the IUCN Red List (IUCN, 2019a, 2019b). The conservation actions are classified following the IUCN/CMP Conservation Actions Classification Scheme Version 2.0. (https://www.iucnredlist.org/resources/conservation-actions-classification-scheme), as defined by Salafsky et al. (2008). We focused on Level 1 Conservation Actions, which are broad categories (Table 2) that convey the general types of actions implemented to improve the chances of species recovery. We note that the Red List recommends but does not require experts to document conservation actions in place; therefore, there may be omissions in these data.

To assess the effectiveness of conservation actions among multiple species and multiple sites, we investigated the conservation actions implemented for the subset of 38 AZE species at 32 sites that were downlisted to lower categories of extinction risk on the IUCN Red List or that increased their distribution such as to occur at multiple sites by 2018. Eleven of the sites with species that genuinely improved also had AZE species (28) for which the extinction risk was not reduced by 2018 sufficiently to be downlisted to a lower category on the IUCN Red List. We used paired *t* tests to assess the number of threats and implemented conservation actions for these 38 removed species compared with the 28 AZE species at the same AZE sites that were not removed from the AZE list by 2018. Analysis of Variance tests were used to compare the number of times that specific conservation actions were implemented for removed species compared with the AZE species at the same sites that were not removed. Species that genuinely improved between 2005 and 2010 were not included in this analysis, as we could not confirm if conservation actions recorded as implemented on the Red List took place before or after 2010. We used the conservation action categories at Level 1 of the IUCN Conservation Action Classification Scheme (Salafsky et al., 2008).

2.3 | Is listing as an AZE species or site associated with increased protected area coverage or improved conservation outcomes compared with other Endangered and Critically Endangered species or KBAs?

Paired *t* tests were used to assess the protected area coverage of AZE sites compared with the protected area coverage for KBAs identified for non-AZE CR and EN species in 2005, 2010, and 2018. We also assessed the percent of overlap between species' ranges and protected areas. We used the World Database on Protected Areas (UNEP-WCMC, 2020) polygons for protected areas in categories I–VI to assess the percentage of range overlap and

TABLE 2 Conservation actions (level 1 classes from the IUCN Conservation Action Classification Scheme and Salafsky et al., 2008), the number of species receiving them that were removed from the AZE list owing to genuine improvements in status, and the number of species receiving them that occurred at the same sites but did not genuinely improve in status sufficiently to be removed from the AZE list

Conservation Action Level 1 Category	Definition	Number of species and percent of species whose conservation status improved	Number of species and percent of species whose conservation status did not improve
Land/water protection	Actions to identify, establish, or expand parks and other legally protected areas	35 (100%)	28 (100%)
Land/water management[a]	Actions directed at conserving or restoring sites, habitats, and the wider environment	19 (50%)	7 (28%)
Species management[a]	Actions directed at managing or restoring species, focused on the species of concern itself	13 (34%)	1 (4%)
Education and awareness	Actions directed at people to improve understanding and skills, and influence behavior	13 (34%)	4 (14%)
Law and policy[a]	Actions to develop, change, influence, and help implement formal legislation, regulations, and voluntary standards	12 (32%)	2 (7%)
Livelihood, economic, and other incentives	Actions to use economic and other incentives to influence behavior	1 (3%)	0 (0%)
External capacity building	Actions to build the infrastructure to do better conservation	2 (5%)	0 (0%)

[a]Indicates conservation actions that were statistically significant in paired comparisons.

frequency of overlap for AZE species compared with non-AZE CR and EN species.

Because mammals, amphibians, and birds are the only completely assessed vertebrate classes whose distributions have also been comprehensively mapped, we focused on these groups to have a full set of non-AZE CR and EN species for comparison. We obtained spatial data for the three classes from IUCN (2019a, 2019b) and Handbook of the Birds of the World and BirdLife International (2018). The ranges of CR and EN amphibians, birds, and mammals were extracted using ArcMap v. 10.6.1 (ESRI, Redlands, CA). The attributes presence, origin and seasonality associated with each species' range polygon were included; more specifically, we included species that were extant or probably extant (presence values of 1 and 2, respectively) and those that were native or reintroduced (origin values of 1 and 2, respectively). Additionally, range polygons classified as "passage" or "uncertain" (season values of 4 and 5) were excluded. To determine if either group was more likely to have its range covered by protected areas, we calculated the percentage of AZE species that had at least some of their range protected and used a chi-square test to compare it with the percentage of non-AZE CR and EN species that had at least some of their range protected. We further calculated the mean coverage by protected areas of the ranges of species in each group.

To assess whether AZE site protection has increased over time and to compare the trends in protected area coverage of AZE sites with trends for KBAs identified for non-AZE CR and EN species, we conducted a spatial overlap between polygons for protected areas from the World Database on Protected Areas (UNEP-WCMC, 2020), categories I-VI, which were filtered to remove UNESCO MAB sites and those with a status of "proposed" or "not reported," and KBAs (from the World Database of KBAs, BirdLife International, 2018), including Important Bird and Biodiversity Areas (IBAs), AZE sites, and other KBAs. We computed the mean percentage of each KBA covered by protected areas for each year following the methods of Butchart et al. (2015) and UNSD (2020). We also determined whether sites were completely covered by protected areas (>98% coverage), partially covered (2–98%), or not covered (<2%). Thresholds of 2 and 98% were used rather than 0 and 100% given known digitization errors in the boundary polygon for protected areas and AZE sites. Since the partially covered category has a wide range of values, we also used histograms to examine patterns in finer detail (Figure S1, Supporting Information).

To determine whether AZE species were more likely to have benefited from conservation actions than other CR/EN species, we compared the proportion of 2005/2010 AZE species that qualified for downlisting to a lower category of extinction risk by 2018 with the proportion of non-AZE CR and EN species that qualified for downlisting over the same time period. We queried the Red List Index (RLI) dataset to assess how many birds, mammals, amphibians, corals and cycads genuinely improved in status sufficiently to qualify for a lower IUCN Red List category. We determined the total number of species listed as AZE in 2005 or 2010 that are still taxonomically recognized, and the total number of other species qualifying as CR/EN during 2005–2010 for each of the five taxonomic groups. To identify other species qualifying as CR/EN during 2005–2010, we included any species in the five taxonomic groups (other than AZE species) that are currently CR or EN. For birds, we also included species retrospectively assessed as qualifying as CR or EN during 2005–2018 (as defined in the genuine changes in the Red List Index). The other four taxonomic groups have only been assessed twice, with the first date of assessment pre-dating 2005.

3 | RESULTS

3.1 | Which species were removed from the AZE list due to improved knowledge, genuine improvements, or extinction?

Across the 2005–2018 time period, 302 species (84% of all species removed) were removed from the AZE list owing to changes in knowledge and taxonomy, including reclassification as Data Deficient or Extinct and species no longer known from any site (Tables 1 and S1 and Figure 1). The other 58 species (16% of those removed) no longer qualified as AZE species owing to genuine improvements in status, including 42 species (12%) that were downlisted to lower categories of extinction risk owing to genuine improvement in status, and 16 species (4%) that were no longer considered restricted to a single site owing to genuine range expansion, but which remained classified as CR/EN (Table S1). For some of the latter (e.g., Laysan Duck *Anas laysanensis*), range expansion (e.g., through translocation) occurred prior to listing as an AZE species in 2005, but the proportion of the population occurring outside the AZE site exceeded 5% only after the original AZE assessment. Of the species removed from the AZE list, 34% were amphibians, 30% birds, 25% mammals, and 7% reptiles, with other taxonomic groups representing <4% of the species removed.

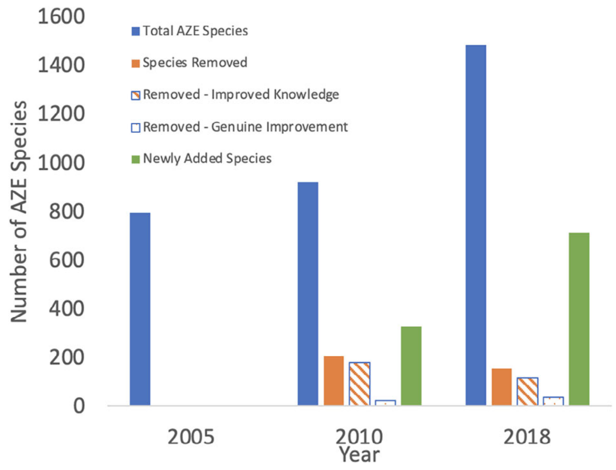

FIGURE 1 Total number of AZE species and the number of AZE species added and removed in 2005, 2010, and 2018

Twenty-five (7%) of the removed species were considered Extinct or Extinct in the Wild, according to the Red List or are no longer known from any site. However, nearly all of these species (6% of the total changes; 21 species) are thought to have become extinct or were last recorded prior to the original 2005 AZE list; thus, these removals are due to changing knowledge rather than genuine changes in extinction risk. The median year in which they were last seen was 1980, with a range from 1962 to 2011. Only four species (1% of the species removed from AZE list) are known or suspected to have become Extinct or Extinct in the Wild since 2005: Christmas Island pipistrelle (*Pipistrellus murrayi*), Bramble Cay melomys (*Melomys rubicola*), Alagoas foliage-gleaner (*Philydor novaesi*), and Puerto Rican crested toad (*Bufo lemur*).

3.2 | Which conservation actions were associated with species removed from the list of AZE species owing to genuine improvements in their status?

In the 2018 AZE update, AZE species removed from the AZE list due to downlisting to lower categories of threat on the IUCN Red List and/or range expansions to additional sites included 15 amphibians (22% of the amphibians that were removed in 2018), 21 birds (36% of the birds that were removed in 2018), 1 conifer (14% of the conifers that were removed in 2018), and 1 mammal (5% of the mammals that were removed in 2018). Conservation actions implemented for these 38 species included Land/Water Protection, Land/Water Management, Invasive Alien or other Problematic Species Management and Community Education & Awareness (Tables 2 and S2).

Of these 38 species removed in 2018, 11 were located at AZE sites that had more than one AZE species. Twenty-eight other AZE species found at these 11 sites did not improve in status sufficiently to be removed from the AZE list. These 28 species still require actions ranging from Land/Water Management (9 species), Invasive Alien or other Problematic Species Management (8 species), Enforcement of existing laws (3 species), and Reintroductions/Translocations (2 species) to help their populations recover.

AZE species that were removed had fewer listed threats than AZE species at the same sites that were not removed from the AZE list (t-ratio 2.4, $df = 10$, $p = .041$) and significantly more conservation actions implemented compared with AZE species from the same locations that were not removed from the AZE list (t-ratio, 4.45, $df = 6$, $p = .004$). The species that were removed from the AZE list owing to genuine improvements had significantly more Land/Water Management ($F_{1,64} = 4.37$, $p = 0.04$), Species Management ($F_{1,64} = 10.18$, $p = .002$), and Law and Policy ($F_{1,64} = 6.12$, $p = .016$) conservation actions implemented than the AZE species at the same locations that remained on the AZE species list.

3.3 | Is listing as an AZE species or site associated with increased protected area coverage or improved conservation outcomes compared with other Endangered and Critically Endangered species or KBAs?

As of 2018, 15% of 2018 AZE sites were completely covered (i.e., overlapped entirely) and 42% were partially covered by protected areas, while 13% of KBAs identified for non-AZE CR and EN species were completely covered and 45% partially covered by protected areas. The percentage of AZE sites that were completely covered by protected areas in 2005, 2010, and 2018 was significantly greater than the percentage of KBAs supporting non-AZE CR and EN species that were completely covered by protected areas at the same time points (t-ratio 5.07, $df = 2$, $p = .037$) (Figure 2). Both AZE sites and KBAs for non-AZE CR and EN species had the same mean protected area coverage (36%), which has increased for both sets of sites from 29% coverage in 2005.

Of the original 2005 AZE sites, 68% are now partially or completely protected, compared with 49% that were partially or completely protected in 2005 (Figure 3). On average, each partially protected AZE site has slightly over half of the AZE site (53%) covered by a protected area (68% [2005 sites], 45% [2010 sites], and 47% [2018 sites]). Of the partially protected AZE sites, 46% had less than 50% coverage by protected areas, and 54% had greater than 50% coverage.

In addition to AZE species, a total of 1,359 non-AZE CR and EN amphibian, bird, and mammal species have ranges that overlap with AZE sites. Forty-six percent of AZE species and 70% of non-AZE CR and EN species have ranges that overlap with current protected areas ($X^2 = 157.24$, $df = 1$, $p < .001$). For AZE sites triggered by amphibians, 14% were at least partly overlapped by protected areas, while 57% of AZE sites triggered by birds and 30% of AZE sites triggered by mammals were at least partly overlapped by protected areas. On average,

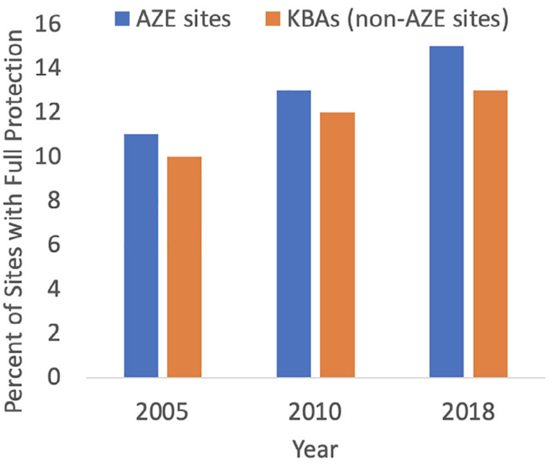

FIGURE 2 The percentage of sites completely covered by protected areas for Alliance for Zero Extinction (AZE) sites and Key Biodiversity Areas identified for non-AZE Critically Endangered and Endangered species as of 2005, 2010, and 2018

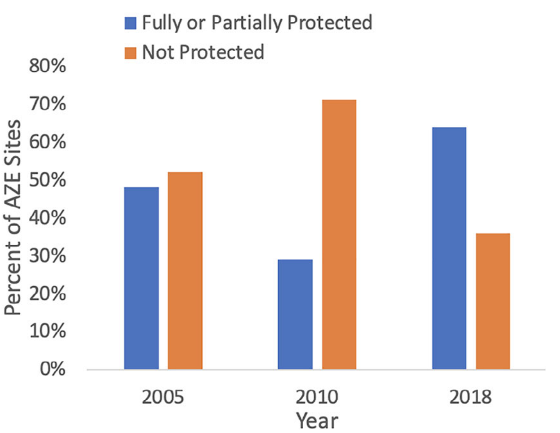

FIGURE 3 The percentage of 2005 AZE sites that are fully or partially protected or not protected in 2005, 2010, and 2018

AZE species had 43% of their ranges covered by protected areas, while the non-AZE CR and EN species had 21% of their ranges covered by protected areas.

There was no significant difference between the proportion of AZE species (5/856 = 0.58%) and non-AZE CR and EN species (13/2291 = 0.57%) downlisted to lower categories of extinction risk on the IUCN Red List between 2005 and 2018. At present, 3% of the current set of AZE species have stable populations and only 1% is increasing, while the other 96% have declining populations.

4 | DISCUSSION

The AZE inventory highlights those species that are both highly threatened by extinction and vulnerable owing to their restriction to single sites. While increased taxonomic coverage, particularly in the 2018 update, added a large number of sites and species to the AZE list, there was also a relatively large number of sites and species that were removed from the list because they no longer met AZE criteria. Ongoing efforts to update AZE sites and species will continue to increase taxonomic coverage, remove sites and species that no longer meet AZE criteria and add other species and sites that newly meet the criteria. Species were removed due to improved knowledge of their sites, status and distribution, revisions to their taxonomy, deterioration to extinction, downlisting to a lower IUCN Red List category, or because the species was no longer effectively restricted to a single site. Conservation actions such as the establishment of protected areas, habitat management, species management, and law and policy implementation were associated with the highest proportion of genuine improvements in species' status and subsequent removal from the AZE list. Protected areas were associated with the highest proportion of species removals from the AZE list, underscoring their role in improving the conservation status of highly threatened and site-restricted species, and emphasizing the importance of effective management of these sites for species conservation (Le Saout et al., 2013).

4.1 | Which species were removed from the AZE list due to improved knowledge, genuine improvements, or extinction?

The 2010 and 2018 AZE list updates allow exploration of the drivers of change in the list of AZE species. The majority of species removed from the list were dropped because of improved knowledge of their distribution or status, or revisions to their taxonomy, with 49% removed due to better knowledge of the distribution of the species. In some cases, the increased attention that AZE status confers on AZE sites and species may have led to the improvements in knowledge, as these sites and species received greater research focus. An example is the Mehuin AZE site in Chile, triggered by the Miguel's Ground Frog (*Eupsophus migueli*) (IUCN SSC ASG, 2019). Research on this poorly understood species led to the finding that while it remains Endangered, it is now found at more sites than previously known. Given current rates of habitat loss and the highly vulnerable and irreplaceable status of AZE species and sites, searching for new populations and monitoring current populations should be of high priority. After AZE species are removed from the AZE list, the sites remain as KBAs, as they are still of high biodiversity value.

Conservation biologists often make important conservation decisions based on imperfect knowledge of a species or landscape, but as more information becomes available, they reassess conservation priorities based on the new information. While there are risks from dynamism in the Red List and AZE list, it is more important to be precautionary in identifying species and sites that may be at high risk, given the irreversibility of global extinction. In the case of AZE species, very little is known about many species, especially the amphibians, and new information has led to non-trivial numbers of species no longer qualifying for AZE status, with consequences for their relative conservation priority. For example, 17% of species removed from the AZE list were dropped owing to revised taxonomic treatment on the IUCN Red List (e.g., taxa that were split, lumped, or no longer recognized in the taxonomic sources followed by the Red List Authorities for each taxonomic group). These taxa were from a wide range of amphibian, bird, and mammal families and genera, including the parrot *Aratinga brevipes* from Mexico, the frog *Petropedetes dutoiti* from Kenya, and the marsupial *Sminthopsis aitkeni* from Australia.

Roughly half of all species removed from the AZE list were removed due to new knowledge about their ranges. Improved knowledge about spatial distributions is critical to informing effective conservation management, as inadequate data on distributions can bias locations for conservation or the need for conservation intervention. An unresolved question is how much of this new information was stimulated specifically by AZE designation, and how much would have been generated by ongoing research anyway. Knowledge gaps about species tend to be greater in the tropics and we expect AZE listings to change further in tropical regions as more information about less well-studied groups becomes available through new avenues of research. In particular, citizen science efforts, such as *eBird* and *iNaturalist*, can play a role in improving understanding of the distribution of AZE species or finding new populations of them.

For species that genuinely improved and were removed from the AZE list, these removals were a consequence of implemented conservation actions, which provides hope that other AZE species and threatened species in general can be helped to recover. The birds and mammals removed were mostly from oceanic islands in the Pacific and Caribbean, the reptiles were largely from Caribbean islands, and the amphibians were mostly in South America and Africa. For example, the Pink Pigeon *Nesoenas mayeri* from Mauritius and Tolimense Poison Frog *Ranitomeya tolimensis* from Colombia genuinely improved in response to conservation efforts. Other AZE species are likely to have also improved in status, but not sufficiently to be downlisted or to have their distributions expand such that less than 95% of the population remains at a single site.

4.2 | Which conservation actions were associated with species removed from the list of AZE species owing to genuine improvements in their status?

Several classes of conservation actions were associated with genuine improvements in the status of AZE species. Site protection was implemented both at all of the AZE sites where species genuinely improved and at many sites where AZE species did not improve, suggesting that while site protection is essential to conserve threatened species (Hoffmann et al., 2015; Luther et al., 2016), further conservation actions, such as site management (including habitat management and restoration), alleviation of hunting pressures or invasive species control, may also be needed for threatened species to recover (Le Saout et al., 2013). AZE species that genuinely improved received more land management, species management, and new laws and policies than species at the same sites that did not genuinely improve, which indicates that while many species benefit from broad-scale or site-scale habitat protection, some species also require species-specific conservation actions. Bolam et al. (2020) found that 18% of all threatened and Extinct in the Wild species need tailored species-specific actions to recover. On oceanic islands, for example, invasive species are the leading cause of extinction of native species (Clavero & Garcia-Berthou, 2005). On these islands, threatened species that occur where invasive species have been eradicated are 10 times more likely to have increasing population trends (Luther et al., 2016).

Our results are aligned with the recent surge in studies that have quantified the impact of conservation actions on threatened species (Butchart et al., 2006; Hoffmann et al., 2010; Johnson et al., 2017; Jones et al., 2016; Rodrigues, Pilgrim, Lamoreux, Hoffmann, & Brooks, 2006). Bolam et al. (2020) estimated that 21–32 bird and 7–16 mammal species would have gone extinct without conservation action from 1993 to 2020 (the lifetime of the CBD), including 11–25 species that would have gone extinct without action from 2010 to 2020. Without conservation actions, the rate of increase in extinction risk to birds and mammals in recent decades would have been 20% greater (Hoffmann et al., 2010), while for ungulates specifically, the increase in extinction risk between 1996 and 2008 would have been eight times greater without conservation actions (Hoffmann et al., 2015). Our results point to the importance of conservation actions, such as land and species management, addressing indirect societal drivers of threats, and area protection, yet the details of when and where each action is most beneficial are still limited. These results add to global findings of the importance of conservation actions to prevent extinctions by demonstrating that conservation actions can help even the most vulnerable species and irreplaceable sites in the world.

4.3 | Is listing as an AZE species or site associated with increased protected area coverage or improved conservation outcomes compared with other Endangered and Critically Endangered species or KBAs?

A greater proportion of AZE sites were completely covered by protected areas than were KBAs that were identified for non-AZE CR and EN species. These results hint that AZE designation may bring extra conservation attention to these sites and species. Since 2005, there has been a growing trend toward the creation of new protected areas overlapping AZE sites, which holds promise that many more sites might be protected in the future. It is encouraging that 68% of the 2005 AZE sites are now fully or partially protected, an increase of almost 20% in 15 years. However, 36% of current AZE sites still lack any formal protection, providing a blueprint for future conservation action. Effective management of all AZE sites is also critical to prevent extinctions (Leverington, Hockings, & Costa, 2008; Struhsaker, Struhsaker, & Siex, 2005; Watson, Dudley, Segan, & Hockings, 2014). The gaps in protection at many AZE sites should receive targeted attention from governments as protected area networks are expanded, and as Other Effective Area-based Conservation Measures (OECMs), such as community reserves, are recognized (Donald et al., 2019; IUCN, 2019a, 2019b). OECMs—sites managed primarily for purposes other than conservation but for which management is nevertheless consistent with the persistence of the biodiversity for which the site is important—provide potential alternatives to formal protected areas in safeguarding AZE sites (Donald et al., 2019). Donald et al. (2019) assessed how many KBAs (including AZEs) falling outside protected areas were in locations that may qualify as OECMs. Analysis of the data in this publication shows that 30% of unprotected or partially protected AZE sites in the 10 countries examined may potentially qualify as OECMs.

Given the importance of protected areas for species conservation, an increased network of effectively managed protected areas is essential for preventing the extinction of AZE species. However, additional actions will also be required for many AZE species, including ex situ conservation, reintroduction, translocation, and targeted recovery actions. It is imperative that opportunities to advance global action to prevent species extinctions, such as through the post-2020 Global Biodiversity Framework, include the effective conservation of AZE sites. Such actions would also contribute to the conservation of potentially an additional 1,359 CR and EN species whose ranges overlap AZE sites, as well as substantial ecosystem service values (Larsen, Turner, & Brooks, 2012).

5 | CONCLUSION

Effectively conserving AZE sites and species will require a mix of conservation actions from site-level protection and management to species-specific recovery actions. The fact that conservation actions resulted in 63 AZE species genuinely improving in status sufficiently to no longer qualify for AZE designation between 2005 and 2018 provides encouragement that scaled-up action could similarly avert extinction of the remaining AZE species. Our results suggest that establishing protected areas and OECMs at AZE sites, effectively managing these sites, and implementing targeted species-specific conservation actions where needed can prevent extinctions of the most threatened species on Earth. These results should inspire decision-makers to adopt ambitious goals to prevent further human-induced extinctions of known threatened species in the post-2020 Global Biodiversity Framework that is currently being negotiated. Efforts to expand networks of protected and conserved areas (e.g., to cover 30% of the area of terrestrial, freshwater, and marine environments, as called for in the draft framework) should target those AZE sites and other KBAs that are not currently covered by protected or conserved areas. Achieving these aims will also require close monitoring of the status of AZE and other threatened species, and of the implementation and impact of conservation efforts.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

AUTHOR CONTRIBUTIONS

David Luther, Amy Upgren, and Stu Butchart conceived of the project idea and wrote the paper. Justin Cooper, Jesse Wong, Margaretta Walker, Ashley Simkins, and Sarah Farinelli helped with data analysis. All other authors contributed through data collection, organization, and writing and editing the manuscript.

DATA AVAILABILITY STATEMENT

All data are publicly available through the Alliance of Zero Extinction https://zeroextinction.org/, or through direct contact with the lead author dluther@gmu.edu.

ETHICS STATEMENT

All research meets the Code of Ethics of the Society for Conservation Biology.

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