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THE CONSERVATION STATUS OF WEST AFRICAN VULTURES: AN UPDATED REVIEW AND A STRATEGY FOR CONSERVATION

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ABSTRACT. – The vulture populations in West Africa are undergoing dramatic decline over the last 30 years. Their particular ecology and sociality makes them vulnerable to various risks, including environmental changes, poisoning and bioaccumulation of toxic substances from agricultural products, pesticides, and veterinary drugs used in cattle livestock. In addition, these birds are subject to direct persecution for the trade of products used in traditional medicine. This manuscript analyzes the conservation status of eight vulture species in West Africa and the threats affecting their survival. In order to assess the conservation status of vultures in West Africa, this paper analyzes all the available literature that has been published in scientific peer-reviewed journals, including also technical reports and unpublished reports related to the whole West African region. Overall, and despite the high risk of extinction facing several vulture species all throughout the world, our literature surveys revealed that the scientific papers on the conservation of West African vultures are relatively few. Therefore, due to limited available literature, the main causes of vulture declines in West Africa remain relatively unclear. Apparently, all African vultures suffer from similar threats, especially poisoning, habitat alteration and conversion to agro-pastoral systems, loss of wild ungulates leading to a reduced availability of carrion, hunting for trade, for use in traditional medicine and bushmeat, persecution and human disturbance. Our review also addresses future steps that are needed for reversing the negative population trend of their free-ranging populations, including some specific conservation measures that are proposed to mitigate their decline.

INTRODUCTION

In Africa, in the last 30 years, a high number of bird species have been experiencing considerable reduction in abundance as land use intensifies (Sinclair *et al*. 2002, Söderström *et al*. 2003). Birds of prey experienced even more dramatic declines than other bird groups (Thiollay 2006a, 2007a, Ogada & Keesing 2010, Virani *et al*. 2011, Buij *et al*. 2013a). These declines have been accomplished with land-use and livestock alteration, cultivation, pesticide use, and human disturbance, causing a shortage in prey availability, nest sites, and reproductive success (Ogada *et al.,* 2009, Virani & Harper 2009). Indeed, 14 out of 23 (61 %) vulture species worldwide could be considered close to extinction, with the most rapid declines occurring in Asia and Africa (Ogada *et al*. 2011).

In addition, because of their high trophic position, birds of prey act as adequate bioindicators of persistent contamination, either in the present time or in the past decades (Solonen & Lodenius 1990, Falandysz *et al*. 1994, Bowerman *et al*. 1995, Koistinen *et al*. 1995, Falandysz *et al*. 1996, Nygaard 1999, Cade *et al*. 2011). Therefore, these species are crucial for the correct functioning of the ecosystems, and therefore their eventual extinction could produce cascade effects on the global scale.

The decline of vulture populations in Europe and North America started in the mid-19th century and some species such as the Bearded vulture (*Gypaetus barbatus*) and the California condor (*Gymnogyps californianus)* already approach extinction (Synder 1983, Mingozzi & Esteve 1997, Ogada *et al*. 2011). However, despite large population declines recorded historically in Europe and North America, populations of several vulture species are now increasing or stable (Ogada *et al*. 2011). Vulture population declines have also been reported in the Middle East and in Central and South America (Ogada *et al*. 2011).

Concerning the African continent, the overall picture is worrying. In North Africa, the decline of vulture species has been reported. For instance, in Morocco, two species, Cinereous vulture (*Aegypius monachus*) and Lappet faced vultures (*Torgos tracheliotos*) have been extirpated (Ogada *et al*. 2011). In East Africa, vulture declines of 70 % were recorded over a three-year period in north-central Kenya (Ogada & Keesing 2010).

In West Africa, most of the vulture populations, except the Hooded vulture (*Necrosyrtes monachus*), deeply declined over the last 30 years, especially in the rural areas, where a population loss by an average of 95 % was estimated (Rondeau & Thiollay 2004, Thiollay 2006a, b, 2007b).

The ecology of vultures makes them extremely vulnerable to some threats, especially toxic substances (Houston 1996) because most of them feed on carcasses or waste products, hence being particularly exposed to contaminants. Vultures are also long lived species and occupy high trophic level, and thus these concomitant factors increase their exposure to bioaccumulation, with negative effects on their reproduction and survival (Jenkins 1980, Erry *et al*. 1999, Miller *et al*. 2002, Kenntner *et al*. 2007, Gangoso *et al*. 2009). In addition, another threat responsible of vulture decline is their use for consumption as bushmeat and traditional medicine in West and Southern Africa (Adeola 1992, Verdoorn *et al*. 2004, McKean 2004, Mander *et al*. 2007, Buij *et al*. 2016, Petrozzi 2018).

The aim of this study is to summarize and report the conservation status of West African vultures and to propose potential actions in order to minimize the risk of local extinction of these threatened birds. In particular, (i) we describe the dramatic recent and historic declines of many vulture species in West Africa, and (ii) we investigate the causes of these declines in the different regions of West Africa, focusing on the actions necessary for successful vulture conservation programs.

METHODS

Our study area encompassed 17 West African countries (Fig. 1). In order to assess the conservation status of vultures in West Africa, we reviewed papers published in scientific peer-reviewed journals, technical reports and unpublished reports related to the whole West African region. We analyzed the conservation status of the eight vulture species present in West Africa (Fig. 2) by using the IUCN 2017 Red List (http://www.iucnredlist.org), six of them resident (*i.e*. Palm-nut Vulture *Gypohierax angolensis*, White-backed Vulture *Gyps africanus*, Rueppell's Griffon *Gyps rueppelli*, Hooded Vulture White-headed Vulture *Trigonoceps occipitalis* and Lappet-faced vulture), one migrant and wintering (Egyptian vulture *Neophron percnopterus*) and one, the Eurasian Griffon vulture *Gyps fulvus*, which now occurs in the study region as a wintering species (Di Vittorio *et al*. 2018). For

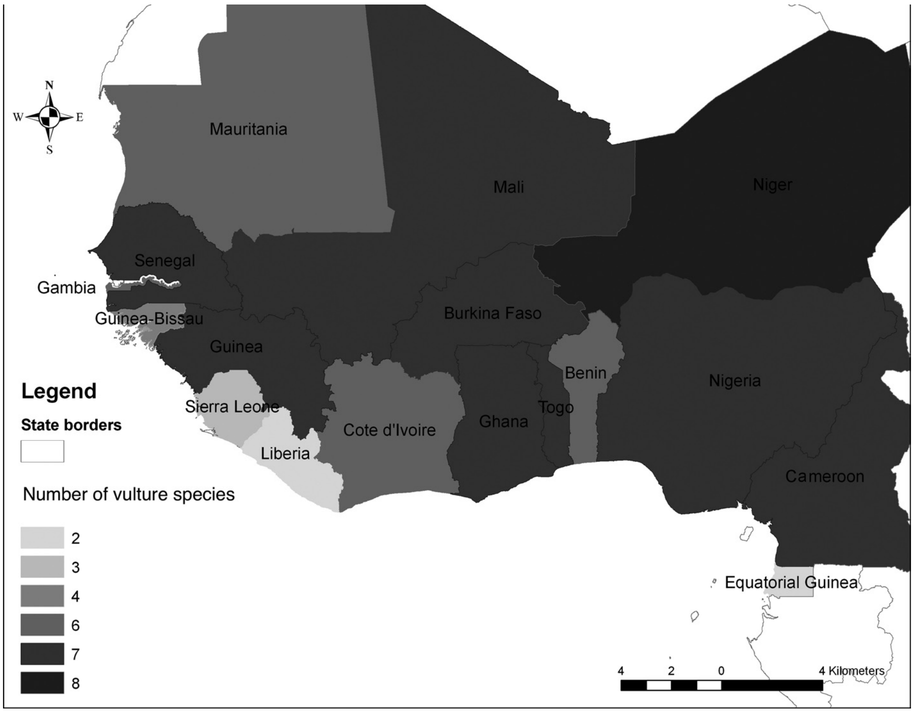

Fig. 1. – Map of West Africa, showing the 17 countries included in the present review and the number of vulture species for each country. Grey shades indicate the number of vulture species found in each of the studied countries.

Fig. 2. – Some species of West Africa vultures: 1) Palmnut vulture; 2) White-headed vulture; 3) Egyptian vulture; 4) Hooded vulture; 5) White-backed vulture; 6) Eurasian Griffon vulture (original pictures by Di Vittorio M., Zafarana M., Gioitta N.).

each species, we also report distribution and population trend in West Africa (BirdLife International 2016).

We classified anthropogenic threats using the IUCN standard nomenclature (IUCN-CMP 2012; review in Battisti *et al*. 2006).

RESULTS AND DISCUSSION

The overall picture

West African countries are actually inhabited by eight vulture species (Fig. 2), also including the Palm nut vulture, which is not a vulture *sensu stricto* as it also eats plants (*e.g*. the fruits of the oil palm *Elaeis guineensis*) and the Eurasian Griffon vulture, which is, probably, quite regularly present in the region during wintertime (Di Vittorio *et al*. 2018).

Two species, *i.e*. the Palm nut vulture and the hooded vulture, are still widespread, being present in 17 and 15 countries, respectively. The rarest species are the Eurasian Griffon vulture (5 countries) and the Egyptian vulture (8 countries) (Table I). Thus, overall, all the species of West African vulture still have a considerable range over the study region, despite their declining trends (see below).

According to IUCN (2017; Di Vittorio *et al*. 2018), four species are Critically Endangered, two are Endangered and only two are Least Concern (Table I). This would indicate that these birds have a threatened conservation status worldwide. In fact, apart from the Palm-nut vulture (that has a stable population trend) and the Eurasian Griffon vulture (that is increasing in Europe), all other species are suffering for a rapid decline in all West African countries (IUCN 2017, Table I).

By country, Niger hosts all the eight species, followed by Nigeria, Burkina Faso, Cameroon, Ivory Coast, Mauritania, Guinea, Togo and Senegal, which host seven species, while the countries with lower vulture species presence are Sierra Leone (3 species) and Equatorial Guinea, Guinea-Bissau and Liberia (2 species; Table I). Apparently, there is an area effect on the species richness of vultures by country, as some of the most species-rich countries are among the largest countries in the region (*i.e*. Niger and Nigeria) and the lowest species richness is observed in some of the smallest countries (*i.e*. Guinea-Bissau and Sierra Leone; Fig. 1).

Vulture in West Africa: a plethora of threats affect their populations

Due to limited available literature (Anderson 2004), the main causes of vulture declines in West Africa remain relatively unclear (Rondeau & Thiollay 2004, Thiollay 2006a, b, c) or merely analyzed at a general level, with little emphasis on the local scale. Apparently, all African vultures suffer from similar threats, especially poisoning, habitat alteration and conversion to agro-pastoral systems, loss of wild ungulates leading to a reduced availability of carrion, hunting for trade, for use in traditional medicine and bushmeat, persecution and human disturbance (Table II).

Following the IUCN standard nomenclature (IUCN-CMP 2012) these threats could be classified as: (i) poisoning and bioaccumulation (Code IUCN: 9.3 "Agricultural and forestry effluents": *i.e*. pollutants from agricultural, silvicultural, and aquaculture systems that include toxic chemicals, including the bioecological effects of these pollutants on the site where they are applied); (ii) habitat alteration and decline in food availability (Code IUCN 7.3 "Other ecosystem modifications": *i.e*. actions that convert or degrade habitats or biological processes, reducing

Table I. – Species and distribution range; Acronyms: LC = Least Concern; EN = Endangered; CR = Critically Endangered; BF = Burkina Faso; CA = Cameroon; IC = Ivory Coast; GH = Ghana; NI = Niger; NG = Nigeria, MA = Mali; MT = Mauritania; GU = Guinea; EG = Equatorial Guinea; TO = Togo; BE = Benin; SE = Senegal; GB = Guinea Bassau; GM = Gambia; SL = Sierra Leone; LI = Liberia.

Common name	Scientific name	IUCN Red List Category	Population trend	BF	CA	IC	GH	NI	NG	MA	MT	GU	EG	TO	BE	SE	GB	GM	SL	LI
Palm-nut vulture	*Gypohierax angolensis*	LC	Stable	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
White-backed Vulture	*Gyps africanus*	CR	Decline > 90%	×	×	×		×	×	×	×	×		×	×	×	×	×	×	
Eurasian Griffon vulture	*Gyps fulvus*	LC	Increase in European range				×	×	×		×					×				
Rueppell's Griffon	*Gyps rueppelli*	CR	Decline > 90%	×	×	×	×	×	×	×	×	×		×	×	×		×		
Hooded Vulture	*Necrosyrtes monachus*	CR	Decline 83%	×	×	×	×	×	×	×		×		×	×	×	×	×	×	×
White-headed Vulture	*Trigonoceps occipitalis*	CR	Decline > 90%	×	×	×	×	×		×	×	×		×	×	×	×	×		
Egyptian vulture	*Neophron percnopterus*	EN	Decline > 50%	×	×		×	×	×	×		×		×						
Lappet-faced vulture	*Torgos tracheliotos*	EN	Decline 80%	×	×	×	×	×	×*	×	×	×	×	×	×	×		×		

resource availability); (iii) capture for traditional medicine and bushmeat (Code IUCN 5.1 "Hunting and collecting terrestrial animals", defined as the process of killing or trapping wild animals or animal products for commercial, recreation, subsistence, or cultural purposes, or for control/persecution reasons); (iv) electrocution, considered as mechanism of impact (sensu Balmford *et al.* 2009) derived from threat classified as Code IUCN 4.2 "Utility and service lines; transport of energy and resources"; (v) human disturbance (Code IUCN 6.1 "Recreational activities" (*i.e.* disturbance directly or indirectly induced by people on animals).

Poisoning

Poisoning could be defined as the intentional or unintentional killing or harming of vultures through consumption of contaminated carcasses or remains (Ogada *et al.* 2011). The use of poison baits for "protecting" livestock from carnivores could kill scavenger species as well as the target victims. It is probably the most widespread reason of vulture poisoning (Bridgeford 2001, Mijel 2009, Ogada *et al.* 2016) because of the facility of finding poison in local markets. For example, in Kenya, carbamate pesticides, as Furadan, often used for poisoned baits, are low-priced, highly effective, and easily accessible (Odino & Ogada 2008a, b). Although similar studies on the effects of pesticides on West African vultures are not available in the scientific literature, there is very easy availability of pesticides in local markets (our unpublished observations), thus it is unlikely that the situation is different from that highlighted in East Africa.

Poisoning and intoxication of vultures by consumption of non-steroidal anti-inflammatory drugs, particularly diclofenac-sodium, could be another cause for a rapid and severe population declines in vulture populations as it happened in Asia (Green *et al.* 2004, 2006, 2007, Oaks *et al.* 2004, Shultz *et al.* 2004, Swan *et al.* 2006, Taggart *et al.* 2007, BirdLife International 2016, Cuthbert *et al.* 2016, Rhys *et al.* 2016). The recent introduction of veterinary practice using some class of drugs, as diclofenac for livestock, and the intensification of pesticides use in farming, can be therefore considered as one of the greatest risks for these species (Ogada *et al.* 2011). The effects of dioxins derivatives and other levels of toxic elements on productivity and population dynamics have already been demonstrated to be impacting raptor populations worldwide (Ratcliffe 1967, 1970, Berger *et al.* 1970, Enderson & Berger 1970, Blus *et al.* 1971, Peakall 1975, Newton 1979, 1988, Peakall & Kiff 1988, Crick 1992, Locke & Thomas 1996, Herzke *et al.* 2002). The degree of exposure to toxic substances depends largely on the amounts transferred via the diet. The prey consumed by vultures collect toxins from the environment, and vultures accumulate them (Roberts & Johnson 1978, Smith & Rongstad 1982, Eisler 1988, Ismail & Roberts 1992, Pascoe *et al.* 1994, Donázar *et al.* 2002).

In general, all vulture species are particularly vulnerable to toxic substances because of their foraging and social behavior (Houston 1996). Indeed, most vultures

Table II. – Threats (based on cited references) of the West Africa vulture species (* uncertain data). Eurasian Griffon vulture are not inserted due to lack of information for West Africa.

Species	Poisoning	Habitat alteration	Decline in food availability	Bioaccumulation (drugs and pesticides)	Capture for traditional medicine and bushmeat	Electrocution	Human disturbance
Palm-nut vulture		x			x		
White-backed Vulture	x	x	x	x	x	x	x
Rueppell's Griffon	x	x	x	x	x		x
Hooded Vulture	x	x	x		x		
White-headed Vulture	x	x	x	x	x		x
Egyptian vulture	x	x	x	x	x*	x	x
Lappet-faced vulture	x	x	x	x	x	x	x

are obligate scavengers that eat only dead animals or waste products, and therefore their foraging habits may increase the risk of exposure to contaminants (Gangoso *et al*. 2009). In addition, vultures feed normally in communal groups and thus a large number of individuals can be poisoned at a single carcass.

Interestingly, in some East Africa countries, poisoning events (particularly from the highly toxic pesticide carbofuran) occur primarily outside protected areas. The large body size of vultures, in fact, would need very large individual home ranges, thus forcing these birds to inevitably spend considerable time outside protected areas (Ogada & Keesing 2010, Otieno *et al*. 2010, Kendall & Virani 2012, Murn *et al*. 2016). Therefore, it would be important to focus conservation efforts not only at the level of protected areas, but also outside. However, the protected areas play an important role in the maintenance of raptor populations (Thiollay 2006a, 2007b). Outside protected areas, many raptor species have an unfavorable conservation status, and many populations are decreasing (Ogada *et al*. 2011) with a decline in raptor abundance positively correlated with distance from protected areas (Herremans & Herremans-Tonnoeyr 2000, Thiollay 2007b, BirdLife International 2008). In fact, at least 11 large eagle species and six large vulture species suffered dramatic declines outside protected areas (Thiollay 2006a, b, 2007a, b).

Habitat loss and food resources exploitation

Habitat loss and degradation due to human population growth are suspected to be a major cause of the intense declines of large vultures outside protected areas in West Africa (Thiollay 2006a, 2007a). The increase of human population in all countries, land-use change and the resultant exploitation of wildlife as "free resources", which also occurs frequently in protected areas in these regions, deeply influence vulture populations status (Brashares *et al*. 2004, Newmark 2008, Alves *et al*. 2013).

The reduction in food availability, caused by overhunting and/or changes in livestock husbandry, could have major impacts on vulture demography (Houston 1987) and may have greatly provided to large-scale vulture declines in West Africa (Rondeau & Thiollay 2004, Thiollay 2007b).

Trade for bushmeat and traditional medicine

The trade and use of vulture parts for traditional medicine is another serious threat and has been documented in West and Southern Africa (McKean 2004, Verdoorn *et al*. 2004, Mander *et al*. 2007). Indeed, vultures are used not only for consumption (bushmeat), but many individuals are also hunted and traded to be used in traditional medicine practices (Adeola 1992, Buji *et al*. 2016).

Overall, the impact of the bushmeat trade for West African vultures may be modest compared to other factors (Buij *et al*. 2013a, b, Petrozzi 2018). However, the impact of trade can be non-negligible because vulture populations are already decimated in the wild over very wide regions, especially in the Sahel. The commercial trade of wildlife-based medicinal products is often performed in traditional markets, where many animals, including threatened vultures, are freely sold (Nikolaus 2011a, b). The numbers of vultures traded in West Africa, especially for traditional medicine reasons, probably represented a significant proportion of the regional population (Buji *et al*. 2016). For example, in Nigeria, the Hooded Vulture was the most commonly traded species, with 90 % of all vulture parts traded belonging to the species (Saidu & Buij 2013). Across West and Central Africa, this species is certainly one of the most heavily traded, with an estimated 5,850-8,772 individuals traded over a six-year period in West Africa (Buji *et al*. 2016).

The Palm-nut vulture is another important and valuable species for fetish purposes in West Africa. It is estimated that about 0.2 % of the wild population (at least 356-534 individuals per year) is affected by this trade (Buji *et al*. 2016), although this number is possibly underestimated as it is often consumed in bushmeat hunting camps rather than being transported to markets (Whytock *et al*. 2016). In terms of trade of vultures for fetish market, within West Africa, Benin and Nigeria together accounted for 95 % of the carcasses traded during the period 2008-2013, thus, conservation actions centered in these two countries would therefore have the most significant impact on the cessation of this trade within the wider region (Buij *et al.* 2016).

Direct persecution and intentional killing seem to be a significant cause of mortality for vulture populations including, for instance, Cape griffons in South Africa, Hooded vultures in West Africa, and large vultures in Nigeria (Mingozzi & Esteve 1997, Rondeau & Thiollay 2004, McKean 2004, Nikolaus 2006, Thiollay 2006a, Thiollay *et al.* 2006a, Margalida *et al.* 2008), as well as in the United States, Europe, and North Africa both without specific reasons, as a form of sport (Miller *et al.* 1965, Mingozzi & Esteve 1997, Mundy 2000, Hunt *et al.* 2009). In some instances, the vulture killing is done as a revenge for the suspected killing of newborn lambs, or, as already pointed out, to acquire vulture parts for traditional medicine trade.

Effects of threats in West Africa to the global status of vulture species worldwide

The decline of vultures in West Africa also affects European populations. Indeed, one of the most endangered vulture species breeds in Europe (*i.e.* the Egyptian vulture), and winters in West Africa (Benítez *et al.* 2004, Meyburg *et al.* 2004, García-Ripollés *et al.* 2010, BSPB 2013). Every year, fewer and fewer individuals come back from Africa to their breeding areas, indicating that a considerable portion of migrating individuals actually die in the African area, including Mali, Mauritania, Niger and Nigeria (EVFAP 2015). To illustrate this, there is the case of an Egyptian vulture tagged with a satellite transmitter in Greece in 2013 and killed by a traditional vulture hunter in Nigeria in 2014 (Nikolov 2014). In Nigeria and Niger, vultures are intensively killed for commercial aims by specialized hunters, even though they are protected by law, and the collected data showed that the losses of vultures (all species) should be expected to be significant (Nikolov 2014).

Considering their specific ecological role, the reduction or absence of vultures from carcasses may impact the scavenger community composition, and, consequently, modify scavenging rates for other species (Ogada *et al.* 2011). Decomposing carcasses are incubators for many pathogens, and animals coming into contact with carcasses in putrefaction could be exposed to infectious agents (Wobeser 2002, Butler *et al.* 2004, Jennelle *et al.* 2009).

In the parts of the world where vultures are functionally extinct, the absence of vultures at carcasses cause a rapid abundance increase of other opportunistic species, as feral dogs or rats (Pain *et al.* 2003, Prakash *et al.* 2003, Selva & Fortuna 2007). These species are well-known disease reservoirs, and this may increases rates of infectious disease transmission to other species, as rabies and bubonic plague (Ogada *et al.* 2011), canine distemper virus, canine parvovirus, and *Leptospira* spp. bacteria, thus seriously increasing the risk also for human health (Mudur 2001).

Lastly, the vulture presence at carcasses maintain community structure, restricting mammalian scavengers at carcasses (Ogada *et al.* 2012a, b). Indeed, the absence of vultures increases carcass decomposition time and the time that mammal scavengers spend at carcasses, and this could facilitate disease transmission (Ogada *et al.* 2012a, b, Moleón *et al.* 2014). In Kenya, in the absence of vultures, carcass decomposition time nearly tripled, and both the number of scavenging mammals and the time they spent at carcasses increased threefold. Further, there was a nearly threefold increase in the number of contacts between mammalian scavengers at carcasses without vultures, suggesting that the demise of vultures could facilitate disease transmission at carcasses (Ogada *et al.* 2012a, b) between other species as hyenas (*Crocuta crocuta, Hyaena hyaena*) and jackals (*Canis mesomelas*), which host a number of pathogens that infect a wide range of other wild and domesticated species (Alexander & Appel 1994, Alexander *et al.* 1994, Harrison *et al.* 2004). In this regard, it should be mentioned that rabies and canine distemper are the two major diseases affecting African carnivores. These diseases may spread through direct contact between infected and susceptible individuals, and carnivores often interact closely at carcasses (Mills 1993, Roelke-Parker *et al.* 1996). Hence, vulture decline may increase the emergence of these serious illnesses, also for endangered species as lions (*Panthera leo*) (Roelke-Parker *et al.* 1996).

Conservation measures

Despite the severity of the problem, the vast majority of African governments have provided no substantial help for vulture conservation, despite vultures being the most threatened group of birds in the world with > 60 % of species listed in the IUCN Red List of Threatened Species (Sekercioglu 2006). This absence of governmental actions is not only caused by fund shortage availability for nature conservation (that is quite a widespread issue in West African institutions) but also by a cultural attitude that minimizes the usefulness of vultures for the natural ecosystems. Thus, a priority measure should be to organize solid awareness campaigns in favor of vultures directly targeted at governmental agencies devoted to conservation and management of nature.

It is also necessary to set conservation actions based on collaboration among scientists, regional governments, donors and the media. Furthermore, the development of citizen science programs, public education and outreach projects would help to effectively conserve vultures through effective and targeted interventions, as restricting or forbidding the use or sale of pesticides that are purported to be less toxic to wildlife (Odino & Ogada 2008a).

In some West African countries, it is necessary to enforce conservation legislation, but also to seek funding and to develop specific projects that take into account the different socioeconomic realities of different states in West Africa, based on the following guidelines:

1) *Assessing population size and mapping extant populations*: experienced researchers could help to detect the occurrence of target species by doing specific field surveys, recording breeding success, environmental information and potential dangers. Moreover, because of the importance of livestock in vulture diet, it would be necessary to carry out a census of farms and of their animals, with an analysis of the distribution of herds and cattle and their mortality ratio. In the areas of higher density, if needed, other significant environmental improvements should be developed, *i.e.* maintaining suitable landscape, creating open spaces in potential foraging areas, and preserve large trees suitable for building nests.

2) *Monitoring vultures with GPS transmitters*: in order to obtain data on behavior, movements and home range of vultures, it would be necessary to mark some of them with GPS transmitters for each species, in every West African countries, by different types of capture methods (Gradev *et al.* 2012, López-López *et al.* 2014). Egyptian vultures marked in Europe (mainly Spain, Greece, France, Bulgaria and Italy) and wintering in West Africa could be monitored in West Africa for obtaining useful information about the frequented areas and improve the analysis on potential risks and death causes.

3) *Development of a management plan for each of the West African vulture species*: this plan is urgently needed, and should contain the guidelines for the management and conservation for each species throughout the study area. The plan should also highlight the potential sources of funding that should be applied for if a given vulture conservation project is implemented.

4) *Identify the most dangerous toxins and poisons to the target species*: the knowledge of the level of contamination is fundamental for long-term conservation of several species, and a spatial explicit approach can be very useful in this issue. Indeed, it would be very helpful to map the areas with higher contamination (current or potential), with important implications not only in terms of conservation but also of public health (*e.g.* action on substances used in agriculture and livestock, etc.). To obtain such useful information about the most dangerous toxins and poisons for target species, biological material (blood, feathers and fecal castings) from wild-caught vultures should be collected. When dead vultures are found, it would be advisable that some samples of the carcass would be taken and analyzed in the laboratory. The same analysis should be repeated for livestock and wild ungulates. In this latter case, the samples should be taken from muscle and liver, taken in slaughterhouses, meat sellers, and in bushmeat markets. Surveying the chemicals and veterinary equipment (pesticides, antibiotics, anti-inflammatories, etc.) used by "big" farmers may also be useful in order to determine (by analyzing the chemical composition) the most used harmful and dangerous products in the region. The following step should be to identify the alternative solutions with non-hazardous products. However, a standardized analysis naming and assessing the regime by scores (duration, frequency, intensity, extension) of each anthropogenic threat is necessary, using recent approaches (Salafsky *et al.* 2003, 2008, review in Battisti *et al.* 2016).

5) Local population awareness: it would be advisable to increase local population awareness by organizing meetings with local authorities, explaining vulture conservation problems in order to have their consent and their participation, and for planning meetings in the villages where deaths of vultures were recorded or where the vulture are present in big concentrations. Because the use of pesticides and veterinary dangerous products undoubtedly causes problems also to human health, awareness campaigns can be essential in social terms. Finally, the consistency of the bushmeat and traditional medicine trade issue (the species and number of individuals) should be analyzed by specific surveys, including also the economic implications of the vulture trade.

6) Installation of vulture feeding stations: vultures feeding stations could be built in strategic areas of every country to improve productivity and survival rate of vultures (Ceballos & Donázar 1990, Meretsky & Mannan 1999, Del Moral & Martí 2002, García-Ripollés & López-López 2011, Monsarrat *et al.* 2013, López-López *et al.* 2014, Lieury *et al.* 2015, Di Vittorio *et al.* 2018). Obviously, an enhanced protection of national parks and protected areas would also help considerably the conservation of these bird species.

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