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Editorial

Again on the mass extinction issue

The issue of mass extinction was the subject of a previous editorial (Massa 2015). Three years later I resume again this matter, very relevant for birds, particularly on the light of the rapid increase of extinction rate due to the so-called sixth extinction, the first mass extinction caused by man *Homo sapiens*, a particularly numerous species present on Earth only for about 200,000 years. The term "*Antropocene*" has been coined by the 1995 Nobel prize winner Paul Crutzen, for the current epoch, in some respects dominated by man, whose activities have transformed between one third and half of the Earth`s surface, has diverted or embanked most rivers, produced (by agriculture factories) more nitrogen than that emitted naturally by plants in the terrestrial ecosystems, removed (by fish farms) more than one third of the primary production of oceanic coastal water, used more than half of the world`s accessible water, and altered the composition of the atmosphere. Already some 60 years ago a number of scientists had already understood the seriousness of this problem; one of them, Hutchinson (1959) wrote that man had reduced diversity by a rapidly increasing tendency to cause extinction of supposedly unwanted species, often in an indiscriminate manner; and he believed that a limited reversal of this process should have occurred when man would become aware of the value of diversity no less in an economic than in an esthetic and scientific sense. In the '90s about one-quarter of the bird species on the planet have been driven to extinction (Leakey & Lewin 1995, Vitousek *et al*. 1997). It is evident that man is causing the sixth mass extinction; on this more and more tragic event many data has been collected in the last years and the public opinion must be informed (Kolbert 2014).

Old extinctions

First pluricellular Metazoa, provided of organs and tissues, date back to ca. 600 million years ago (Cambrian). During the last 500 million years the biological richness has grown a thousand fold, evidence that through time a quantitative saturation has not been reached. From then on, the majority of extinctions on Earth have occurred. Following Raup (1993) since ca. 3.5 thousand billions of years 99% of species that lived on the Earth became extinct; very many chrono-species followed one another during this long time. In many instances, other species evolved before extinction and in some instances descendants survived while a branch became extinct. Generally in the last 500 million years only five events of mass extinctions were reported in bibliography (Raup 1993); the most famous of them occurred in the K-T (between the last Cretaceous and the start of Tertiary), about 65 million of years ago, when the dinosaurs disappeared. Namely: 1) 440 million of years ago (end of the Ordovician); 2) 365 million of years ago (end of the Devonian); 3) 245 million of years ago (end of the Permian), when 52% of families of sea animals (including 77-96% of species and all trilobites) and a high number of terrestrial species became extinct; 4) 200 million years ago (end of the Triassic); 5) 65 million years ago (end of the Cretaceous), when at least 50% of living animal species became extinct (including ammonites and dinosaurs). Nevertheless, Raup & Sepkoski (1986) identified in the last 250 million years twelve periods of extinctions, nine of which were distributed at regular intervals of 26 million years; thus, these authors have hypothesized a recurrent extinction of sea organisms. On this subject there is still a deep debate and some authors believe that the hypothesis deserves more data.

Present mass extinctions

Now we are in the middle of a great wave of extinctions caused by man. Extinction is a natural phenomenon, on whose causes it has been much debated (bad genes or bad luck? Raup 1993), but we do know for certain this phenomenon (e.g., extinctions of trilobites, ammonites and dinosaurs). However, nowadays this phenomenon is induced by man, who during his history on Earth very probably caused the extinction of his related hominid, Neanderthal man *Homo neanderthalensis* and certainly that of the mammoth in Northern Europe, as well as that of many other big and small living species. The current extinction is caused mainly by biotic factors induced by man, such as isolation and habitat loss; of course the extinction risk is different depending on the circumstances, but it largely depends on man`s activities. We have witnessed hundreds of species' extinctions during human history and man as a predator has proved his effectiveness many times: the Passenger Pigeons *Ectopistes migratorius*, Great Auks *Pinguinus impennis*, Mauritius Dodo *Raphus cucullatus* and Labrador Ducks *Camptorhynchus labradorius* have all gone extinct and man has had a strong hand in each, although other events have played their part (Mac Arthur 1972). The Mauritius Dodo, a giant pigeon unable to fly, becoming extinct in the late 1600, 100 years after its discovery (1598), is an icon, a symbol of extinction caused by the obstinately destructive action of man (Hume *et al*. 2006). The Great Auk, also unable to fly and clumsy on the ground, but speedy and able to swim in the sea, lived in the cold waters of the North Atlantic, from western Europe to North America; in the first years of 1800 it became rarer and rarer and in the middle of the century it was not possible to find any individual of the last population on Funk island and Eldey Rock, where the last specimen was killed in 1844. Their populations were destroyed by euro-american sailors, who hunted adults and their eggs for eating and museum collections. However, the extinction of this very popular seabird had a positive effect; its disappearance influenced emotionally a high number of British ornithologists of Victorian age, who promoted the first law for the protection of seabirds (Gaskell 2000).

The extinction rate due to anthropic causes may be variable, depending on the isolation of the geographical area and the endemism degree. Four species of very large-sized birds, the Moas lived in New Zealand, two of which *Dinornis maximus* and *D. ingens* 3.5 m tall, became extinct through human persecution between 1500 and 1850. The Kakapo *Strigops habroptilus*, an extraordinary parrot for its size (3.5 kg in weight), with its nocturnal habits, inability to fly and its polygamy, is on verge of extinction as a result of the introduction of mustelids and deer in New Zealand. After the colonization of New Zealand by European 50% of the 250 bird species became extinct.

The Lear Ara *Anodorhynchus leari*, the Madagascar Buzzard *Buteo brachypterus*, the Eskimo Curlew *Numenius borealis*, the Slender-billed Curlew *Numenius tenuirostris*, the Gurney's Pitta *Pitta gurneyi* are more or less very close to oblivion. The Slender-billed Curlew currently is probably one of the rarest birds in the Palearctic Region; according to the International Union for Conservation of Nature (IUCN 2017) it is one of the most 'Critically Endangered' European bird species. The last observations date back to 1999: one individual was observed in April in Greece and in February in Oman, and three young individuals again in Oman in August (evidence that in 1999 the species was still able to breed). The only evidence of its breeding site dates back to the first years of 1900 and concern the area of Tara, in the region of Omsk (South-West Siberia, East of Ural Mts). Once it wintered regularly in the Mediterranean and was rather frequent also in Italy, more common than the Whimbrel *Numenius phaeopus*; Morocco was a favoured wintering area, last flights of more than 100 individuals were observed in January 1964 in the lagoon of Puerto Cansado, Khnifiss (500-800 ind.) and in December 1974 in the Oued Chebeika (123 ind.). Since 1995, in the last regular wintering site in Morocco, Merja Zerga, the Slender-billed Curlew was no longer observed (Gretton *et al*. 2002).

Species or subspecies, global or partial extinction?

Furthermore, some bird populations are considered taxonomically separated and named as subspecies. Biodiversity is the total variety of life on Earth, including all genes, species and ecosystems and the ecological processes of which they are part (Wilson 1988, Mc Neely *et al.* 1990); maintaining it means preserving species on the whole and their isolated subspecies as well. Some biogeographical populations are the re-

sult of an evolutionary process in progress; they should be preserved for the potential evolution and acquisition of unique characteristics, which represent important components of biological diversity. According to O'Brien & Mayr (1991) and Amadon & Short (1992), bird subspecies are allopatric subpopulations, generally maintained by spatial segregation, that share a unique geographic range or habitat, a group of phylogenetically concordant array of phenotypic and genetic characters, a unique natural history relative to other subdivisions of the species, (still) genetically compatible with other subpopulations. Each of the geographical forms classed as subspecies occupies particular areas which, all together, give the range of the species as a whole. If these geographical forms were classed as allospecies (populations derived from the same common ancestor whose ranges differ and do not meet), we would have several smaller ranges in place of a large one (Newton 2003). Populations on islands encounter a physical impediment to gene-flow between populations, and it is therefore expected that such populations may diverge in isolation (Phillimore & Owens 2006); if effectively isolated, they may become new species by acquiring genetic isolating mechanisms (Massa 2006). From a conservation point of view there is an important difference in treating a species as whole or its subspecies separately. Taxa that are apparently well differentiated, possibly having very rare (if not absent at all) gene flow with other subspecies, very probably have reached a reproductive isolation. The Heath Hen *Tympanuchus cupido* in pre-Columbian epoch was widespread in the North American prairies, from Texas to the Canadian provinces. Later, following man`s colonization of North America, it has undergone a decline, mainly due to agriculture, sheep-farming and hunting; taxonomists recognized three subspecies: *cupido* from Massachusetts to Maryland, now extinct, *pinnatus* from the Dakotas to Nebraska, Kansas and Missouri (disappeared from central Alberta, South-East Ontario to Arkansas) and *attwateri* in the coastal areas of Texas (disappeared in South-West Louisiana). According to Halliday (1978) and Reid & Miller (1989) the subspecies *cupido* in 1840 lived only in Long Island, some lands of Pennsylvania, New Jersey and few other sites. Since 1870 it was found on Martha's Vineyard Island (off the Massachusetts coast); in 1890 this population was reduced to 200 individuals and in 1896 to less than 100. In 1908 a shelter was established on the island and the decline was stopped; 12 years later the population grew to 2000 individuals, but in 1916 a serious fire, a severe winter, an unusually abundant population of goshawks, a disproportion of males/females ratio, and a zoonosis introduced together with turkey cocks reduced drastically the population size. In 1920 the population was so low that inbreeding caused a serious genetic deterioration; in 1927 only eleven males and two females lived on the island and in 1928 only one individual survived, observed for the last time in 1932. This event reminds us of the legend of Noah's Ark, that has always received a great appeal; a similar experiment should have achieved the same success? In reality, no! The survival of a species means that a minimum vital population (sensu Mac Arthur & Wilson 1967 and Soulé 1987) is alive, with a potential for evolutionary adaptations. When we dispose of only one or few pairs this is impossible, because inbreeding is the cause of a slow decline to the final extinction. Extinction occurs when the last reproductive unity of the last population disappears (Frankel & Soulé 1981).

Another case of a subspecific taxon on the verge of extinction is that of the Common Buttonquail *Turnix sylvaticus*; it is very probable that it became extinct in Europe and its remaining population in the western Palearctic (Morocco) is very small and is in danger of extinction (Violani & Massa 1993); furthermore, it is actually impossible for a natural re-colonization from Asian or sub-Saharan populations to North Africa or Europe. Considering also the clear biometrical differences that exist between specimens from the Mediterranean area and those living in Asia and sub-Saharan Africa (very probably corresponding to genetic differences), a tentative to reintroduce the species with specimens from the latter localities should be discouraged. When the Mediterranean population will disappear, no specimens for reintroduction projects will be available, as it is different from the Asian and sub-Saharan populations. Thus, at this moment we are witnesses to the extinction of the Mediterranean Buttonquail, very probably endemic and genetically different (Violani & Massa 1993). This tragedy has been caused mainly by habitat loss and hunting.

The Northern Rockhopper Penguin *Eudyptes moseleyi* living in the island of Tristan da Cunha, in the southern Atlantic has been considered for longtime a subspecies of *Eudyptes chrysocome*, of which many millions of individuals are known in the austral lands; Banks *et al*. (2006) have shown that there are genetic

and morphological differences between them, and that they live in waters with 10 °C of difference compared to the latter species. Since a few years ago the inhabitants of Tristan da Cunha collected and made omelettes with the eggs of this endemic species, now represented only by few individuals!

Ecological footprint

Biocapacity represents the terrestrial and marine productivity of ecological assets (plant-based food and fibre products, livestock and fish products, timber and other forest products, space for urban infrastructure). The ecological footprint measured in global hectares (standardized hectares with world average productivity) the biocapacity that we require to produce the natural resources that we consume and to absorb their waste, especially carbon emissions. If the ecological footprint of one country exceeds the biocapacity, we may observe an ecological deficit. In other words, if the request for fruits, vegetables, meat, fish, wood, and carbon dioxide absorption that one country can provide exceeds what the ecosystems may renew, an ecological deficit occurs. On the contrary, if biocapacity exceeds the ecological footprint, an ecological reserve is observed. The ecological deficit of the world is known as global ecological overshoot; since at least forty years our planet has been in ecological overshoot due to human activities, as a result of our request of resources being higher than that the planet may renew every year. Nowadays, man uses a proportionate value of 1.6 planets to provide the resources that he uses and to absorb waste; in addition, more than 80 percent of the world's population lives in countries that are running ecological deficits, using more resources than what their ecosystems can renew. In other words we need one year and six months to regenerate what we use in one year. We should use much less ecological resources and services than we are using, because nature cannot regenerate overfishing, forest overharvesting, and the higher emission of carbon dioxide into the atmosphere than forests can sequester (Lin *et al*. 2016).

Earth's population consume ecological resources produced in all corners of the world; thus, their ecological footprint corresponds to the sum of these areas, wherever they are. There are some geographical regions whose biocapacity is higher than the local inhabitants may exploit, but regrettably this is consumed by other people, legally or illegally, through the exportation of natural resources. For example, an African person has an ecological footprint of about 1.1 global hectares (corresponding to ca. 40% of mean world ecological footprint); however, the biocapacity in Africa is relatively low (1.3 global hectares per person), and Africa is a wide region where the population doubled in the last fifty years. While some geographical areas (like Europe, China and North America) have a mean ecological footprint much higher than their biocapacity, others (Africa and parts of Asia) maintain below the mean footprint; overall, there is not a geographical area which uses criteria for a sustainable use of natural resources, where life quality has a good standard and resources exploitation does not exceed the biocapacity of the ecosystems. Debtor countries consume more than their ecosystems may provide, while creditors have ecological reserves and their ecological footprint is lower than the mean biocapacity.

The main problems of each country are not only to provide resources to inhabitants but also to eliminate waste materials; China in the last years emitted a high quantity of carbon dioxide produced from fossil fuel, not sequestered by ecosystems. Part of the deficit of countries with higher ecological footprint is balanced by the biocapacity (in the shape of products) in other countries, but it is obviously necessary to restore the ecological balance.

Present extinction rate

There are approximately 10,000 known bird species distributed among a vast range of habitats, from tropical rainforests to icy shores. BirdLife International (IUCN 2017, Birdlife International 2018) has established that 1,375 bird species (13% of the total) are threatened with extinction and many others are declining from causes induced by man. The majority of critically threatened birds are parrots, pheasants and related species, albatrosses and related species, rallids and pigeons (Bennett & Owens 2002). The known extinction rate is about 0.30/year (0.60/year if we count since 1900) (Butchart *et al*. 2006). The current extinction rate of bird species due to human activities is considered to be from 1000 to 11,000 times higher than in natural

conditions (Pimm *et al*. 1995, Butchart *et al*. 2006). The rate of natural habitat loss or degradation does not consent to forecast the destiny of many species, which is generally due to multiple causes. Habitat loss and fragmentation is considered by far the most pervasive threat, impacting ca. 85% of endangered birds; over-exploitation and invasive alien species are also impacting about 30% of threatened birds (the latter 67% on islands) (IUCN 2017, Birdlife International 2018).

Since at least the past 11,000 years man has been exploiting natural resources, modifying indirectly the ecosystem equilibrium. One of the actual problems is habitat fragmentation that produces a reduction of the total extension of habitat and consequently of species, including endemics, and the setting of isolation barriers, that in turn produces local extinctions. Even though the extinction rate in pre-historic and historic times is unknown, it seems possible that it has been growing in recent times. According to Duncan *et al*. (2013), the largest extinction event in the Holocene occurred on Pacific islands, where late Quaternary fossils revealed the loss of thousands of bird populations following human colonization of the region. Two-thirds of the bird populations on these islands became extinct in the period between first human arrival and European contact, with extinction rates linked to island and species characteristics that increased susceptibility to hunting and habitat destruction. The above cited authors have calculated that human colonization of remote Pacific islands (within the last 1000-4000 years) caused the global extinction of ca. 1,000 species of non passerines, excluding seabirds, that could be added to the total of extinctions (see also Pimm 1998). Excavations carried out in tropical islands of Pacific Ocean have shown that more than 2000 bird species became extinct in the last 10 thousand of years, corresponding to an extinction rate of one species every five years in the last 10 thousand of years, remarkably higher than the previous estimate of one species every 100 or 1000 years (Bennett & Owens 2002). Many Oligocene insular species were apterous or colonial and were much more vulnerable to the destructive action of sailors and settlers. Current extinctions (89.3%) concern also islands, very fragile and vulnerable ecological systems. It seems that the extinction rate of birds has been growing since 1500, with a peak in the late 1800 and early 1900, corresponding to 0.72 species/year. The majority of extinctions occurred in Hawaii (27 species), Mauritius Is. (18), New Zealand (14), Réunion (11) and St. Helen (9). In continental areas the extinction risk is much lower, and the proportion of threatened birds is approximately 8%.

Major risks of extinction

Smaller populations shall become extinct in a shorter time, and, independently from the population size, within a long lapse of time the extinction probability shall grow. While species of a larger size may survive for a long time with a few pairs, those of a smaller size cannot maintain their populations with little numbers (Pimm *et al*. 1988). However, Terborgh & Winter (1980) concluded that extinction proceeds impartially towards big and small species, and within different trophic layers. In addition, migrant birds face more risks and their population sizes are more fluctuating across time; higher fluctuation corresponds to higher extinction risk. Differently, sedentary species face only local abiotic factors. However, if a migrant bird becomes extinct in only one distribution area, a possible recolonization may occur from another area where another population still is living. This is not possible for a sedentary species, except for the cases when man introduces it from another locality. Generally, rarity is the best index of vulnerability.

One of the most important causes of species extinction is the introduction of alien species. Following Butchart *et al*. (2006) at least 77 bird species became extinct after the introduction of alien species. Invasive alien species are a major driver of biodiversity loss. In fact, an analysis of the IUCN Red List (2017) shows that alien species are the second most common threat associated with species that have gone completely extinct. In many cases the alien species was a predator (like dogs, pigs, cats, rats, etc). An emblematic case is that of Stephens Island Wren *Traversia lyalli*: in 1894 some cats were introduced in the islet and the bird became extinct. Another example is the Micronesian Kingfisher *Todiramphus cinnamominus* endemic to the island of Guam (Western Pacific), but following predation by the invasive alien Brown tree snake *Boiga irregularis*, it became extinct in the wild in 1986 when the last remaining wild birds were taken into captivity for captive breeding. In fact the Brown tree snake has caused many extinctions on Guam, including the

local extinction of over half of Guam's native bird and lizard species as well as two out of three of Guam's native bat species. The Guam Rail *Gallirallus owstoni* survived only thanks to a captive breeding program, the Mariana Fruit Dove *Ptilinopus roseicapilla* became extinct on Guam but survived in other nearby islets; overall, five bird species became extinct through the introduction of this snake (Savidge 1987).

Some concluding remarks

Many scientists think that we are just now entering a profound spasm of extinction and that one of its main causes is global climate change. Furthermore, population growth, which has increased so dramatically since industrialization, global climate change and many other factors (e.g., habitat destruction, modification and fragmentation) are connected to nearly every aspect of the current extinction events. Little time remains to stave off mass extinctions, if still possible at all (Wake & Vredenburgh 2008). About 1.5 million described animal species are known, but following some hypotheses probably at least 20 million live on the Earth. We may presume that the proportion of extinctions among undescribed species is the same as among the described species; then the number of extinctions would be approximately some thousands species per 100 years. These numbers probably are conservative and indicate the seriousness of the current sixth mass extinction caused by man.

Ceballos *et al*. (2010) highlighted that the sixth extinction wave not only threatens our aesthetic and moral senses, but the very survival of civilization. World governments have tried to change direction through the United Nations Framework Convention on Climate Change, the Convention on Biological Diversity and other international agreements, but for all the people to see the world economy as well as some powerful government leaders will hardly commit seriously and morally oneself to renounce to some income for saving a small portion of biodiversity.

We are aware that we do not have the strength to convince the public opinion that we are in the middle of a serious wave of extinctions caused by man, that we humans have produced heavy environmental degradations, which in turn will have obvious consequences against us. We know that many global change stresses on terrestrial and marine ecosystems affect not only ecosystem services that are essential to humankind, but also the trajectory of future climate by altering energy and mass exchanges with the atmosphere (Bonan & Doney 2018). We, as simple researchers represent a very small percentage of the population and we have limited possibilities to have some listeners. In addition, we are also aware that a high percentage of the human population does not have the availability to follow these kinds of "ecological" problems. The sole grain of hope is that we will be taken seriously by some personality with a good television appeal, an opinion leader who could relaunch what we continue to write since a long time.

I conclude with a sentence of Hutchinson (1962): *a world containing none of these animals would be intellectually impoverished to a degree that we are only just beginning to realize*. He wrote this fifty-six years ago!

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