UN environment programme

CMS

CONVENTION ON MIGRATORY SPECIES

UNEP/CMS/COP14/Inf.30.4.2

22 December 2023

Original: English

14th MEETING OF THE CONFERENCE OF THE PARTIES
Samarkand, Uzbekistan, 12 – 17 February 2024
Agenda Item 30.4.2

INSECT DECLINE AND ITS THREAT TO MIGRATORY INSECTIVOROUS ANIMAL POPULATIONS

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CMS

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LIB Leibniz Institute for the Analysis of Biodiversity Change

INSECT DECLINE AND ITS THREAT TO MIGRATORY INSECTIVOROUS ANIMAL POPULATIONS

REPORT

Prepared by scientists of the LIB,

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on behalf of the CMS Secretariat

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EXECUTIVE SUMMARY

KEY MESSAGES

1) **Insect decline represents one of the threats that contribute to population decline of many CMS-listed migratory insectivorous species.**

2) **The global insect decline affects migratory insectivorous species by reducing the availability of food during migration and at other stages of their lifecycles.**

   a) Insectivorous species rely on insects as their main food source. The decline of insects that make up the food resources of insectivorous animals can affect the survival of entire populations of insectivorous species.

   b) Migratory insectivorous species are threatened by changes in insect biomass, abundance or diversity.

   c) Insect decline is known to be highly variable between insect orders and ecosystems and between terrestrial and aquatic environments.

3) **Land-use change, climate change and pollution are the main drivers of insect decline worldwide; these drivers are often intertwined and may act simultaneously.**

   a) The main factors contributing to the decline in insects that are important food for birds are land use by agriculture and certain forest management practices, as well as pollution from agricultural effluents, and shifts and alterations in habitats resulting from climate change. These threats are associated with reduced food availability, lower body-condition of birds associated with sub-optimal feeding and migratory and stop-over area shifts.

   b) The main threats affecting the bat species are unsustainable management practices, such as the clear-cutting of forests, artificial light pollution at night and climate change, potentially triggering higher levels of bat activity in winter. These threats cause - directly or indirectly - a reduction in food availability for bats by reducing the availability of insect habitat (e.g. clear-cutting) and the quantity of insects (e.g. pollution). The scarcity of insects in many areas in Europe during winter may lead to high energetic foraging costs for insectivorous bats.

   c) The assessed fish species are threatened by insect decline as a result of modifications to natural systems and pollution. Natural system modifications, such as dams, are suspected to cause a reduction in aquatic insect abundance due to the artificial manipulation of the physical properties of the water. Water pollution can hinder aquatic insect larval development or lead to a decrease in adult insect abundance as a result of the lethal effects of polluted water.

4) **Insects and the migratory insectivorous animals feeding on them are important for ecosystem functioning** and provide critical ecosystem services, such as pollination.

5) **There are gaps in the understanding of the impacts of insect decline on migratory insectivorous species and quantifying these threats is difficult.** More information is needed on the population status and trends for a number of insectivorous migratory species, in particular bats.

RECOMMENDATIONS

1) **Put in place insect conservation measures** to ensure the availability of food for migratory insectivorous species:

    a) **Align policies and management measures with the objective of reducing threats such as unsustainable land use changes, climate change and water, soil and light pollution** as the main causes of the global insect decline affecting insectivorous migratory species.

    b) **Promote heterogenetic agricultural landscapes** to improve food availability and habitat heterogeneity for migratory insectivorous animals throughout their entire range.

    c) **Create, maintain, connect and protect habitats** for insects, for the benefit of migratory insectivorous species, and protect them from the impacts of climate change.

    d) **Reduce pollution of terrestrial and aquatic ecosystems** to ensure the availability of food for migratory insectivorous species before, during and after their migration.

2) **Intensify insect monitoring**, prioritizing sites that are important habitats for breeding or stopovers during migration.

3) **Support global insect monitoring efforts and exchange of data.**

4) **Work with international organizations, governments, NGOs, the private sector and other stakeholders** to improve habitat heterogeneity and connectivity, thus contributing to increased insect food availability.

5) **Develop guidelines for the most urgent or prioritized actions identified,** addressing the cascading effects of insect decline on migratory insectivorous species. While the guidelines should be globally applicable, they could also define region-specific measures.

1. Introduction

1.1 Aims and Objectives

In February 2020, at the 13th meeting of the Conference of the Parties to CMS (COP13, Gandhinagar, India), the subject of Insect Decline and its Threat to Migratory Insectivorous Animal Populations, prepared by the European Union, was introduced as UNEP/CMS/COP13/Doc.26.4.10. The Parties adopted the Resolution 13.6 Insect Decline and its Threat to Migratory Insectivorous Animal Populations, calling for the analysis and action concerning the dramatic insect decline and related cascading effects on migratory insectivorous species.

Objectives of the report follow the mandate from the Decision 13.129, directed of the Scientific Council and adopted by the 13th meeting of the Conference of the Parties (COP13):

a) identifying and prioritizing the main factors causing the established loss of insect biomass;

b) collecting relevant information regarding the current insect decline, and assessing its cascading effects on migratory insectivorous animal species;

c) developing guidelines for the most urgent or prioritized actions identified;

d) publishing any such guidelines following circulation to all Parties for approval

The report has a focus on section a) and b). Section c) is partly included and needs further attention in an additional report.

1.2 Additional Information

The CMS Secretariat commissioned the Leibniz Institute for the Analysis of Biodiversity Change to produce the report, based on the mandate received by COP13 in Decision 13.129. J Rochlitz, D Ott and C Scherber submitted the early drafts of the report, in May and June 2023, to the CMS Secretariat. Based on these outlines and revisions by the CMS Secretariat, research continued and resulted in a version for the Sessional Committee of the Scientific Council (ScC-SC6) as an advanced draft for review. These recommendations and further consultancy by the CMS Secretariat resulted in this revised report.

Relevant literature about the *Insect Decline and its Threat to Migratory Insectivorous Animal Populations* was assessed via literature research using several academic search engines and information portals (Google Scholar, Web of Science and ResearchGate).

For literature research, the term *insectivorous* refers to birds, bats and fish that feed primarily on insects and other arthropods. Note that fish labelled as feeding more generally on invertebrates were listed as not insectivorous.

All migratory insectivorous bird, bat and fish species of the report are CMS-listed species obtained from CMS database (www.cms.int/en/species). For comparison, the definition for migratory animals of the CMS was put in a context with ecological definitions and definitions by GROMS and IUCN.

The review process of migratory insectivorous bird, bat and fish species included all species mentioned in the CMS database (www.cms.int/en/species) of the taxa *Aves*, *Mammalia: Chiroptera* and *Actinopterygii*.

1.3 State of the Art

Approximately two-thirds of all terrestrial species on Earth are insects (Sánchez-Bayo & Wyckhuys 2019). These two thirds correspond to 5.5 million insect species worldwide, of which 80% of species remain undescribed (Stork 2018). Insects are the main component of biodiversity in most terrestrial habitats, providing multiple ecosystem functions and ecosystem services (Losey & Vaughan 2006; Weisser & Siemann 2008). Globally, 10 % of insects are threatened with extinction (IPBES 2019). A loss of 9% per decade in the abundance and biomass[1] of terrestrial insects has been reported (Van Klink *et al.* 2020). While trends of the insect decline show a strong variation between insect orders (Dirzo *et al.* 2014) and between and within freshwater and terrestrial environments (Van Klink *et al.* 2020), there is evidence of an overall global decline in insects (Van Klink *et al.* 2020; Raven & Wagner 2021; Wagner *et al.* 2021). Land-use change, agriculture, introduced species, nitrification, pollution and climate change have been identified as the main drivers underlying of insect declines, with the potential to affect other organisms (Wagner *et al.* 2021).

Similarly, the populations of many migratory animal species are declining rapidly on a global scale (Wilcove & Wikelski 2008). These include migratory birds, bats and fish (Bairlein 2016; Fleming 2019; Deinet *et al.* 2020).

About 1,924 of the world's land- and waterbirds are migratory (BirdLife International 2023). Approximately, 11% of all migratory land- and waterbirds are listed as threatened or near-threatened on the IUCN Red List (Kirby *et al.* 2008). Bird species dependent on insects for food have declined drastically over the last 50 years (Jetz *et al.* 2007; Tallamy & Shriver 2021). The impact of insect declines on birds is manifested directly by reducing the birds ability to meet energetic needs, or indirectly through abiotic factors that affect the birds ability to respond to a given environmental change (Bowler *et al.* 2019). Migratory insectivorous bird species and migratory bird species *per se* are exposed to drivers that occur during the annual life cycle on the breeding/wintering grounds and during autumn/spring migration (Sherry & Holmes 1995; Faaborg *et al.* 2010). Population trends of these species are therefore the result of complex interactions of stressors that occur at different spatial scales and during different phases of migration (Spiller & Dettmers 2019). For example, food availability must be ensured throughout the life cycle to avoid a trophic or phenological mismatches on breeding or wintering grounds (Kwon *et al.* 2019). Otherwise, potential stressors at one stage of the life cycle may be transferred to the next through carryover effects (Harrison *et al.* 2011).

On average, bats migrate much shorter distances than birds (Fleming 2019). A significant number of bat species from temperate and tropical ecosystems make seasonal movements between habitats (Fleming & Eby 2003; Avgar *et al.* 2014). The spatial distances covered by bat migrations can vary from 100 km to more than 1,000 km (Fleming 2019). Insectivorous bat species exhibit geographically diffuse migratory behaviour that is highly dependent on intact foraging habitats and stopover roosts (Wiederholt *et al.* 2013). Prey availability plays a critical role during migration (Frick *et al.* 2019). In contrast, frugivorous migratory bats mainly follow a food/diet gradient

[1] Patterns are mainly based on trends in North America and Europe.

characterised by the availability of specific fruit plants (Richter *et al.* 2006). Of the approximately 1,400 bat species that exist worldwide, which account for one-fifth of mammalian biodiversity (Burgin *et al.* 2018), many feed primarily on insects and other arthropods (Hutson *et al.* 2001). 180 bat species[2] are listed as threatened on the IUCN Red List (Frick *et al.* 2019). Migratory insectivorous bats occur in many different genera. Frugivorous migratory bats are most common in tropical and subtropical biomes, where species information is often limited (Popa-Lisseanu & Voigt 2009; Fleming 2019).

Connectivity between freshwater and marine habitats is important for some migratory fish (Verhelst *et al.* 2021). Compared to other fish groups, migratory fish are highly threatened (Darwall & Freyhof 2015). Fish typically migrate between freshwater and saltwater (diadromous), within freshwater systems (potamodromous), and within marine systems (oceanodromous) (Shaw 2016). Migratory diadromous and potamodromous freshwater fish declined by 76%[3] globally between 1970 and 2016 (Deinet *et al.* 2020). 31% of freshwater species on the IUCN Red List are classified as Critically Endangered, Endangered or Vulnerable (Darwall & Freyhof 2015). Scientific studies focusing on threats to migratory insectivorous fish due to declines in insect biodiversity are lacking, as overfishing, pollution, water withdrawals, aquaculture, non-native (invasive) species, habitat degradation, hatcheries and climate change have been identified as main direct drivers of the freshwater fish declines (Waldman & Quinn 2022). However, the decline of aquatic insects in freshwater ecosystems will most likely affect fish as insects are an important food source in part of many fish lifecycle (Suter II & Cormier 2015).

[2] Number refers to 1,236 bat species assessed by Frick *et al.* (2019).
[3] 50% of the freshwater fish species were assigned to Europe and North America. Data for Africa, Asia, Oceania and South America was limited.

2. Global Insect Decline

2.1 Overview

The latest version of the IUCN Red List, published in February 2022, contains 12,438 insect species (IUCN 2023a). Almost 25% of the listed insect species are classified as Near Threatened, Vulnerable, Endangered or Critically Endangered, which corresponds to 3,125 insect species (Fig. 1).

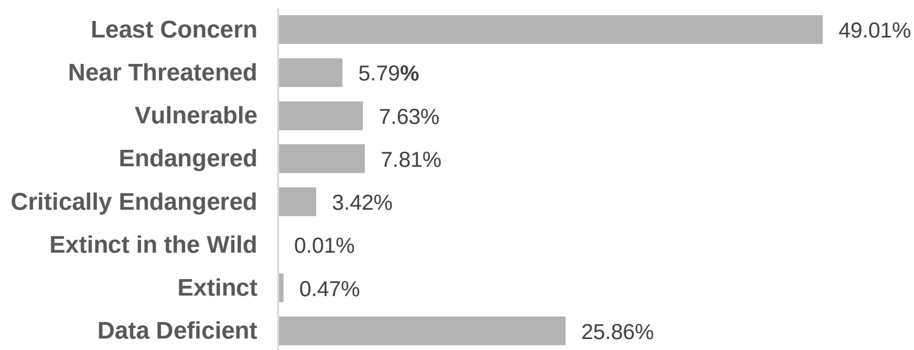

Fig. 1 Proportions of IUCN Red List categories for insects. A total of 12,438 insects were classified by the IUCN as Least Concern (n = 6,096), Near Threatened (n = 720), Vulnerable (n = 949), Endangered (971), Critically Endangered (n = 425), Extinct in the Wild (n = 1), Extinct (n = 59) and Data Deficient (n = 3,217) (IUCN 2023a).

The number of insect species assessed by the IUCN is 1.2% of an estimated number of 1,053,578 described insect species (IUCN 2022). According to IPBES, 1 million insect species alone are threatened with extinction, representing 10% of global insect biodiversity (IPBES 2019). Insects account for 84% of the global biotic species richness (Eggleton 2020). Declines in insect abundance, biomass and diversity have been reported in many studies and reviews across ecosystems and taxa (Tab. 1).

Tab. 1 Highly cited studies and reviews on insect decline, ranked by number of citations.

Author	Year	Citations[1]	Style	Region	DOI
Dirzo *et al.*	2014	4013	Review	Global	www.doi.org/10.1126/science.1251817
Biesmeijer *et al.*	2006	3703	Study	Europe	www.doi.org/10.1126/science.1127863
Hallmann *et al.*	2017	3202	Study	Europe	www.doi.org/10.1371/journal.pone.0185809
Sánchez-Bayo & Wyckhuys	2014	2763	Review	Global	www.doi.org/10.1016/j.biocon.2019.01.020
Seibold *et al.* [2]	2019	890	Study	Europe	www.doi.org/10.1038/s41586-019-1684-3
Wagner	2020	822	Review	Global	www.doi.org/10.1146/annurev-ento-011019-025151
Klink *et al.*	2020	748	Review	Global	www.doi.org/10.1126/science.aax9931
Wagner *et al.*	2021	646	Review	Global	www.doi.org/10.1073/pnas.2023989118

[1] Accessed on September 2023 via Google Scholar.
[2] Included arthropods.

Insect declines have been shown to be highly variable between insect orders (Dirzo *et al.* 2014). A review of 100 long-term studies based on data from Greenland, North Africa, South America, East Asia, Australia, Europe and North America over the last three decades, focusing on 10 major insect taxonomic orders, showed an average decline of 36.9% and an increase in species numbers of 18.2% (Sánchez-Bayo & Wyckhuys 2021). Negative population trends were profound for the orders of *Coleoptera* (47.0%), Aquatic *Hemiptera* (68.0%), *Hymenoptera* (46.7%), *Lepidoptera* (50.6%), while half of the *Trichoptera* species showed a positive population trend (50%). Population trends differed between aquatic and terrestrial species, where 36% of insect species declined compared to 41.8% of terrestrial species.
Consistent with Basset & Lamarre (2019), a bias towards certain taxa (*Lepidoptera*, *Coleoptera* and *Odonata*) and geographical regions (Europe and North America) was found in the data of the review (Sánchez-Bayo & Wyckhuys 2021). Different patterns for freshwater and terrestrial insects were also identified by Klink *et al.* (2020). Based on 166 long-term studies, they identified a decline of 9% per decade in the abundance of terrestrial insects and an increase of 11% per decade in the abundance of freshwater insects. The largest declines in terrestrial insect biodiversity were found in North America and Europe. Patterns of insect decline were much more pronounced in unprotected areas than in protected areas. The increase in freshwater insect abundance was attributed to habitat protection programs (Van Klink *et al.* 2020). Alarmingly, insects can also decline in protected areas, as shown by a highly cited study from Europe (Hallmann *et al.* 2017). Over a 27-year period, aerial insect biomass declined by 75% in protected areas due to the impact of surrounding agricultural fields. Landscape-scale patterns are important for understanding patterns of insect decline (Seibold *et al.* 2019) and biodiversity *per se* (Tscharntke *et al.* 2005).

Land-use change, pollution and climate change are currently considered the main drivers of insect decline (Sánchez-Bayo & Wyckhuys 2019; Wagner *et al.* 2021).
Agricultural intensification can change habitats rapidly, making it insects unable to adapt. As a result, agricultural intensification is vastly reducing insect biodiversity worldwide (Raven & Wagner 2021). Agriculture is often associated with direct chemical and indirect environmental pollution, including synthetic pesticides and fertilisers. Insect pollinators are particularly threatened by the use of synthetic pesticides (Brittain *et al.* 2010). Both wild and domestic insect pollinators (e.g. *Diptera* and *Hymenoptera*) are reported to be declining along with the plants they are associated with (Biesmeijer *et al.* 2006; Potts *et al.* 2010). An increasingly important driver of insect decline is climate change, which is strongly linked to agricultural intensification (Raven & Wagner 2021) and geographical factors (Halsch *et al.* 2021). Main and minor drivers have been summarised by Wagner *et al.* (2021) (Fig. 2).

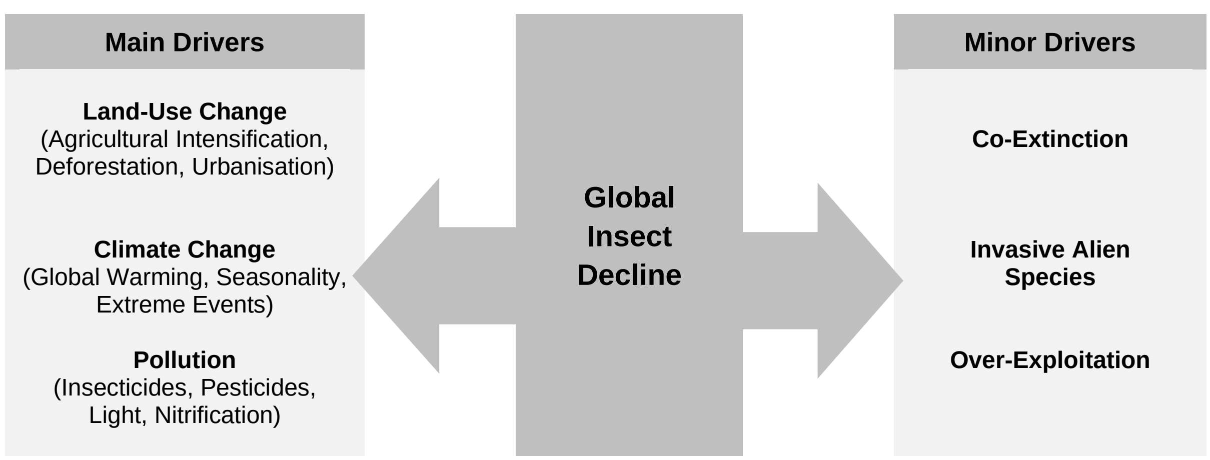

Fig. 2 Schematic overview of main and minor drivers of the global insect decline, modified from Wagner et al. (2021). Note: The figure is schematic and simplifies the global insect decline. All drivers have a strong impact on insects. The

terms "main" and "minor" are chosen for a schematic overview. The real-world insect decline is much more complex, with drivers interacting and being co-dependent (Forister *et al.* 2019).

Information about main drivers, which include land-use change, climate change and pollution, can be found in Cardoso *et al.* (2020), Eggleton (2020), Kehoe *et al.* (2021), Sánchez-Bayo & Wyckhuys (2021) and Wagner *et al.* (2021). Minor drivers of the global insect decline were obtained from Cardoso *et al.* (2020), Kehoe *et al.* (2021) and Wagner *et al.* (2021). All drivers with further information about the impact of insect decline on the habitat and insect are listed in Tab. 2.

Tab. 2 Main and minor drivers of the insect decline with mechanisms and impact affecting insects and their habitats.

Drivers affecting Insects	**Mechanism** of the Driver affecting Insects	**Impact** on the Habitat and Insects	**Further Information**
Land-Use Change	Agricultural Intensification Deforestation Urbanisation	Habitat Degradation Habitat Fragmentation Habitat Loss	Öckinger *et al.* 2006; Hanski *et al.* 2007; Hendrickx *et al.* 2007; Yoshimura 2012; Tchakonté *et al.* 2015; Poniatowski *et al.* 2018; Münsch *et al.* 2019; Seibold *et al.* 2019; Fenoglio *et al.* 2021; Ríos-Touma *et al.* 2022
Climate Change	Global Warming Climate Extremes Seasonality	Insect Distribution Insect Phenology Insect Interaction	Deutsch *et al.* 2008; Stange & Ayres 2010; Jactel *et al.* 2019; Harvey *et al.* 2020, 2023; Lehmann *et al.* 2020
Pollution	Pesticides Fertiliser Light at Night	Insect Diversity Insect Ecosystem Services Insect Behaviour	Zhang *et al.* 2007; Goulson 2013; Manfrin *et al.* 2017; Cardoso *et al.* 2020; Owens *et al.* 2020; Kehoe *et al.* 2021
Co-Extinction	Co-Dependency	Insect Loss	Dunn *et al.* 2009; Colwell *et al.* 2012; Kehoe *et al.* 2021
Invasive Alien Species	Competitive Exclusion	Habitat Change	Mooney & Cleland 2001; Wagner & Van Driesche 2009; Cardoso *et al.* 2020; Pyšek *et al.* 2020
Over-Exploitation	Species Removal	Insect Community Structure	New 2005; Ramos-Elorduy 2006; Cardoso *et al.* 2020; Kehoe *et al.* 2021

Globally, insects are stressed by direct and indirect drivers that are often intertwined (Forister *et al.* 2019) and which act simultaneously (Wagner *et al.* 2021). For example, climate change is a major stressor for agriculture itself, leading to dramatic shifts in land suitable for agricultural production (Adams *et al.* 1998; Raven & Wagner 2021).

In addition, a bias towards the dominance of studies conducted in Europe or North America is apparent when assessing insect declines globally (Cardoso *et al.* 2019; Simmons *et al.* 2019).

The highly cited review by Sánchez-Bayo & Wyckhuys (2019) included three out of 73 studies examining insect decline in tropical biomes (Cardoso *et al.* 2019). Similarly, in Van Klink *et al.* (2020), the vast majority of studies were conducted in North America or Europe (Fig. 3).

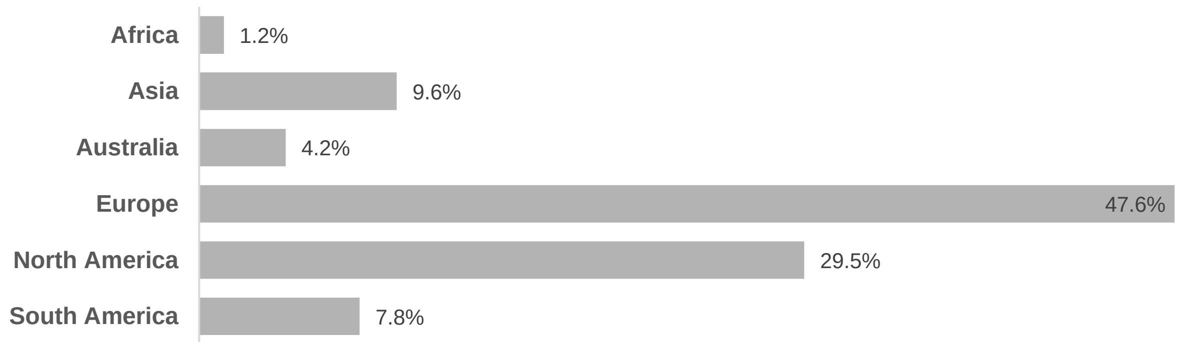

Fig. 3 Proportions of the locations of the 166 studies used by Van Klink et al. (2020) to review the global insect decline, sorted by continent. In total, two studies were reviewed from Africa, 16 from Asia, 7 from Australia, 79 from Europe, 49 from North America and 13 from South America. The dataset is available at www.doi.org/10.5063/F11V5C9V .

Consequently, entomological reviews at global scales should aim to be unbiased in terms of research conditions, geographical area and assessment of drivers (Simmons *et al.* 2019).
The available data for inferring large-scale spatial global patterns of insect trends need to be continuously improved (Montgomery *et al.* 2020). Developments in taxonomy, inventory, monitoring, data management, statistics and science communication will help to improve insect conservation (Cardoso *et al.* 2011).

2.2 Impact on Ecosystem Services

Insects are involved in the regulation and dynamics of many ecosystem services (Noriega *et al.* 2018). Ecosystem services (ES) can be defined as processes that contribute directly or indirectly to human well-being (Eggleton 2020). There are include main types of ES (Millennium Ecosystem Assessment 2003):

(1) Provisioning Services,
(2) Regulating Services,
(3) Supporting Services and
(4) Cultural Services.

Insect can be contributors to all four types of ecosystem services (Noriega *et al.* 2018; Cardoso *et al.* 2020) by for example:

(i) Pollination,
(ii) Biological Control,
(iii) Decomposition and
(iv) Education.

However, insects can also provide ecosystem disservices, processes that are directly or indirectly contribute to human problems (Eggleton 2020).

Despite this, 35% of the world's food production depends on crops pollinated by wild or managed insect pollinators (Klein *et al.* 2007). However, Klein *et al.* (2007) state, that most of the leading crop species diversity (70%) are actually dependent on insect pollination. Biodiverse agricultural systems can increase yields and profitability through pollination services (Kremen *et al.* 2002; Nicholls & Altieri 2013). A biodiversity-based agriculture[4] is also known to be more resilient to environmental change (Jackson *et al.* 2007). In addition, even highly extensive and homogeneous agricultural systems can benefit indirectly from insect pollinators from surrounding natural habitats in the form of higher yields (Klein *et al.* 2003). Insect pollination contributes directly to the global volume of crop production, with an annual market value of US$ 235-577 billion for all animal pollination services (IPBES 2016).

Insects can play an important role in agricultural production as biological control agents (Losey & Vaughan 2006). By using native insects directly as a biological antagonists of pests, or by creating suitable habitats with management practices that promote native insects as natural enemies, agriculture is already actively benefiting insects as biological control agents (Cardoso *et al.* 2020). Biological pest control can have environmental and economic benefits, as insect predation, parasitism or seed removal can reduce yield loss without the potential negative ecosystem consequences of chemical pollution (Bianchi *et al.* 2006). Crop and landscape management are important factors in the implementation of large-scale insect pest strategies (Rusch *et al.* 2010). A homogeneous agricultural landscape can be expected to have lower levels of biological pest control than a heterogeneous landscape (Rusch *et al.* 2016).

Insects support the improvement of the soil structure and fertility through the decomposition of animal or plant detritus (Noriega *et al.* 2018). In particular, dung beetles (*Coleoptera: Scarabaeidae*), which feed as larvae and adults on animal faeces, contribute to several ecosystem functions such as nutrient cycling, bioturbation or plant growth enhancement (Nichols *et al.* 2008). The livestock industry, for example, benefits greatly from dung removal by beetles, both economically (Losey & Vaughan 2006) and ecologically (Steinfeld *et al.* 2006). Highly diverse dung beetle communities are found in tropical forest and savannah ecosystems (Hanski & Cambefort 1991). Today, tropical forest ecosystems are facing major habitat changes and fragmentation, which may negatively affect dung beetle diversity and the ecosystem services provided by these insects (Nichols *et al.* 2007, 2008).

Positive emotions towards nature in childhood can promote commitment for nature in later adulthood (Turtle *et al.* 2015). However, compared to charismatic vertebrate megafauna, insects are not a typical medium for environmental education programs due to negative emotions towards invertebrates (Bixler & Floyd 1999; Cho & Lee 2017). Environmental education programs that focus on insects, particularly bees, can improve young people's human-nature relationships with insects (Cho & Lee 2017). Furthermore, by combining environmental knowledge with emotional drivers, environmental education creates connection to nature that increases ecological behaviour (Otto & Pensini 2017).

[4] see Hill (1998) or Duru *et al.* (2015) for further information about the term of "biodiversity-based agriculture".

3. Terms and Definitions on Migration and Insectivorous Target Species

Migration is a common behaviour among animals, however the number of migratory species across animal taxa varies. Derived from the biological concept of animal migration (see 3.1), the numbers of migratory animals also vary depending if either the CMS list, or alternative definitions by GROMMS and IUCN are considered. **This report strictly assessed only CMS-listed animal species**, which feed on insects and other arthropods as their primary diet throughout the annual cycle, or only transiently as a supplementary protein source during the breeding season (target species).

Consequently, this report on the decline of insects and its threats to migratory insectivorous animal populations is based on 32 bird-, 55 bat- and 4 fish CMS target species.

3.1 Animal Migration – A Biological Concept

Migratory animal species are globally distributed and can be found in aquatic and terrestrial environments, belonging to different animal taxa such as birds, fish, mammals, reptiles, amphibians and insects (Dingle 2014). Although, migration is common among animals, the number and proportion of migratory species in animal taxa can vary widely (Tab. 3).

Tab. 3 Number and proportions of migratory species sorted by animal taxa of birds, bats, mammals, fish and insects. Modified from Robinson *et al.* (2009).

Migratory Taxon	Number of Migratory Species	Proportion of Migratory Species	Reference
Birds	1,855	19%	Kirby *et al.* (2008)
Bats	113	10%	Robinson *et al.* (2009)
Terrestrial Mammals	30	1%	Robinson *et al.* (2009)
Aquatic Mammals	63	36%	Robinson *et al.* (2009)
Fish	874	3%	Robinson *et al.* (2009)
Insects	Unknown	Unknown	Chapman *et al.* (2015)

In addition, migratory behaviour is known to vary within animal families and even genera (Chapman *et al.* 2014). An extreme form of animal migration is partial migration, where individuals from the same population may be migratory or entirely resident (Chapman *et al.* 2011).

In the classical biological sense, animal migration can be characterised as the regular seasonal movement of an individual from one habitat to another (Webster et al. 2002). A habitat is defined as the geographical area (or home range) in which a species can occur and which provides the resources required for each stage of the species life cycle (Southwood 1981 in Dingle 2014). Migration allows an individual to move from its current habitat to a new habitat with a new home range, often with some distance between the current and the new habitats (Dingle & Drake 2007). The two habitats are often described as breeding grounds and wintering areas (Dingle 2014).
An organism migrates to enhance its growth, survival, or reproduction (Shaw 2016). As such, the movement patterns of migratory animals are often driven by the seasonal availability of resources such as food, shelter or mating partners (Brower & Malcolm 1991; Dingle & Drake 2007). Therefore, migratory behaviour is thought to have evolved in response to periodic and predictable changes in environmental conditions (Chapman *et al.* 2014).

3.2 Migratory Species - Definitions of CMS/GROMS/IUCN

The CMS (1979) defines migratory species as:

" […] the entire population or any geographically separate part of the population of any species or lower taxon of wild animals, a significant proportion of whose members cyclically and predictably cross one or more national jurisdictional boundaries" (CMS 1979, Article 1)

GROMS (Global Register of Migratory Species) definition of migratory species included "true migrants" which are:

" […] animal species covering more than 100 km, or crossing from sea to freshwater" (Riede 2001).

The approximate number of true migrants in the GROMS has been estimated in 2020 with 4,000 animal species belonging to the groups of mammals, birds, turtles, fish and invertebrates (Riede 2020).

The IUCN definitions of animal migrations have been recorded for animals in the online Species Fact Sheet (www.iucnredlist.org) under the Habitat and Ecology section in the Movement Patterns subsection with the categories:

(i) Full Migrant, (ii) Altitudinal migrant, (iii) Nomadic, (iv) Not a migrant, (v) Unknown

and whether it is congregatory or not (IUCN 2023b).

3.3 Insectivorous Feeding - Ecological Definition

Insectivores can be described as insect eating animals belonging to a wide range of taxa including mammals, fish, birds, amphibians and reptiles. Insectivores feed on insects and other arthropods as their primary diet throughout the annual cycle, or only transiently as a supplementary protein source during the breeding season (Vafidis *et al.* 2019).

As a result, the term "insectivorous" is commonly used to also characterise animals that feed on arthropods. Arthropods are the phylum to which insects belong as a class (lat. *Insecta*) (Snodgrass 2018). The more biologically accurate term of *arthropodivors* by Segura-Trujillo *et al.* (2016) is not used for the report.

3.4 Target Species – Migratory Insectivorous Bird, Bat and Fish Species

This review on migratory insectivorous species **concentrated on all species mentioned in the CMS lists** (www.cms.int/en/species) of the taxa *Aves*, *Mammalia: Chiroptera* and *Actinopterygii* (Tab. 4).

Tab. 4 Numbers of birds, bats and fish listed in the CMS Species Lists and numbers of CMS-listed insectivorous species. All CMS-listed species can be found in the Supplement in able S1, S2 and S3. For comparison the number of migratory species and insectivorous migratory species following a biological definition are listed in light grey colour.

Group	CMS Species	Insectivorous CMS Species	Biological migratory species	Biological insectivorous migratory species
Birds	385	**32**	1,924	723
Bats	57	**55**	113[5]	28
Fish	21	**4**	247	84

Insectivorous bird feeding was assessed by literature searches on www.birdsoftheworld.org (Billerman *et al.* 2023) and www.audubon.org (National Audubon Society 2023). The CMS-listed bird species and the categorisation into insectivores are listed in Table S1 in the supplement.

The dietary preferences of insectivorous bats of the suborder *Yangochiroptera* were determined separately for each bat species at www.iucnredlist.org (IUCN 2023b) under Text Overview, section Habitat and Ecology Information and at the website of the Global Biodiversity Information Facility www.gbif.org (GBIF 2023) in section Food and Feeding. The CMS-listed bat species and the categorisation into insectivores are listed in Table S2 in the supplement.

For feeding information of fish, the FishBase on www.fishbase.se/search.php?lang=English (Froese & Pauly 2023) was used in section Information by Topic and search criteria Type of Food Items. The CMS-listed fish species and the categorisation into insectivores are listed in Table S3 in the supplement.

The dietary preferences of some species could not be determined, although they may be insectivorous. Species with no feeding information were classified as not insectivorous.

Additionally, the report lists animal species, which are known to be migratory in a biological sense. The migratory information about birds, bats and fish is based on following information:

(1) **Birds** are well-studied animal migrants with a wide range of migratory behaviours (Newton 2010). The BirdLife International species search page contains many migratory bird species (www.datazone.birdlife.org/species/search).

(2) **Bat** movement patterns have been increasingly studied in the recent years (Popa-Lisseanu & Voigt 2009). Information about bat migration can be found on www.iucnredlist.org (IUCN 2023b) in the subsection Movement Patterns, matching the search term Full Migrant, and specific literature (e.g. Popa-Lisseanu & Voigt 2009).

(3) **Fish** migrate between and within different freshwater and saltwater systems (Morais & Daverat 2016). Fish migration has been reviewed by the following authors: Carolsfeld & Bank (2003), Lucas & Baras (2008), Limburg & Waldman (2009), Brönmark *et al.* (2014), Morais & Daverat (2016), Deinet *et al.* (2020) and Waldman & Quinn (2022).

[5] Number based on Robinson *et al.* (2009); no detailed species list accessible.

4. Birds

4.1 Bird Migration System

Bird migration is a global phenomenon covering all continents and oceans (Fudickar *et al.* 2021). Approximately 19% of the world's 9,856 described bird species migrate (Kirby *et al.* 2008). Several hundred species of migratory water and landbirds migrate in three major bird migration systems (Dingle 2008; Jahn *et al.* 2020):

(i) Nearctic-Neotropical system: Migration between North American breeding grounds and Neotropical wintering grounds.
(ii) Palearctic-Paletropical system: Migration between European or Asian breeding grounds and southern Asian or central/southern African wintering grounds.
(iii) Austral system: Migration between Australian or South American breeding grounds and northern wintering grounds closer to the equator.

The three migratory systems are geographically limited and do not include altitudinal migration of birds (Fudickar *et al.* 2021). Bird migration within the Neotropical system (intratropical migration) is notoriously poorly understood and studied when compared to the Nearctic-Neotropical system (Jahn *et al.* 2020). This is not surprising, as global patterns of migratory bird diversity show that bird migration is characteristic of the Northern Hemisphere (Somveille *et al.* 2013). Here, the diversity of migratory birds and the intercontinental turnovers of species composition between breeding and non-breeding areas are high (Somveille *et al.* 2013).

However, migratory bird species and populations often connect their breeding and non-breeding grounds along broadly similar and well-established routes or flyways (BirdLife International 2010f). The eight global flyways of migratory land- and waterbirds have been refined by BirdLife International (2010b) for species that are a) fully migratory; b) conduct biannual and c) latitudinal migration; d) migrate between breeding and non-breeding grounds and e) belong to populations in which all individuals migrate (Fig. 8). Unfortunately, populations of the migratory birds along the world's main flyways have declined in recent decades (Kirby *et al.* 2008).

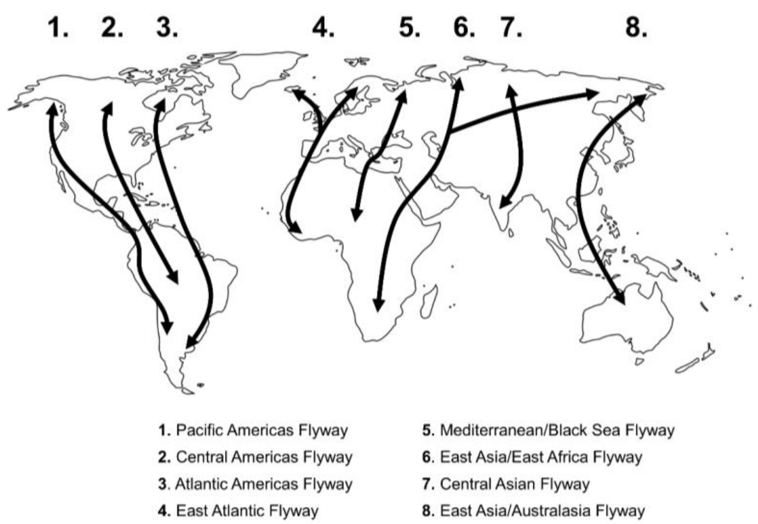

Fig. 4 Overview of the eight main global flyways of migratory land- and waterbirds. Adapted from Bagley (2022) based on BirdLife International (2010b). Maps used under CCO 1.0 Universal Public Domain Dedication.

UNEP and CMS have divided the flyways into five sections, with some overlap (UNEP & CMS 2009):

(1) Central Pacific Flyway
(2) American Flyways
(3) African/West Eurasian Flyways based on AEWA Agreement (UNEP & AEWA 2022)
(4) Central Asian Flyway (CAF)
(5) East Asian Australasian Flyway (EAAF)

4.2 Migratory Land- and Waterbirds

The flyway concept includes all migratory land- and waterbirds. Of the 11,188 bird species listed in the IUCN Red List of Threatened Species, an estimated of 12% are globally threatened (Fig. 5), including bird species that were classified as Vulnerable, Endangered and Critically Endangered (BirdLife International 2022; IUCN 2023a).

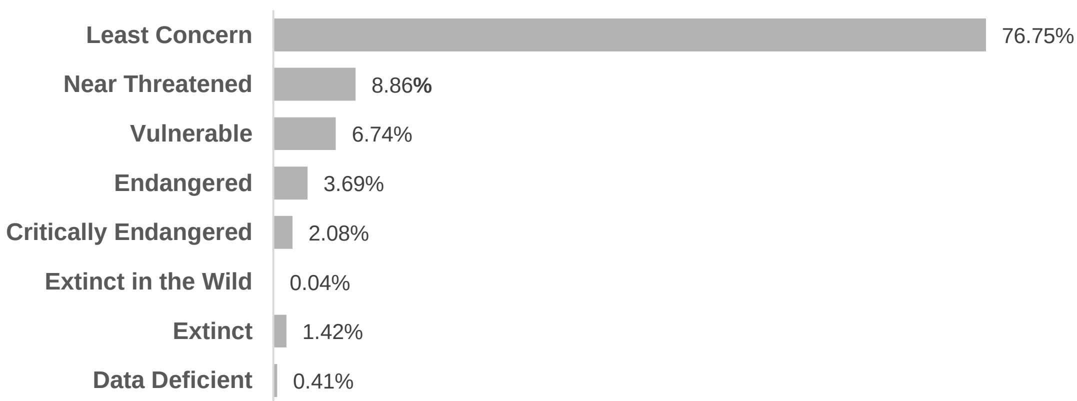

Fig. 5 Proportion of IUCN Red List categories for all documented bird species. A total of 11,188 birds were classified by the IUCN as Least Concern (n = 8,587), Near Threatened (n = 991), Vulnerable (n = 754), Endangered (n = 413), Critically Endangered (n = 233), Extinct in the Wild (n = 5), Extinct (n = 159) and Data Deficient (n = 46) (IUCN 2023a).

BirdLife International classified 11% of migratory birds as threatened or near-threatened on the IUCN Red List (Kirby *et al.* 2008). According to Kirby *et al.* (2008) the status of migratory bird species varies widely geographically, with 8% threatened species in the Americas, 10% threatened in Europe, Asia and Africa, and 14% threatened in Asia-Pacific region. The review of Kirby *et al.* (2008) assessed the major threats to land- and waterbirds in general, whether they are considered globally threatened or not. Agriculture and aquaculture, biological resource use and natural system modification were identified as the main three threats to migratory bird species, followed by 8 other threats based on the classification of Salafsky *et al.* (2008) used by the IUCN (Kirby *et al.* 2008).

It has been shown, that migratory bird species face many threats during their annual life cycle in the breeding and wintering grounds and during autumn and spring migration (Sherry & Holmes 1995; Faaborg *et al.* 2010).

Current knowledge of bird migration behaviour includes the subjects of migratory connectivity, carry-over effects and phenological mismatch:

Population dynamics of migratory birds can be vary depending on the migratory connectivity of the bird species (Webster *et al.* 2002). Migratory connectivity can be simply described as the extent to which individuals from the same breeding site migrate to the same non-breeding site (Esler 2000). Migratory species with a low migratory connectivity are more adaptive to local environmental changes than those with high migratory connectivity (Knight *et al.* 2021). Migratory connectivity is considered to be low when subpopulations of a migratory species have a high degree of spatial and temporal interaction (Knight *et al.* 2021).

Carry-over effects (COEs) affect the performance or fitness of individuals at different stages of migration. These effects are processes that occur at one phase of the migratory life cycle and can influence the success of individuals in the following phase (Harrison *et al.* 2011). Consequently, non-lethal negative effects are carried over to the next phase and influence the success of individuals, such as reproduction or habitat selection (Norris 2005; Norris & Taylor 2006). These effects are often based on changes in resource availability to individuals in a population (Harrison *et al.* 2011).

In phenological mismatches, interactions between resource and consumer species are shifted (Visser & Gienapp 2019). Therefore, they occur at times in an individual's annual cycle when consumer resource demand is high but cannot be met by resource availability (Kwon *et al.* 2019; Visser & Gienapp 2019). The amplitude of the mismatch for a migratory bird species can depend on the geographical region, the bird migration system, the migration distance and the species composition of the migrants (Jones & Cresswell 2010). In the context of the migration system, conditions at the stopover sites (e.g. food availability or predation pressure) along the flyway can have an important influence on the migration schedule (Trierweiler *et al.* 2014). However, climate warming is expected to further promote phonological mismatch (Møller *et al.* 2008; Saino *et al.* 2011).

4.3 Migratory Insectivorous Bird Populations (Overview)

Bird populations with at least one annual life cycle phase that dependent on insects as a food source are most likely to suffer from the expected reductions in insect biomass and diversity (Tallamy & Shriver 2021).

America's migratory insectivorous birds

Migratory insectivorous birds of the **Americas Flyway** that feed on insects in flight (aerial insectivores), such as swallows, swifts, nightjars, and flycatchers have been experienced significant population declines (Spiller & Dettmers 2019). Population declines of North American migratory insectivores are expected to vary by species and region (Nebel *et al.* 2010; Michel *et al.* 2015; Smith *et al.* 2015). La Sorte *et al.* (2014) suspected that bird populations have different migratory behaviour between the western and eastern parts of the Americas Flyways due to different spring phenology of ecological productivity (e.g. availability of insects and their associated plants).

North America

Non-aerial insectivorous grassland and farmland birds in North America have declined in recent decades as well due to the negative impacts of land use intensification (Stanton *et al.* 2018). Spiller & Dettmers 2019 identified potential drivers of the declines in aerial insectivorous birds, including declines in insect prey abundance, effects of environmental pollution, habitat loss, phenological changes due to climate warming, and deterioration of stopover sites and wintering ground conditions. The drivers are thought to act simultaneously at different times in the annual cycle, which may make carry-over effects an important issue in declines (Spiller & Dettmers 2019). The North American avifauna declined in abundance by three billion birds between 1970 and 2017 (Rosenberg *et al.* 2019). Migratory insectivores were mainly assessed in the species group of land birds and aerial insectivores, which showed a loss in abundance of 27.1% and 31.8%, respectively, over a 47 year period (Rosenberg *et al.* 2019). Declines affected both threatened and common species from different habitats and families, suggesting that impacts on the bird communities operate at multiple scales with interacting threats (Rosenberg *et al.* 2019). Threats may be more severe in areas where birds are highly concentrated during migration stopovers, forming so called migratory bottlenecks (Bayly *et al.* 2018).

South America

The insectivorous birds of South America form highly species diverse communities (Sherry *et al.* 2020). However, the richness of migratory species in the Southern Hemisphere is generally low when compared to the Northern Hemisphere (Somveille *et al.* 2013). Approximately 171 bird species can be classified as insectivorous and live in the Neotropics and the Nearctic (Sherry *et al.* 2020). The most common long-distance migrants in South America are primarily insectivores, whose migratory behaviour is strongly linked to rainfall cycles (Jahn *et al.* 2010). Austral migrants are usually found in open or shrubby areas, whereas Nearctic migrants prefer forests and woodlands (Chesser 1994). Tropical forests and woodlands and their biodiversity are particularly threatened by changes in land-use for crops, pasture, and wood fuel (Wagner 2020). Losses of insects in South America (Van Klink *et al.* 2020) are likely to cascade through the ecosystem to migratory insectivorous bird populations, although studies of insect-bird interactions in the Neotropics are limited.

Africa’s/Eurasian migratory insectivorous birds

An estimated 2.1 billion (2,100 million) passerines and near-passerines birds migrate between **Europe and Africa** in autumn (Hahn *et al.* 2009). Interestingly, 73% of these 2.1 billion birds belong to just 16 bird species, most of which are insectivorous, such as the Willow Warbler (*Phylloscopus trochilus*) or the Tree Pipit (*Anthus trivialis*).

Europe

For Europe, a 13% long-term decline in migratory populations of insectivorous birds was found for 66 bird species between 1990 and 2015 for (Bowler *et al.* 2019). Insectivorous feeding behaviour was associated with long-distance migration within the African/West Eurasian Flyway. According to Bowler *et al.* (2019), farmland bird species, particularly grassland species, showed the greatest declines. Consistent with the findings of Vickery *et al.* (2001), the authors concluded, that changes in grassland due to intensification of management have likely reduced the extent and quality of grassland as foraging and breeding habitat for migratory insectivorous birds. The decline of European farmland birds, which are often insectivorous, has been linked to the harmful use of insecticides in agriculture (Benton *et al.* 2002; Hallmann *et al.* 2014). As a result, insectivorous birds tend to be more sensitive to environmental change than other bird guilds (Bowler *et al.* 2019).

The review by Møller *et al.* (2008) of 100 European migratory bird species between 1970 and 2000 analysed the phenological response of bird species to climate change. It was concluded that bird species that did not advance their spring migration declined. For many European-African migrants, including many insectivores, illegal hunting, habitat loss and degradation have been defined as main threats (Bairlein 2016). Furthermore, Bowler *et al.* (2019) showed that the long-term decline of many migratory insectivorous bird species in Europe may be linked to agricultural intensification and the loss of many grassland ecosystems.

Africa

Studies on the decline of insects on the **African** continent are lacking (Klink *et al.* 2020b). Research on migratory insectivorous bird species endemic to Africa and their population trends is difficult to find. Hockey (2000) showed that austral African migrants are most likely to be insectivorous and that the migratory behaviour of species moving from tropical to temperate areas for breeding is closely linked to the onset of summer and the rain season. Around 10% of migratory land- and waterbirds that spend a phase of their life cycle in Africa are threatened or near-threatened (Kirby *et al.* 2008). Overgrazing and increased pesticide use has been identified as a serious threat to migratory insectivorous bird species in sub-Saharan Africa, as insect prey populations decline as a result of reduced habitat quality (BirdLife International 2010d, e). In addition, bird species migrating through the Mediterranean and Middle East are threatened by illegal hunting and trapping (BirdLife International 2010d, e).

Central Asian migratory insectivorous birds

Migratory insectivorous bird populations in Asia may face declines in intensively used landscapes (Menon *et al.* 2019). Although, the Central Asian flyway is the shortest in the world, threats along the migration routes through the steppes and cold desserts of Central Eurasia and much of the Himalayan chain, have the potential to drive many bird populations into decline (BirdLife International 2010a). Information on population trends of migratory insectivorous bird species are difficult to obtain due to a lack of research. For general population trends of migratory bird species, see Kirby *et al.* (2008).

Threats to migratory birds in Central Asia and East Asia/Australasia include habitat degradation of rivers and wetland ecosystems, climate change, land use and human infrastructure (BirdLife International 2010b, c). Yong *et al.* (2015) identified illegal hunting/trapping of migratory birds for food and pet trade, invasive species and collisions with human-made structures as the main threats at stopover and wintering sites, while breeding grounds were increasingly affected by the impacts of habitat loss and climate change. For example, the illegal trapping of the migratory insectivore Yellow-breasted Bunting (*Emberiza aureola*), caused a population decline by 84.3 to 94.7% across its geographical range in East Asia between 1980 and 2013 (Kamp *et al.* 2015).

East Asian migratory insectivorous birds

East Asia and Australia are home to a diverse community of migratory insectivorous birds dominated by flycatchers, chats and leaf warblers, with approximately 170 species defined as long-distance migrants (Yong *et al.* 2015). Of these 170 species defined as long-distance migratory songbirds by Yong *et al.* (2015), 21 species are threatened or near threatened and 56 showed a declining trend in in population numbers along temperate and tropical East Asia. In Australia, forest fragmentation is known to cause severe declines in bird populations of all feeding guilds (Watson *et al.* 2002). Similarly, many landbirds in East Asia rely on tropical forests for overwintering, exposing populations to habitat loss and degradation across their geographic range (Yong *et al.* 2015).

4.4 Insect Decline and Migratory Insectivorous Birds (CMS-listed Species)

The majority (59.4%) of the 32 CMS bird species that were identified as insectivores, are listed as Least Concern by the IUCN (Fig. 6a). Globally threatened species, which include the IUCN categories Near Threatened, Vulnerable, Endangered and Critically Endangered account for 40.6% of the 32 CMS-listed species. The population trends of the CMS-listed bird species are largely Decreasing (65.6%) (Fig. 6b). 12.5% are classified as Stable and 6.3% show a positive population trend. For 15.6% of the CMS-listed bird species, the population trend is unknown.

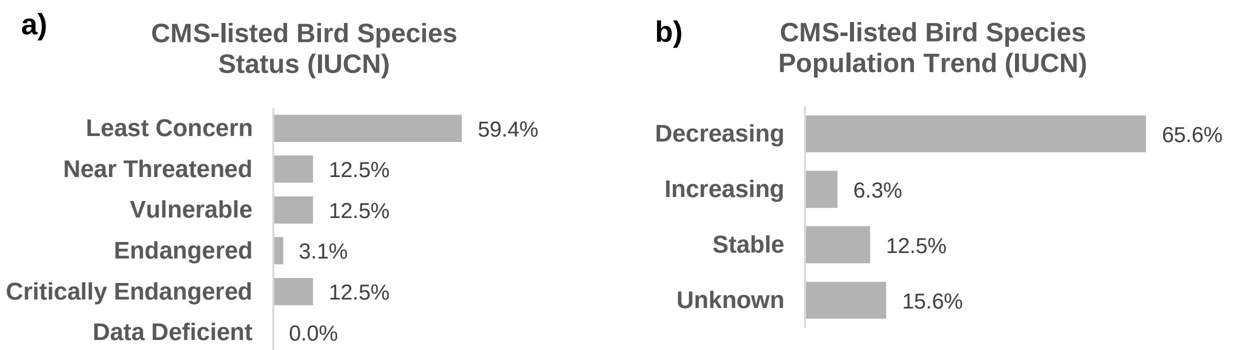

Fig. 6 a) IUCN status and b) population trend of 32 migratory insectivorous CMS-listed bird species based on the IUCN Red List Version 2022-2 (IUCN 2023b). Proportions are based on: Least Concern (n = 19), Near Threatened (n = 4), Vulnerable (n = 4), Endangered (n = 1), Critically Endangered (n = 4) and Data Deficient (n = 0); Decreasing (n = 21), Increasing (n = 2), Stable (n = 4) and Unknown (n = 5).

The IUCN defined global threats for animals (IUCN 2023c). The insect decline is not defined as a threat for migratory (insectivorous) birds directly, but is included in many categories indirectly, which are listed by the IUCN (Fig. 7).

Insects are essential for the survival of insectivorous bird species worldwide (Tallamy & Shriver 2021).The insect decline may affect insectivorous species directly or indirectly, depending on the insect in the ecosystem (Bowler *et al.* 2019).

53.1% of the CMS-listed migratory insectivorous bird species are threatened by agriculture and aquaculture. Populations of the Black-winged Pratincole (*Glareola nordmanni*) can be affected by land-use change in grassland that implies ploughing and loss of grazers (Kamp *et al.* 2009). Grazers play an important role in improving food supply for Pratincoles as they are known to feed on coprophagus insects attracted by dung (Kamp *et al.* 2009). Moderate grazing and mowing also improve food availability as well as habitat heterogeneity for young Northern Lapwings (*Vanellus vanellus*) (Devereux *et al.* 2004).

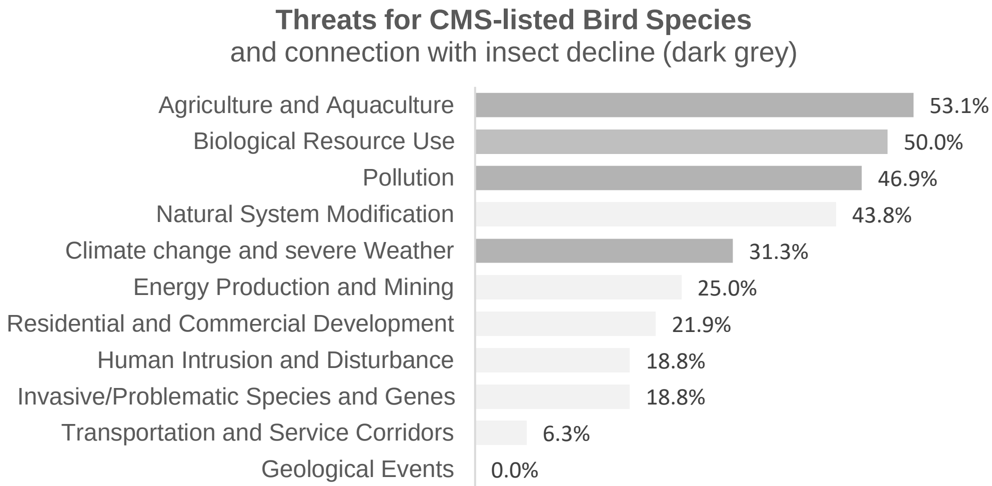

Fig. 7 Threats for 27 out of 32 migratory insectivorous CMS-listed bird species and connection to insect decline (marked in dark grey). Threat categories are based on categorisation of Salafsky *et al.* (2008) and can be found in the IUCN Threat Classification Scheme. Proportions are based on: Agriculture and Aquaculture (n = 17), Biological Resource Use (n = 16), Pollution (n = 15), Natural System Modification (n = 14), Climate Change and severe Weather (n = 10), Energy Production and Mining (n = 8), Residential and Commercial Development (n = 7), Human Intrusions and Disturbance (n = 6), Invasive/Problematic Species, and Genes (n = 6), Transportation and Service Corridors (n = 2), Geological Events (n = 0).

Biological resource use such as timber harvesting, affects 50.0% of the assessed CMS-listed bird species. For instance, the CMS-listed Cerulean Warbler (*Setophaga cerulea*), a bird that is adapted to disturbances in managed forests, can successfully maintain stable populations when forest management treatments create a heterogeneous forest structure (Boves *et al.* 2013).

European Rollers (*Coracias garrulus*) are known to be sensitive towards land-use intensity and the use of insecticides (Avilés & Parejo 2004). Insecticides and other pollutants can have effects on 46.9% of the bird species listed by the CMS. In case of the European Rollers, insecticides result in higher juvenile mortality due to reduced insect availability (Avilés & Parejo 2004). Indirect poisoning of *Pernis apivorus* (European Honey-buzzard) that feed on bumble-bees and wasps (*Hymenoptera*) contaminated with neonicotinoids might affect Honey-buzzard populations (Byholm *et al.* 2018).

Climate change and severe weather are threats for 31.3% of the CMS-listed species (Fig. 7). The effects of climate change on migratory insectivorous birds may manifest in shifted timing of breeding (Visser & Gienapp 2019). First-laying dates of Golden Plovers (*Pluvialis apricaria*) advanced since 1990 by 9 days as a result of changing temperature and rainfall regimes (Pearce-Higgins *et al.* 2005). This advanced breeding phenology may cause a mismatch between young plover hatching and the availability of crane flies (Diptera), the main food source of young plovers, as the insects declined with changing rainfall regimes (Pearce-Higgins *et al.* 2005).

5. Bats

5.1 Bat Migration

In general, bats migrate over shorter distances, than birds (Fleming 2019). Bat species associated with long-distance migratory behaviour are found in at least 15 bat genera and approximately 25 species worldwide (Popa-Lisseanu & Voigt 2009). The migratory behaviour of bats has been described to distinguish between temperate and tropical geographical zones (Fleming & Eby 2003).

Bat species of the temperate zone exhibit characteristic annual migratory movements that are closely linked to hibernation (Fleming 2019). Temperate bats migrate mainly in response to cold climate conditions in breeding areas and favourable milder climate in roosting sites (Popa-Lisseanu & Voigt 2009). These migratory movements can be described as (a) regional migration, with distances between summer and winter roosts of 100 to 500 km, or (b) long-distance migration, with distances between seasonal roosts of 1,000 km or more (Fleming & Eby 2003; Fleming 2019). However, partial or sex-biased migration and migratory flexibility are common in bats of the temperate zone (Fleming & Eby 2003).

In contrast, bats of the tropical zone show little migratory behaviour (Fleming & Eby 2003). When migrating, tropical and subtropical bats mostly follow resource gradients due to seasonal and geographical shifts in food availability (Popa-Lisseanu & Voigt 2009). Migration for hibernation purpose does not play an important role in tropical bats (Fleming 2019).

The distribution of the world's bat species can be grouped into six zoogeographical regions (Fig. 8), using microbats *(*here *Microchiroptera)* as an example, which include Afrotropical, Australasian, Indomalayan, Nearctic, Neotropical, and Palaearctic regions (Hutson *et al.* 2001). Bats are absent from the Arctic, Antarctica and several isolated islands (Hutson *et al.* 2001).

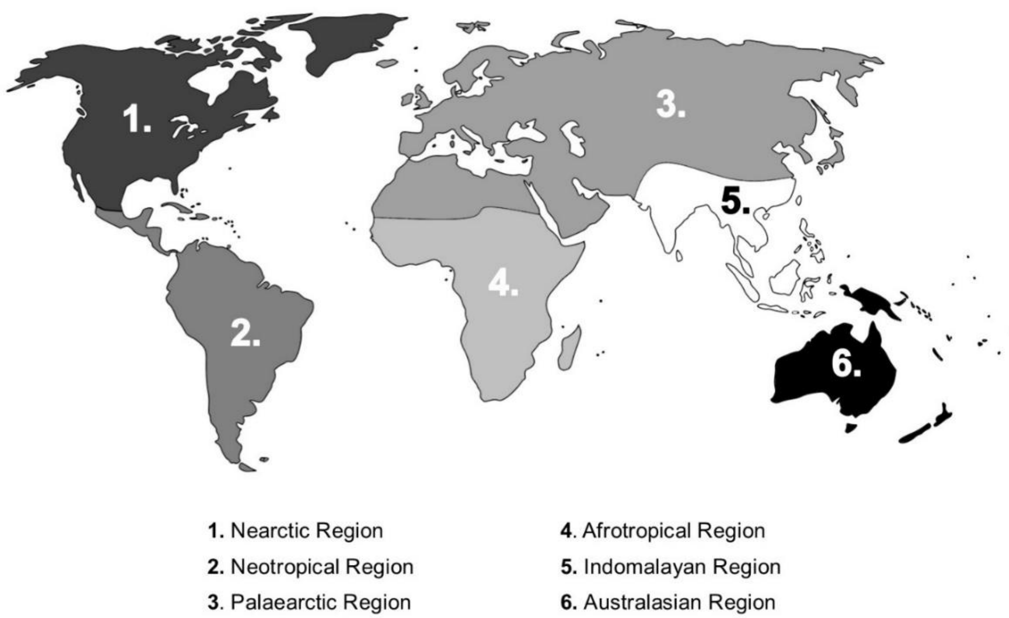

Fig. 8 Overview of the six zoogeographical regions of the distribution of bat species (microbats of the former suborder *Microchiroptera*)**.** The map is based on Hutson *et al.* (2001) and has been used under the CCO 1.0 Universal Public Domain Dedication.

5.2 Macro- and Microbats (or Yinpterochiroptera and Yangochiroptera)

Bats are widely distributed and represent a highly diverse order within the class of mammals (Frick *et al.* 2019). The order of bats (Chiroptera) consisted of two suborders with distinct feeding preferences: *Megachiroptera* (formerly megabats) are mainly consume fruits and flowers, while the majority of *Microchiroptera* (formerly microbats) feed on insects, but also on fish, amphibians, small mammals, fruits and flowers (Mickleburgh *et al.* 1992; Hutson *et al.* 2001). Recent molecular evidence suggests a close relationship between Old World fruit bats (*Pteropodiformes*) and several traditionally classified families of *Microchioptera* (Hutcheon & Kirsch 2006). In agreement with Teeling *et al.* (2005), a placement of *Pteropodidae*, *Rhinolophidae* in the suborder *Yinpterochiroptera,* and *Emballonuridae, Noctilionidae* and *Vespertilionidae* in *Yangochiroptera* was announced.

The IUCN listed 23.4% of the 1,332 bat species as threatened and 58.2% as Least Concern (Fig. 9) (IUCN 2023b). 236 bat species (17.7%) are classified as Data Deficient. Frick *et al.* (2019) estimate that more than one third of the global bat species are classified as threatened and data deficient by the IUCN. Information on yinpterochiropteran and yangochiropteran species can be obtained from Mickleburgh *et al.* (1992) and Hutson *et al.* (2001)[6].

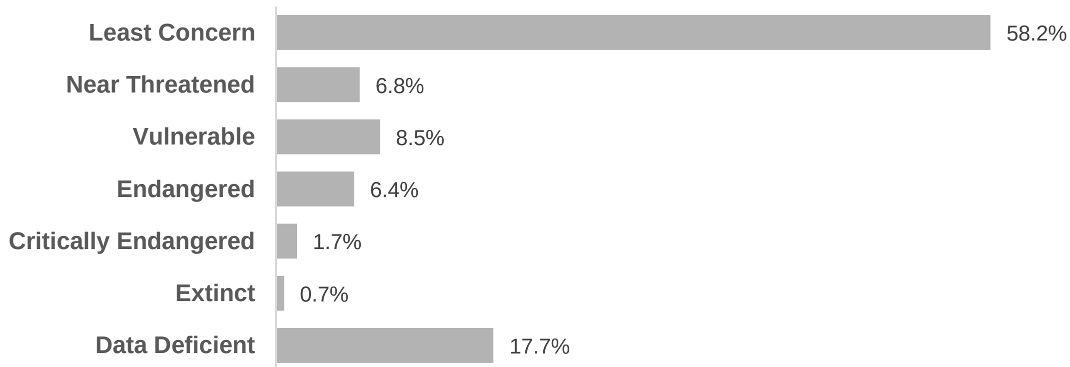

Fig. 9 Proportion of IUCN Red List categories for all documented bat species. A total 1,332 bats were classified by the IUCN as Least Concern (n = 775), Near Threatened (n = 91), Vulnerable (n = 113), Endangered (85), Critically Endangered (n = 23), Extinct (n = 9) and Data Deficient (n = 236) (IUCN 2023b).

Arthropods and insects are the primary food source for around 75% of yangochiropteran (formerly microchiropteran) bat species (Hutson *et al.* 2001). Thus, insectivorous bat species provide an important ecosystem service by regulating insect and arthropod populations that may cause potential agricultural pests or transmit pathogens to humans and animals in ecosystems (Kunz *et al.* 2011). Frugi- and nectarivorous bats play an important role in plant pollination and seed dispersal in tropical and subtropical ecosystems (Kunz *et al.* 2011). Compared to migratory fruit- or nectar eating bats, migratory insectivorous bats show a geographically defuse migratory behaviour (Wiederholt *et al.* 2013). Some characteristics of migratory insectivorous bats are:

> Long-distance migratory bats use torpor to minimise energy costs during daytime stopovers on migration routes (McGuire & Guglielmo 2009). Typically, prolonged and continuous torpor is associated with winter hibernation (Speakman & Thomas 2003). In this case, the term of torpor-assisted migration has been introduced (McGuire *et al.* 2012). Species of the Silver-

[6] Both literatures need to be updated.

haired Bat (*Lasionycteris noctivagans*) used torpor instead of remaining euthermic to save up to 91% of their energy (McGuire *et al.* 2014).

Bats migrate almost exclusively at night, making daytime stopovers essential (McGuire *et al.* 2012). Suitable roosts in trees and artificial structures and their microclimate are important for bats at stopover sites (McGuire *et al.* 2012, 2014).

The frequent stops made by bats during migration to feed on insects and to store fat can be described as a fly-and-forage strategy (Šuba *et al.* 2012). In autumn, just before hibernation and migration, bats feed intensively on insects to store fat (McGuire & Guglielmo 2009). Along the migration route, energy costs must be optimised to ensure winter survival and reproductive success (Šuba *et al.* 2012). Compared to birds, bats spend a short time at stopover sites (McGuire *et al.* 2012).

5.3 Migratory Insectivorous Bat Populations (Overview)

Intercontinental migratory behaviour in bats is very rare, as bats are relatively short-distance migrants, with migration distances of 100 to 1,000 km (Fleming 2019). However, some Palaearctic yangochiropteran bat species (formerly microbats) of the are able to migrate over more than 2,400 km (Vasenkov *et al.* 2022). Prey availability plays a crucial role during migration (Frick *et al.* 2019).

Insectivorous bats along the migration routes are sensitive to changes in insect prey abundance due to direct or indirect anthropogenic impacts (Jones *et al.* 2009). Food availability during long-distance migration is critical for insectivorous bats as they can only use a limited amount of their body fat as an energy source during migration. Thus, migratory insectivorous bats are known to combine dietary protein from insects captured along the migration route with body reserves to meet energy requirements for migration (Voigt *et al.* 2012). Reduced insect abundance along the migration route may lead to a higher energy expenditure for successful foraging to compensate for the lack of insect prey. The increased energy cost could result in additional stress for migrating insectivorous bats, affecting individual fitness and survival. To avoid energy expenditure, migratory insectivorous bats can reduce their body temperature during inactive periods, regardless of the ambient temperature at the stopover site (McGuire *et al.* 2014)

Nearctic Region (North America)

52% of the bats of North America are estimated to decline over the next 15 years (Bat Conservation International 2023). The conservation status of North American bats follows strong geographic and temporal patterns: The southwest of North America is characterised by high bat species richness, but threatened bat species are mostly found in the east. The north of North America has the highest number of threatened bat species (Hammerson *et al.* 2017). For example, the insectivorous migratory Tricolored Bat (*Perimyotis subflavus*) is listed as vulnerable with a 50% decline in summer distribution (Bat Conservation International 2023). Populations of the endangered Little Brown Bat *(Myotis lucifugus)* showed a decline, with individuals rapidly decreasing in body size due to declining insect abundance and prey availability (Davy *et al.* 2022).

For insectivorous bats, forests are the most important habitat (Law *et al.* 2016). Managed forests in Europe and North America are known to focus in timber production, which promotes even-aged forests with a homogeneous forest structure and low amounts of habitats for bats (Law *et al.* 2016; Frick *et al.* 2019). However, heterogeneous uneven-aged forests with a mix of managed and excluded areas, regardless of forest type and geographic region, may maintain bat diversity (Law *et al.* 2016).

Palaearctic Region (mostly Europe)

European bat populations were assessed for 16 yangochiropteran bat species with data from 9 countries[7] from 1993 to 2011 (EEA 2013). For 43% of the species an increasing population trend in wintering sites was identified between 1993 and 2011 (EEA 2013). Of the 16 bat species assessed by the EEA, 8 species are known to be long-distance migrants. The EEA report (2013) states that bat populations have declined across Europe, particularly in the second half of the 20th century. According to the IUCN (2023), the Schreiber's Bent-winged Bat (*Miniopterus schreibersii*) is estimated to have declined by at least 30% across its large geographical range. The migratory insectivorous bat is listed as Vulnerable by the IUCN Red List due to the population decline. The near threatened bat species of the Brown Long-eared Bat (*Plecotus auritus*) was also found to be in decline throughout Europe (IUCN 2023).

Neotropical, Afrotropical and Indomalayan Region (Africa, South America and Southeast Asia)

Neotropical insectivorous bats and several forest-dependent species in South America have declined due to habitat fragmentation (Meyer *et al.* 2008; Meyer & Kalko 2008). The sensitivity of bats to habitat fragmentation, logging and deforestation has been found to be highly species and landscape specific (Meyer *et al.* 2016). The loss and degradation of tropical rainforests in the Neotropics and Southeast Asia can be considered a major threat to global bat diversity (Kingston 2010; Meyer *et al.* 2016). Despite caves, forest ecosystems are an important habitat for bats and support a wide variety of bat species (Frick *et al.* 2019). Studies on tropical bats are tend to follow a taxonomic and geographic bias towards the New World leaf-nose bat family (*Phyllostomidae*) and a lack of knowledge on African and Southeast Asian bat species (Meyer *et al.* 2016). The Amazon basin in South America and in Southeast Asia have the highest number of Data Deficient and Threatened bat species according to the IUCN Red List (Frick *et al.* 2019). As noted above, most tropical bats show no migratory behaviour and prefer fruits or nectar as a food source (Fleming 2019). Long-distance migratory insectivorous bats found in the tropical zone are mainly temperate bats in their winter habitat, such as the Mexican free-tailed Bats (*Tadarida brasiliensis*), which migrates between North and South America, or the Particoloured Bat (*Vespertilio murinus*), which has its southernmost range in Southeast Asia. Both bats species are classified by the IUCN (2023) as Least Concern with stable populations.

5.4 Insect Decline and Migratory Insectivorous Bats (CMS-listed Species)

38 (69.1%) of the 55 CMS-listed insectivorous bat species are classified by the IUCN as Least Concern (Fig. 10a). Near Threatened, Vulnerable, Endangered, and Critically Endangered bat species accounted for 21.8% of the listed animals. 32.7% of the bat populations are decreasing, 29.1% are stable and none are increasing (Fig. 10b). For 20 (36.4%) of the CMS-listed bat species the population trend is unknown.

[7]Austria, Germany (Bavaria, Thuringia), Hungary, Latvia, Netherlands, Portugal, Slovakia, Slovenia, United Kingdom

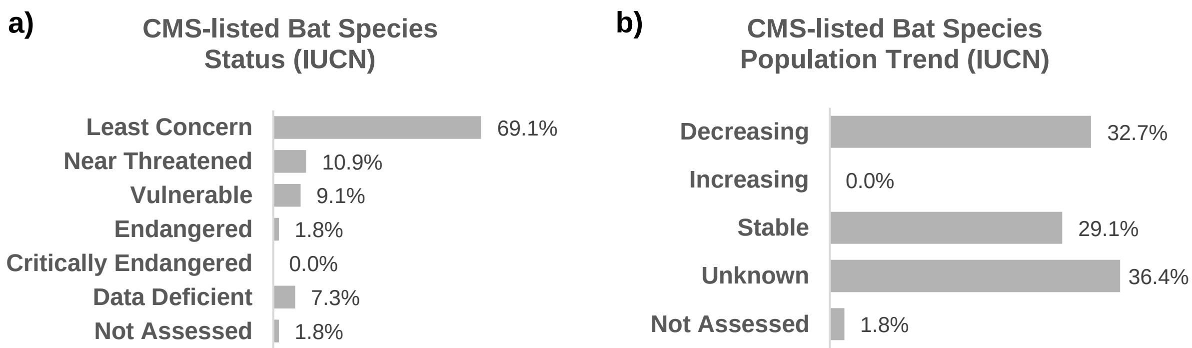

Fig. 10 a) IUCN status and b) population trend of 55 migratory insectivorous CMS-listed bat species based on the IUCN Red List Version 2022-2 (IUCN 2023b). Proportions are based on: Least Concern (n = 38), Near Threatened (n = 6), Vulnerable (n = 5), Endangered (n = 1), Critically Endangered (n = 0), Data Deficient (n = 4), Not Assessed (n = 1); Decreasing (n = 18), Increasing (n = 0), Stable (n = 16), Unknown (n = 20) and Not Assessed (n = 1).

Bats are threatened globally by logging and harvesting of plants, agriculture, and hunting or collecting of animals (Frick *et al.* 2019). Threats to bats are mostly related to anthropogenic demands for land, food and other resources that directly affect ecosystems, resulting in the conversion and degradation of habitats important to bats and other organisms (Mickleburgh *et al.* 2002). Threats and challenges to the worlds bats have been reviewed by Frick *et al.* (2019).

For the CMS-listed insectivorous bats, logging that is part of the category biological resource use plays a crucial role, as 67.9% of the listed species are affected (Fig. 11). The main threat for CMS-listed bat species, human intrusions and disturbances, has no connection to insect decline.

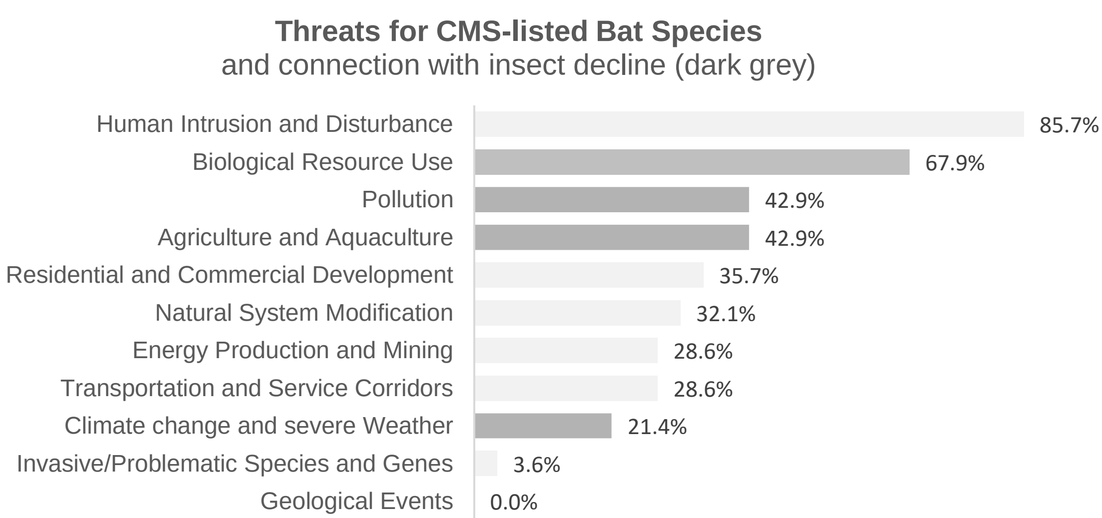

Fig. 11 Threats for 28 out of 55 migratory insectivorous CMS-listed bat species and connection to insect decline (marked in dark grey). Threat categories are based on categorisation of Salafsky *et al.* (2008) and can be found in the IUCN Threat Classification Scheme. Proportions are based on: Human Intrusions and Disturbance (n = 24), Biological Resource Use (n = 19), Pollution (n = 12), Agriculture and Aquaculture (n = 12), Residential and Commercial Development (n = 10), Natural System Modification (n = 9), Energy Production and Mining (n = 8), Transportation and Service Corridors (n = 8), Climate Change and severe Weather (n = 6), Invasive/Problematic Species, and Genes (n = 1), Geological Events (n = 0).

Many managed forest ecosystems can ensure adequate quantities of insect availability (Law *et al.* 2016). High abundances of insects are known to be found in open forest patches, which are often associated with high levels of bat activity (Adams *et al.* 2009). Large clear-cuts in the forest stands that regenerate as silvicultural monocultures decrease insect prey availability for insectivorous forest bats (Dodd *et al.* 2012). Important for insect prey availability in forests are the structure and composition of the plant community in the understory vegetation that also influence the access for bats to the forest interior as well as the microclimate (Law *et al.* 2016). Old forests with patches of different vegetation height were beneficial for the activity of bats of the *Myotis*, *Nyctalus* and *Plecotus* genus (Jung *et al.* 2012). Although, bats showed higher occurrence and activity in structural complex forest stands, effects on bats are different based on their wing morphology and foraging strategies (Jung *et al.* 2012).

42.9% of the migratory insectivorous CMS-listed bat species are threatened by pollution (Fig. 11). This effects on insectivorous bat populations is often mediated through food resources such as the abundance of insects or arthropods.
The change in the availability of insect prey caused a two-week delay in the spring migration and a change in the summer reproductive cycle of the migratory insectivorous Mexican Free-tailed Bats *(Tadarida brasiliensis)* (Stepanian & Wainwright 2018). The authors linked the changes in the behaviour of the bats to pest management practices on the agricultural land in the region. The use of insecticides and insect-resistant crops impacts insectivorous bat species by reducing prey abundance and increasing the risk of direct poisoning (Frick *et al.* 2019). Pollution also implies artificial light at night (ALAN). Many European insectivorous bat species listed by the CMS show a sensitivity towards ALAN on commute or forage, as well as a negative response towards ALAN close to roots and drinking sites (Voigt *et al.* 2021). Especially, bat species that do not forage in light-open areas such as *Rhinolophus ferrumequinum, Rhinolophus hipposideros, Rhinolophus mehelyi and* many *Myotis* species are affected by reduced prey availability in their habitat as many insects are attracted by ALAN (Stone *et al.* 2015; Voigt *et al.* 2021).

Agriculture effects 42.9% of the CMS-listed bat species (Fig. 11). Many insectivorous bats were largely negative affected by land-use intensification, causing population declines (Williams-Guillen *et al.* 2015). Agriculture and its components can lead to a reduction in habitat quality for bats by reducing foraging and habitat resources (Wickramasinghe *et al.* 2003, 2004). Habitat conversion and degradation through agricultural practices can change the habitat quality for bats and their associated insect pray (Poniatowski *et al.* 2018; Münsch *et al.* 2019) (Wickramasinghe *et al.* 2003, 2004). In particular, the reduction of natural elements within the agricultural system, such as hedgerows or woodlands, has significant negative effects on bats (Williams-Guillen *et al.* 2015). The negative effects of agriculture on bats are expected to increase with the expansion of agricultural land cover (Put *et al.* 2019). For migratory insectivorous bat species, responses to intensive agriculture were mostly negative (Davidai *et al.* 2015). *Barbastella barbastellus* for instance, is known to be very specialised on moths as their main diet (Zeale *et al.* 2011). Less intensive farming practices, when compared to intensive farming, can enhance moth species diversity in particular and insect diversity in general (Wickramasinghe *et al.* 2004). For many bats such as *Pipistrellus nathusii, Pipistrellus pipistrellus*, *Pipistrellus pygmaeus*, *Nyctalus noctula*, *Nyctalus leisleri*, *Eptesicus nilssonii,* and *Myotis myotis,* a heterogeneous landscape with a high forest proportion can buffer the negative effects of land-use intensity on insect availability, but still weakens the interactions of bats and insects (Treitler *et al.* 2016).

In a warming climate with changing temperatures and precipitation patterns, hibernation behaviour of bats is expected to be affected (Speakman & Thomas 2003). As insects are ectothermic, insect abundance is influenced by changing climate condition too (Burles *et al.* 2009). Many factors of the warming climate may improve prey availability for bats such as higher temperatures can result in higher insect availability and optimised foraging behaviour (Park *et al.* 2000), or higher precipitation may cause greater availability of dipteran and lepidopteran prey (Frick *et al.* 2009). The effects of climate change on bats are not uniform and not positive per se (Sherwin *et al.* 2013). Warm winter nights are increasing and temperatures of 11°C can trigger bat activity during winter (Mas *et al.* 2022). High activities of bats during winter may lead to high energetic foraging costs for insectivorous bats, as insects are scares in many areas in Europe during winter (Mas *et al.* 2022). Wetlands in the Mediterranean regions in Europe harbour many insects in winter and may become important for bat conservation in a warming climate (Mas *et al.* 2022).

Migratory insectivorous bats species play an important role in monitoring the global impacts of climate change on migratory species (Newson *et al.* 2009). Populations of the cave-dwelling tropical Mexican Free-tailed Bat (*Tadarida brasiliensis*) are an important indicator in identifying the impact of climate change on insects. All northern temperate bats that hibernate during winter are sensitive towards high winter temperatures, which can illustrate changes in the distribution and regional species composition in an changing climate (Newson *et al.* 2009).

6. Fish

6.1 Fish migration

Fish are a group of vertebrate aquatic animals that inhabit freshwater and marine ecosystems. Over the half of all vertebrate species (approx. 32,000) can be describes as fish (Nelson *et al.* 2016). They are known to be extremely diverse and play an important role in aquatic ecosystem functioning worldwide (Holmlund & Hammer 1999). Many fish species of freshwater and marine ecosystems experienced critical population declines and are exposed to local and global extinction risks (Helfman 2007; Darwall & Freyhof 2015; Deinet *et al.* 2020). Depending on the fish species and its life history strategy, fish can migrate inside an aquatic system (only freshwater or marine) or between the systems (freshwater to marine and back) (Morais & Daverat 2016).

Approximately 1,000 freshwater fish species can be defined as migratory (Brink *et al.* 2018). Migratory marine fish species are summarised as highly migratory species (HMS) and are listed in the Annex of the United Nations Convention on the Law of the Sea (UNCLOS). These fish species migrate over long distances in the oceans of the world (Meltzer 1994). Migratory freshwater fish spend at least on part of their lifecycle in freshwater ecosystems and conduct migration as an integral part of their survival (Brink *et al.* 2018). Freshwater ecosystems of the world are extremely affected by anthropogenic impacts and freshwater biodiversity is highly threatened by habitat degradation, species invasion, flow modification, over-exploitation and water pollution (Dudgeon *et al.* 2006). Migration routes and migration patterns of freshwater fish were and are still largely unknown (Brönmark *et al.* 2014). Evidence suggests that a large variety of freshwater fish species show migration behaviour (Lucas & Baras 2008).

The Global Swimways Program achieves to map and monitor associated ecosystems of important freshwater fish after biological, economic and social criteria's (Worthington *et al.* 2022). So far, the program mapped 665 migratory fish species in four grouped regions (Fig. 12) in (1 and 2) West-Central Africa, Southeast Asia due to high species richness, (3) Eastern Europe/Central Asia due to high distribution if threatened species and (4) East Africa due to high endemism criteria's (Worthington *et al.* 2022).

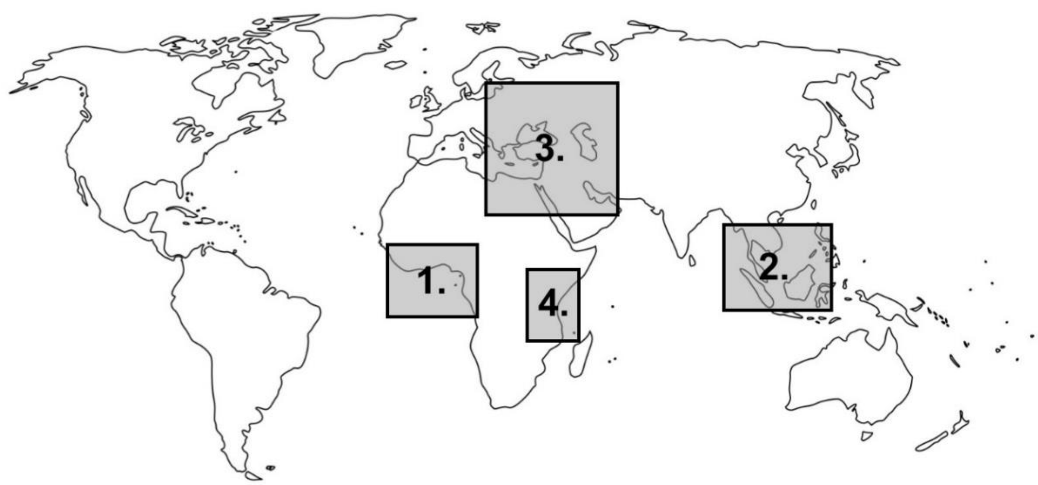

Fig. 12 Assessment regions of the 655 migratory freshwater fish species of the Global Swimways Program (Worthington *et al.* 2022). Further information can be found on www.globalswimways.com.

Other approaches of mapping freshwater fish biodiversity were conducted by Abell *et al.* (2008) with the assessment of global ecoregions or by Lévêque *et al.* (2008) with analysing biographical regions of global fish populations.

Fish migration can be classified into three types based on ecosystem use (Lucas & Baras 2008):

(1) **Oceanodromy** or oceanodromous: Migration only in marine ecosystems.
Example: Atlantic Herring (*Clupea harengus*) (Tamario *et al.* 2019).
(2) **Potamodromy** or potamodromous: Migration only in freshwater ecosystems.
Example: White Sturgeon (*Acipenser transmontanus*) (Deinet *et al.* 2020).
(3) **Diadromy** or diadromous: Migration between freshwater and marine ecosystems.
Example: European Eel (*Anguilla anguilla*) (Tamario *et al.* 2019).

Diadromous freshwater fish further perform different types of migrations based on life history strategies (McDowall 1997; Lucas & Baras 2008):

(i) **Anadromy** or anadromous: Diadromous fish species that mostly live in marine ecosystems but migrate to freshwater ecosystems as an adult to reproduce.
Example: Atlantic salmon (*Salmo salar*) (Deinet *et al.* 2020).
(ii) **Catadromy** or catadromous: Diadromous fish species that mostly live in freshwater ecosystems but migrate to marine ecosystems as an adult to reproduce.
Example: Barramundi (*Lates calcarifer*) (Tamario *et al.* 2019).
(iii) **Amphidromy** or amphidromous: Diadromous fish species that hatch in freshwater ecosystems and migrate as larval fish into marine ecosystems to grow until juvenile stage that is migrating back into freshwater ecosystem to further feed and finally reproduce.
Example: Several species of goby, mullet and gudgeon (Deinet *et al.* 2020).
Note: The term amphidromy was under debate for a long time (Lucas & Baras 2008) and still causes confusion (McDowall 2007).

Not all fish species can be clearly classified into the above mentioned categories as fish populations of the same fish species sometimes show intraspecific variations (Lucas & Baras 2008). In this case, the same fish species can perform multiple life history strategies in different populations (Lucas & Baras 2008).

6.2 *Actinopterygii* (Ray-finned Fish)

The vast majority of fish, approximately 30,000 fish species, are ray-finned fish of the class of *Actinopterygii* (Near et al. 2012). 99.8% of ray-finned fish are classified as teleosts (Volff 2005). Non-teleosts ray-finned fish belong to bichirs (*Polypteriformes)* and sturgeons (*Acipenseriformes*) (Volff 2005). Ray-finned fish can be found in similar numbers in freshwater ecosystems (15,150 species) and marine ecosystems (14,740 species) all over the world (Carrete Vega & Wiens 2012). Characteristics of freshwater and marine ecosystems are quite different, for example lakes, rivers and streams only make up 1% of the world surface, compared to oceans and seas that cover 71% of the world surface (Dawson 2012). Therefore, fish species of the different ecosystems are exposed to different kind of threats (Arthington *et al.* 2016). Threats for freshwater fish are mainly invasive species, climate change and habitat loss (Darwall & Freyhof 2015). Marine fish species are largely threatened by over-exploitation, climate change and habitat loss (Arthington *et al.* 2016).

The IUCN Red List contains 23,995 ray-finned fish species (IUCN 2022). The status of 63.6% of the fish species is considered as Least Concern, while 15.9% are listed as global threatened (Fig. 13).

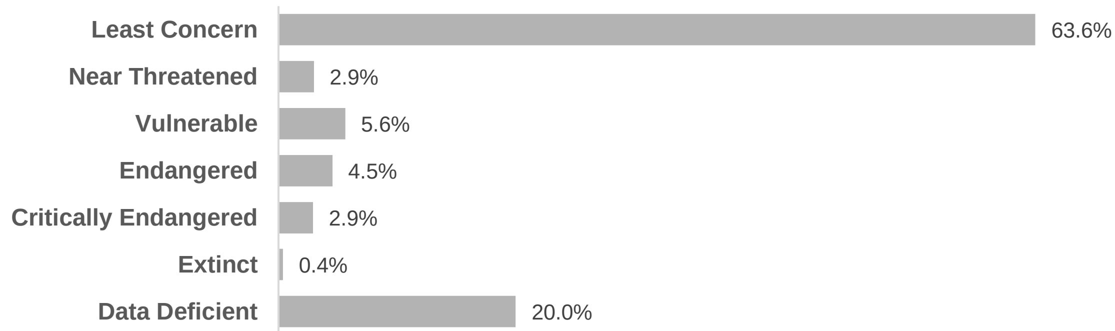

Fig. 13 Proportions of IUCN Red List categories for all documented ray-finned fish species. A total of 23,955 fish were classified by the IUCN as Least Concern (n = 15,268), Near Threatened (n = 714), Vulnerable (n = 1,348), Endangered (n = 1,089), Critically Endangered (n = 697), Extinct (n = 92) and Data Deficient (n = 4,787) (IUCN 2023a).

2.9% of the global threatened fish species are listed as Near Threatened, 5.6% as Vulnerable, 4.5% as Endangered and 2.9% as Critically Endangered. For 20.0% of the ray-finned fish species, the data of status assessment is not efficient. 0.4% of the assessed fish species are considered extinct.

6.3 Migratory Insectivorous Freshwater Fish Populations (Overview)

Migratory diadromous and potamodromous fish species migrate between freshwater or marine ecosystems or only within freshwater ecosystems. On their migration routes through rivers, lakes or seas, fish are exposed to high catchability trough fishing in migration bottlenecks, as well as degradation of breeding habitats (Arthington *et al.* 2016). The migratory behaviour of diadromous fish have been identified to be far more complex than originally assumed (Lucas & Baras 2008).

However, detailed and global information about migratory fish are accessible for 247 anadromous, catadromous, amphidromous, diadromous or potamodromous fish species (Deinet *et al.* 2020). Between 1970 and 2016, the populations of these 247 globally distributed freshwater fish species declined by 76% in abundance (Deinet *et al.* 2020). Continent specific information about migratory fish can be found for North America (Waldman & Quinn 2022), South America (Carolsfeld & Bank 2003), Europe (van Puijenbroek *et al.* 2019) or specific to the North Atlantic (Limburg & Waldman 2009) or for HMS (High Migratory Species; Meltzer 1994).

Aquatic insects are an important source of food for several freshwater fish species (Macadam & Stockan 2015). Season, waterbody size, fish species and size are factors that affect the contribution of insects to a freshwater fish species diet (Macadam & Stockan 2015). For Sturgeon, *Diptera* larvae have been identified to play an important role in the fish diet (Hamidoghli *et al.* 2014). Other important insect taxa are *Trichoptera* and *Ephemeroptera* (Jacquemin *et al.* 2013). Fish are known to prefer large aquatic insects as they are size-selective predators, indirectly affecting the abundance and diversity of smaller aquatic insect taxa (Hershey *et al.* 2010). However, in highly complex ecosystems effects of fish on aquatic insect communities are low (Hershey *et al.* 2010). Fish species richness and endemism are differently distributed over the world, with high biodiversity usually found in regions close to the equator (Abell *et al.* 2008).

6.4 Insect Decline and Migratory Insectivorous Freshwater Fish (CMS-listed Species)

Out of the 21 fish species listed by the CMS, four fish species were identified as dominantly insectivorous. These fish species are Siberian Sturgeon (*Acipenser baerii),* Lake Sturgeon *(Acipenser fulvescens),* Ship Sturgeon (*Acipenser nudiventris*) and Amur Sturgeon (*Acipenser schrencki)*. Three of the four CMS freshwater fish species assessed are classified as Critically Endangered and one species is listed as Endangered (Fig. 14a). A decreasing population trend is shown for three species, while one species has an unknown population trend (Fig. 14b).

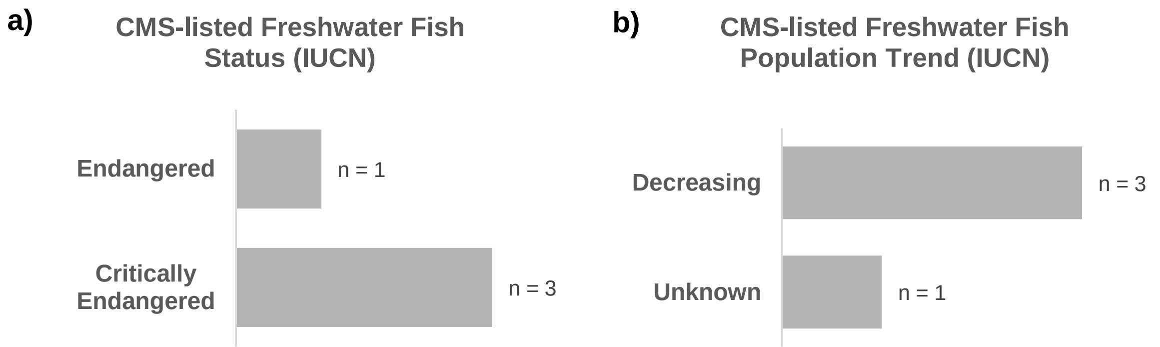

Fig. 14 a) IUCN status and b) population trend of four migratory insectivorous CMS-listed fish species based on the IUCN Red List Version 2022-2 (IUCN 2023b).

Anthropogenic effects on freshwater fish species and freshwater ecosystems are high (Vörösmarty *et al.* 2010). Humans largely affect freshwater biodiversity by deforestation, water pollution, habitat conversion through engineering, wetland drainage, groundwater depletion, overfishing (Dudgeon *et al.* 2006; Arthington *et al.* 2016). Threats for the CMS-listed freshwater fish species and its connection with insect decline are listed in Figure 15.

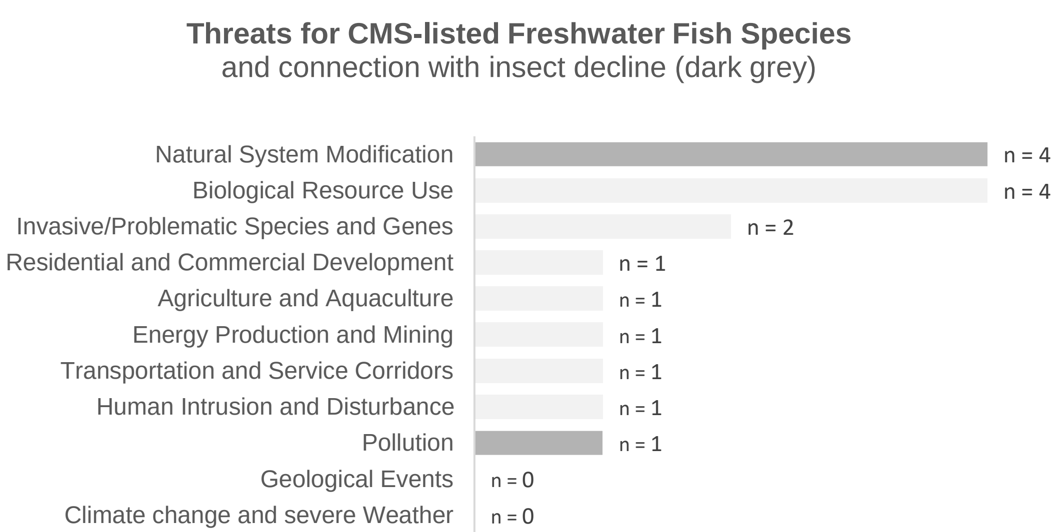

Fig. 15 Threats for four out of four migratory insectivorous CMS-listed freshwater fish species and connection to insect decline (marked in dark grey). Threat categories are based on categorisation of Salafsky *et al.* (2008) and can be found in the IUCN Threat Classification Scheme.

Habitat fragmentation through artificial habitat modification (e.g. dams) can disturb and stop eels (*Anguilla spp.*) and sturgeons (*Acipenser spp*.) from migrating along rivers (Arthington *et al.* 2016).

The natural system modifications often change physical water properties like water volatility, affecting not only fish migration routes, but also fish spawning and nursery areas (Winfield 2004; Arthington *et al.* 2016). Turbidity of water is suspected to lead to reduce foraging success for some insectivorous fish (Bonner & Wilde 2002). Interactions of insects and fish may be affected by natural system modification as aquatic insect abundance can be limited through artificial manipulated physical water properties (Koroiva & Pepinelli 2019). Water reservoirs were identified to be a great risk for rare aquatic insects (Polhemus 1993). Dam construction in spawning grounds may have caused population declines of migratory insectivorous freshwater fish directly such as *Acipenser nudiventris* (CMS Proposal II/19).

Water pollution of freshwater ecosystems can have direct effects (pollution through waist in urban areas, chemicals from industries or poor water quality deployment from mining sites) and indirect effects (eutrophication from agriculture) on fish species (Arthington et al. 2016). A reduction in aquatic insect abundance due to decreasing water quality was described by Polhemus (1993). Water pollution can affect aquatic insects in two ways, first aquatic insect larva development may fail due to contaminants in the water, reducing the aquatic insect larval population, and secondly adult insect may be directly killed by lethal effects of polluted water (Henry *et al.* 2020).
In Europe in the 20th century, many migratory fish species such as sturgeons, herrings, lampreys, salmon and several whitefish species, faced a decline in their distribution due to water pollution and eutrophication of rivers and lakes (Freyhof & Wright 2011). Bottom-feeding fish such sturgeon depending on aquatic insects, especially *Chironomidae* (*Diptera*) as a food resource (Hamidoghli *et al.* 2014). *Acipenser baerii* populations declined due to high pollution levels of Lake Baikal, affecting the fish directly, its food resource and feeding grounds in the lake (CMS Proposal II/14). Similar effects caused declines of *Acipenser nudiventris* in the Caspian Sea (CMS Proposal II/19) and *Acipenser schrenckii* in Chinese and Russian river banks of the Amur River system (CMS Proposal II/22).

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Supplement

S1 Birds of the CMS Species List and Insectivorous Categorisation

Supplement 1 List of migratory bird species of the CMS species list (www.cms.int/en/species). Migratory insectivorous bird species are marked in bold. The assessment of insectivorous feeding of birds is based on www.birdsoftheworld.org (Billerman *et al.* 2023) and www.audubon.org (National Audubon Society 2023). Synonymous species names are put in parentheses.

Scientific name	English name	Report List	Further Information
Condition/Filter		*Insectivore*	
Reference	Billermann *et al.* (2023),	Billermann *et al.* (2023)	
Sum of Species		***32***	
Accipiter badius	Shikra	0	www.cms.int/en/species/accipiter-badius-0
Accipiter brevipes	Levant Sparrowhawk	0	www.cms.int/en/species/accipiter-brevipes
Accipiter gentilis	Northern Goshawk	0	www.cms.int/en/species/accipiter-gentilis
Accipiter gularis	Japanese Sparrowhawk	0	www.cms.int/en/species/accipiter-gularis
Accipiter nisus	Eurasian Sparrowhawk	0	www.cms.int/en/species/accipiter-nisus
Accipiter ovampensis	Ovambo Sparrowhawk	0	www.cms.int/en/species/accipiter-ovampensis
Accipiter soloensis	Chinese Sparrowhawk	0	www.cms.int/en/species/accipiter-soloensis
Accipiter virgatus	Besra	0	www.cms.int/en/species/accipiter-soloensis
Acrocephalus griseldis	**Basra Reed-warbler**	**1**	www.cms.int/en/species/acrocephalus-griseldis
Acrocephalus paludicola	**Aquatic Warbler**	**1**	www.cms.int/en/species/acrocephalus-paludicola
Acrocephalus sorghophilus	**Streaked Reed-warbler**	**1**	www.cms.int/en/species/acrocephalus-sorghophilus
Actitis hypoleucos (Tringa hypoleucos)	Common Sandpiper	0	www.cms.int/en/species/tringa-hypoleucos
Aegolius funereus	Boreal Owl	0	www.cms.int/en/species/aegolius-funereus
Aegypius monachus	Cinereous Vulture	0	www.cms.int/en/species/aegypius-monachus
Alectrurus risora	**Strange-tailed Tyrant**	**1**	www.cms.int/en/species/alectrurus-risora
Alectrurus tricolor	**Cock-tailed Tyrant**	**1**	www.cms.int/en/species/alectrurus-tricolor
Alopochen aegyptiacus	Egyptian Goose	0	www.cms.int/en/species/alopochen-aegyptiacus
Amaurornis marginalis	Striped Crake	0	www.cms.int/en/species/amaurornis-marginalis

Amazona tucumana	Tucuman Amazon	0	www.cms.int/en/species/amazona-tucumana
Anas acuta	Northern Pintail	0	www.cms.int/en/species/anas-acuta
Anas capensis	Cape Teal	0	www.cms.int/en/species/anas-capensis
Anas crecca	Common Teal	0	www.cms.int/en/species/anas-crecca
Anas erythrorhyncha	Red-Billed Duck	0	www.cms.int/en/species/anas-erythrorhyncha
Anas platyrhynchos	Mallard	0	www.cms.int/en/species/anas-platyrhynchos
Anas undulata	Yellow-Billed Duck	0	www.cms.int/en/species/anas-undulata
Anous minutus (Anous minutus worcesteri)	Black Noddy	0	www.cms.int/en/species/anous-minutus-worcesteri
Anser albifrons	Greater White-fronted Goose	0	www.cms.int/en/species/anser-albifrons
Anser anser	Greylag Goose	0	www.cms.int/en/species/anser-anser
Anser brachyrhynchus	Pink-footed Goose	0	www.cms.int/en/species/anser-brachyrhynchus
Anser cygnoides (Anser cygnoid)	Swan Goose	0	www.cms.int/en/species/anser-cygnoid
Anser erythropus	Lesser White-fronted Goose	0	www.cms.int/en/species/anser-erythropus
Anser fabalis	Bean Goose	0	www.cms.int/en/species/anser-fabalis
Anthropoides paradisea (Anthropoides paradiseus)	Blue Crane	0	www.cms.int/en/species/anthropoides-paradiseus
Anthropoides virgo	Demoiselle Crane	0	www.cms.int/en/species/anthropoides-virgo
Aquila adalberti	Spanish Imperial Eagle	0	www.cms.int/en/species/aquila-adalberti
Aquila chrysaetos	Golden Eagle	0	www.cms.int/en/species/aquila-chrysaetos
Aquila heliaca	Eastern Imperial Eagle	0	www.cms.int/en/species/aquila-heliaca
Aquila nipalensis	Steppe Eagle	0	www.cms.int/en/species/aquila-nipalensis
Aquila rapax	Tawny Eagle	0	www.cms.int/en/species/aquila-rapax
Ardea purpurea (Ardea purpurea purpurea)	Purple Heron	0	www.cms.int/en/species/ardea-purpurea-purpurea
Ardenna creatopus	Pink-footed Shearwater	0	www.cms.int/en/species/ardenna-creatopus
Ardeola idae	Madagascar Pond-heron	0	www.cms.int/en/species/ardeola-idae
Ardeola rufiventris	Rufous-Bellied Heron	0	www.cms.int/en/species/ardeola-rufiventris
Ardeotis nigriceps	Great Indian Bustard	0	www.cms.int/en/species/ardeotis-nigriceps
Arenaria interpres	Ruddy Turnstone	0	www.cms.int/en/species/arenaria-interpres
Asio capensis	Marsh Owl	0	www.cms.int/en/species/asio-capensis
Asio flammeus	Short-eared Owl	0	www.cms.int/en/species/asio-flammeus
Asio otus	Northern Long-eared Owl	0	www.cms.int/en/species/asio-otus
Aviceda cuculoides	African Cuckoo-hawk	0	www.cms.int/en/species/aviceda-cuculoides

Aviceda jerdoni	Jerdon's Baza	0	www.cms.int/en/species/aviceda-jerdoni
Aviceda leuphotes	Black Baza	0	www.cms.int/en/species/aviceda-leuphotes
Aythya baeri	Baer's Pochard	0	www.cms.int/en/species/aythya-baeri
Aythya ferina	Common Pochard	0	www.cms.int/en/species/aythya-ferina
Aythya fuligula	Tufted Duck	0	www.cms.int/en/species/aythya-fuligula
Aythya marila	Greater Scaup	0	www.cms.int/en/species/aythya-marila
Aythya nyroca	Ferruginous Duck	0	www.cms.int/en/species/aythya-nyroca
Botaurus stellaris (Botaurus stellaris stellaris)	Eurasian Bittern	0	www.cms.int/en/species/botaurus-stellaris-stellaris
Branta bernicla	Brent Goose	0	www.cms.int/en/species/branta-bernicla
Branta leucopsis	Barnacle Goose	0	www.cms.int/en/species/branta-leucopsis
Branta ruficollis	Red-breasted Goose	0	www.cms.int/en/species/branta-ruficollis
Brotogeris pyrrhoptera (Brotogeris pyrrhopterus)	Grey-Cheeked Parakeet	0	www.cms.int/en/species/brotogeris-pyrrhopterus
Bubo scandiacus	Snowy Owl	0	www.cms.int/en/species/bubo-scandiacus
Bucephala clangula	Common Goldeneye	0	www.cms.int/en/species/bucephala-clangula
Bugeranus carunculatus	Common Goldeneye	0	www.cms.int/en/species/bugeranus-carunculatus
Burhinus oedicnemus	Eurasian Thick-knee	0	www.cms.int/en/species/burhinus-oedicnemus
Butastur indicus	Grey-faced Buzzard	0	www.cms.int/en/species/butastur-indicus
Butastur rufipennis	Grasshopper Buzzard	0	www.cms.int/en/species/butastur-rufipennis
Buteo auguralis	Red-necked Buzzard	0	www.cms.int/en/species/buteo-auguralis
Buteo buteo	Eurasian Buzzard	0	www.cms.int/en/species/buteo-buteo
Buteo hemilasius	Upland Buzzard	0	www.cms.int/en/species/buteo-hemilasius
Buteo japonicus	Japanese Buzzard	0	www.cms.int/en/species/buteo-japonicus
Buteo lagopus	Rough-legged Buzzard	0	www.cms.int/en/species/buteo-lagopus
Buteo oreophilus	Mountain Buzzard	0	www.cms.int/en/species/buteo-oreophilus
Buteo rufinus	Long-legged Buzzard	0	www.cms.int/en/species/buteo-rufinus
Buteo trizonatus	Forest Buzzard	0	www.cms.int/en/species/buteo-trizonatus
Calidris alba	Sanderling	0	www.cms.int/en/species/calidris-alba
Calidris alpina	Dunlin	0	www.cms.int/en/species/calidris-alpina
Calidris canutus	Red Knot	0	www.cms.int/en/species/calidris-canutus
Calidris canutus rufa	Red Knot	0	www.cms.int/en/species/calidris-canutus-rufa
Calidris falcinellus (Limicola falcinellus)	Broad-billed Sandpiper	0	www.cms.int/en/species/limicola-falcinellus

Calidris ferruginea	Curlew Sandpiper	0	www.cms.int/en/species/calidris-ferruginea
Calidris maritima	Purple Sandpiper	0	www.cms.int/en/species/calidris-maritima
Calidris minuta	Little Stint	0	www.cms.int/en/species/calidris-minuta
Calidris pugnax (Philomachus pugnax)	Ruff	0	
Calidris pusilla	Semipalmated Sandpiper	0	www.cms.int/en/species/calidris-pusilla
Calidris pygmaea	**Spoon-billed Sandpiper**	**1**	**www.cms.int/en/species/calidris-pygmaea**
Calidris subruficollis	Buff-breasted Sandpiper	0	www.cms.int/en/species/calidris-subruficollis
Calidris temminckii	Temminck's Stint	0	www.cms.int/en/species/calidris-temminckii
Calidris tenuirostris	Great Knot	0	www.cms.int/en/species/calidris-tenuirostris
Cathartes aura	Turkey Vulture	0	www.cms.int/en/species/cathartes-aura
Cathartes burrovianus	Lesser Yellow-headed Vulture	0	www.cms.int/en/species/cathartes-burrovianus
Cathartes melambrotus	Greater Yellow-headed Vulture	0	www.cms.int/en/species/cathartes-melambrotus
Charadrius alexandrinus	**Kentish Plover**	**1**	**www.cms.int/en/species/charadrius-alexandrinus**
Charadrius asiaticus	**Caspian Plover**	**1**	**www.cms.int/en/species/charadrius-asiaticus**
Charadrius dubius	**Little Ringed Plover**	**1**	**www.cms.int/en/species/charadrius-dubius**
Charadrius forbesi	**Forbes's Plover**	**1**	**www.cms.int/en/species/charadrius-forbesi**
Charadrius hiaticula	Common Ringed Plover	0	www.cms.int/en/species/charadrius-hiaticula
Charadrius leschenaultii	Greater Sandplover	0	www.cms.int/en/species/charadrius-leschenaultii
Charadrius marginatus	White-Fronted Plover	0	www.cms.int/en/species/charadrius-marginatus
Charadrius mongolus	**Lesser Sandplover**	**1**	**www.cms.int/en/species/charadrius-mongolus**
Charadrius pallidus	Chestnut-Banded Plover	0	www.cms.int/en/species/charadrius-pallidus
Charadrius pecuarius	Kittlitz's Plover	0	www.cms.int/en/species/charadrius-pecuarius
Charadrius tricollarius (Charadrius tricollaris)	Three-Banded Plover	0	www.cms.int/en/species/charadrius-tricollaris
Chelictinia riocourii	Scissor-tailed Kite	0	www.cms.int/en/species/chelictinia-riocourii
Chionis albus (Ardea alba alba)	Snowy Sheathbill	0	www.cms.int/en/species/ardea-alba-alba
Chlamydotis macqueenii	Asian Houbara	0	www.cms.int/en/species/chlamydotis-macqueenii-0
Chlamydotis undulata	Houbara Bustard	0	www.cms.int/en/species/chlamydotis-undulata-0
Chlidonias leucopterus	White-winged Tern	0	www.cms.int/en/species/chlidonias-leucopterus
Chlidonias niger (Chlidonias niger niger)	Black Tern	0	www.cms.int/en/species/chlidonias-niger-niger
Chloephaga rubidiceps	Ruddy-headed Goose	0	www.cms.int/en/species/chloephaga-rubidiceps
Ciconia boyciana	Oriental Stork	0	www.cms.int/en/species/ciconia-boyciana

Ciconia ciconia	White Stork	0	www.cms.int/en/species/ciconia-ciconia
Ciconia microscelis	Woolly-necked Stork	0	www.cms.int/en/species/ciconia-microscelis
Ciconia nigra	Black Stork	0	www.cms.int/en/species/ciconia-nigra
Circaetus beaudouini	Beaudouin's Snake-eagle	0	www.cms.int/en/species/circaetus-beaudouini
Circaetus cinereus	Brown Snake-eagle	0	www.cms.int/en/species/circaetus-cinereus
Circaetus gallicus	Short-toed Snake-eagle	0	www.cms.int/en/species/circaetus-gallicus
Circaetus pectoralis	Black-chested Snake-eagle	0	www.cms.int/en/species/circaetus-pectoralis
Circus aeruginosus	Western Marsh-harrier	0	www.cms.int/en/species/circus-aeruginosus
Circus cyaneus	Hen Harrier	0	www.cms.int/en/species/circus-cyaneus
Circus macrourus	Pallid Harrier	0	www.cms.int/en/species/circus-macrourus
Circus maurus	Black Harrier	0	www.cms.int/en/species/circus-maurus
Circus melanoleucus (Circus melanoleucos)	Pied Harrier	0	www.cms.int/en/species/circus-melanoleucos
Circus pygargus	Montagu's Harrier	0	www.cms.int/en/species/circus-pygargus
Circus spilonotus	Eastern Marsh-harrier	0	www.cms.int/en/species/circus-spilonotus
Clanga clanga	Greater Spotted Eagle	0	www.cms.int/en/species/clanga-clanga
Clanga pomarina	Lesser Spotted Eagle	0	www.cms.int/en/species/clanga-pomarina
Clangula hyemalis	Long-tailed Duck	0	www.cms.int/en/species/clangula-hyemalis
Coracias garrulus	**European Roller**	**1**	**www.cms.int/en/species/coracias-garrulus**
Coragyps atratus	American Black Vulture	0	www.cms.int/en/species/coragyps-atratus
Coturnix coturnix (Coturnix coturnix coturnix)	Common Quail	0	www.cms.int/en/species/coturnix-coturnix-coturnix
Crex crex	Corncrake	0	www.cms.int/en/species/crex-crex
Cygnus columbianus	Tundra Swan	0	www.cms.int/en/species/cygnus-columbianus
Cygnus cygnus	Whooper Swan	0	www.cms.int/en/species/cygnus-cygnus
Cygnus olor	Mute Swan	0	www.cms.int/en/species/cygnus-olor
Dendrocygna bicolor	Fulvous Whistling-duck	0	www.cms.int/en/species/dendrocygna-bicolor
Dendrocygna viduata	White-faced Whistling-duck	0	www.cms.int/en/species/dendrocygna-viduata
Diomedea amsterdamensis	Amsterdam Albatross	0	www.cms.int/en/species/diomedea-amsterdamensis
Diomedea antipodensis	Antipodean Albatross	0	www.cms.int/en/species/diomedea-antipodensis
Diomedea dabbenena	Tristan Albatross	0	www.cms.int/en/species/diomedea-dabbenena
Diomedea epomophora	Southern Royal Albatross	0	www.cms.int/en/species/diomedea-epomophora-0
Diomedea exulans	Wandering Albatross	0	www.cms.int/en/species/diomedea-exulans-0

Diomedea sanfordi	Northern Royal Albatross	0	www.cms.int/en/species/diomedea-sanfordi
Dolichonyx oryzivorus	Bobolink	0	www.cms.int/en/species/dolichonyx-oryzivorus
Dromas ardeola	Crab-plover	0	www.cms.int/en/species/dromas-ardeola
Egretta eulophotes	Chinese Egret	0	www.cms.int/en/species/egretta-eulophotes
Egretta vinaceigula	Slaty Egret	0	www.cms.int/en/species/egretta-vinaceigula
Emberiza aureola	**Yellow-breasted Bunting**	**1**	**www.cms.int/en/species/emberiza-aureola**
Emberiza sulphurata	Yellow Bunting	0	www.cms.int/en/species/emberiza-sulphurata
Eudromias morinellus	**Eurasian Dotterel**	**1**	**www.cms.int/en/species/eudromias-morinellus**
Falco alopex	Fox Kestrel	0	www.cms.int/en/species/falco-alopex
Falco amurensis	Amur Falcon	0	www.cms.int/en/species/falco-amurensis
Falco biarmicus	Lanner Falcon	0	www.cms.int/en/species/falco-biarmicus
Falco cherrug	Saker Falcon	0	www.cms.int/en/species/falco-cherrug
Falco columbarius	Merlin	0	www.cms.int/en/species/falco-columbarius
Falco concolor	Sooty Falcon	0	www.cms.int/en/species/falco-concolor
Falco cuvierii	African Hobby	0	www.cms.int/en/species/falco-cuvierii
Falco eleonorae	Eleonora's Falcon	0	www.cms.int/en/species/falco-eleonorae
Falco naumanni	Lesser Kestrel	0	www.cms.int/en/species/falco-naumanni
Falco pelegrinoides	Barbary Falcon	0	www.cms.int/en/species/falco-pelegrinoides
Falco peregrinus	Peregrine Falcon	0	www.cms.int/en/species/falco-peregrinus
Falco rusticolus	Gyrfalcon	0	www.cms.int/en/species/falco-rusticolus
Falco severus	Oriental Hobby	0	www.cms.int/en/species/falco-severus
Falco subbuteo	Eurasian Hobby	0	www.cms.int/en/species/falco-subbuteo
Falco tinnunculus	Common Kestrel	0	www.cms.int/en/species/falco-tinnunculus
Falco vespertinus	Red-footed Falcon	0	www.cms.int/en/species/falco-vespertinus
Fregata andrewsi	Christmas Island Frigatebird	0	www.cms.int/en/species/fregata-andrewsi
Fulica atra (Fulica atra atra)	Common Coot	0	www.cms.int/en/species/fulica-atra-atra
Gallinago gallinago	Common Snipe	0	www.cms.int/en/species/gallinago-gallinago
Gallinago media	Great Snipe	0	www.cms.int/en/species/gallinago-media
Gavia adamsii	Yellow-billed Loon	0	www.cms.int/en/species/gavia-adamsii
Gavia arctica (Gavia arctica arctica)	Arctic Loon	0	www.cms.int/en/species/gavia-arctica-arctica
Gavia immer	Common Loon	0	www.cms.int/en/species/gavia-immer

Gavia stellata	Red-throated Loon	0	www.cms.int/en/species/gavia-stellata
Gelochelidon nilotica (Gelochelidon nilotica nilotica)	Common Gull-billed Tern	0	www.cms.int/en/species/gelochelidon-nilotica-nilotica
Geokichla guttata	Spotted Ground-thrush	0	www.cms.int/en/species/geokichla-guttata
Geronticus eremita	Northern Bald Ibis	0	www.cms.int/en/species/geronticus-eremita
Glareola nordmanni	**Black-winged Pratincole**	**1**	**www.cms.int/en/species/glareola-nordmanni**
Glareola nuchalis	**Rock Pratincole**	**1**	**www.cms.int/en/species/glareola-nuchalis**
Glareola pratincola	**Collared Pratincole**	**1**	**www.cms.int/en/species/glareola-pratincola**
Gorsachius goisagi	Japanese Night-heron	0	www.cms.int/en/species/gorsachius-goisagi
Grus americana	Whooping Crane	0	www.cms.int/en/species/grus-americana
Grus antigone (Antigone antigone)	Sarus Crane	0	www.cms.int/en/species/antigone-antigone
Grus canadensis (Antigone canadensis)	Sandhill Crane	0	www.cms.int/en/species/antigone-canadensis
Grus grus	Common Crane	0	www.cms.int/en/species/grus-grus
Grus japonensis	Red-crowned Crane	0	www.cms.int/en/species/grus-japonensis
Grus monacha	Hooded Crane	0	www.cms.int/en/species/grus-monacha
Grus nigricollis	Black-necked Crane	0	www.cms.int/en/species/grus-nigricollis
Grus vipio (Antigone vipio)	White-naped Crane	0	www.cms.int/en/species/antigone-vipio-0
Gymnogyps californianus	California condor	0	www.cms.int/en/species/gymnogyps-californianus
Gypaetus barbatus	Bearded Vulture	0	www.cms.int/en/species/gypaetus-barbatus
Gyps africanus	White-backed Vulture	0	www.cms.int/en/species/gyps-africanus
Gyps bengalensis	White-rumped Vulture	0	www.cms.int/en/species/gyps-bengalensis
Gyps coprotheres	Cape Vulture	0	www.cms.int/en/species/gyps-coprotheres
Gyps fulvus	Griffon Vulture	0	www.cms.int/en/species/gyps-fulvus
Gyps himalayensis	Himalayan Griffon	0	www.cms.int/en/species/gyps-himalayensis
Gyps indicus	Indian Vulture	0	www.cms.int/en/species/gyps-indicus
Gyps rueppelli	Rüppell's Vulture	0	www.cms.int/en/species/gyps-rueppelli
Gyps tenuirostris	Slender-billed Vulture	0	www.cms.int/en/species/gyps-tenuirostris
Haliaeetus albicilla	White-tailed Sea-eagle	0	www.cms.int/en/species/haliaeetus-albicilla
Haliaeetus leucoryphus	Pallas's Fish-eagle	0	www.cms.int/en/species/haliaeetus-leucoryphus
Haliaeetus pelagicus	Steller's Sea-eagle	0	www.cms.int/en/species/haliaeetus-pelagicus
Hieraaetus ayresii	Ayres's Hawk-eagle	0	www.cms.int/en/species/hieraaetus-ayresii
Hieraaetus pennatus	Booted Eagle	0	www.cms.int/en/species/hieraaetus-pennatus

Hieraaetus wahlbergi	Wahlberg's Eagle	0	www.cms.int/en/species/hieraaetus-wahlbergi
Himantopus himantopus	Black-winged Stilt	0	www.cms.int/en/species/himantopus-himantopus
Hirundo atrocaerulea	**Blue Swallow**	**1**	**www.cms.int/en/species/hirundo-atrocaerulea**
Houbaropsis bengalensis (Houbaropsis bengalensis bengalensis)	Bengal Florican	0	www.cms.int/en/species/houbaropsis-bengalensis-bengalensis
Hydroprogne caspia	Caspian Tern	0	www.cms.int/en/species/hydroprogne-caspia
Ichthyaetus leucophthalmus (Larus leucophthalmus)	White-Eyed Gull	0	www.cms.int/en/species/larus-leucophthalmus
Ixobrychus minutus (Ixobrychus minutus minutus)	Common Little Bittern	0	www.cms.int/en/species/ixobrychus-minutus-minutus
Ixobrychus sturmii	Dwarf Bittern	0	www.cms.int/en/species/ixobrychus-sturmii
Lanius excubitor excubitor	Great Grey Shrike	0	www.cms.int/en/species/lanius-excubitor-excubitor
Lanius minor	**Lesser Grey Shrike**	**1**	**www.cms.int/en/species/lanius-minor**
Larus armenicus	Armenian Gull	0	www.cms.int/en/species/larus-armenicus
Larus atlanticus	Olrog's Gull	0	www.cms.int/en/species/larus-atlanticus
Larus audouinii	Audouin's Gull	0	www.cms.int/en/species/larus-audouinii
Larus genei	Slender-billed Gull	0	www.cms.int/en/species/larus-genei
Larus hemprichii	Sooty Gull	0	www.cms.int/en/species/larus-hemprichii
Larus ichthyaetus	Pallas's Gull	0	www.cms.int/en/species/larus-ichthyaetus
Larus melanocephalus	Mediterranean Gull	0	www.cms.int/en/species/larus-melanocephalus
Larus relictus	Relict Gull	0	www.cms.int/en/species/larus-relictus
Leucogeranus leucogeranus	Siberian Crane	0	www.cms.int/en/species/leucogeranus-leucogeranus
Limosa lapponica	Bar-tailed Godwit	0	www.cms.int/en/species/limosa-lapponica
Limosa limosa	Black-tailed Godwit	0	www.cms.int/en/species/limosa-limosa
Lymnocryptes minimus	Jack Snipe	0	www.cms.int/en/species/lymnocryptes-minimus
Macronectes giganteus	Southern Giant Petrel	0	www.cms.int/en/species/macronectes-giganteus
Macronectes halli	Northern Giant Petrel	0	www.cms.int/en/species/macronectes-halli
Mareca penelope (Anas penelope)	Eurasian Wigeon	0	www.cms.int/en/species/anas-penelope
Mareca strepera (Anas strepera)	Gadwall	0	www.cms.int/en/species/anas-strepera
Marmaronetta angustirostris	Marbled Teal	0	www.cms.int/en/species/marmaronetta-angustirostris
Melanitta fusca	Velvet Scoter	0	www.cms.int/en/species/melanitta-fusca
Melanitta nigra	Common Scoter	0	www.cms.int/en/species/melanitta-nigra
Mergellus albellus	Smew	0	www.cms.int/en/species/mergellus-albellus
Mergus merganser	Goosander	0	www.cms.int/en/species/mergus-merganser

Mergus serrator	Red-breasted Merganser	0	www.cms.int/en/species/mergus-merganser
Merops apiaster	**European Bee-eater**	**1**	**www.cms.int/en/species/merops-apiaster**
Microcarbo pygmaeus	Pygmy Cormorant	0	www.cms.int/en/species/microcarbo-pygmaeus
Milvus migrans	Black Kite	0	www.cms.int/en/species/milvus-migrans
Milvus migrans lineatus (Milvus lineatus)	Black-Eared Kite	0	www.cms.int/en/species/milvus-lineatus
Milvus milvus	Red Kite	0	www.cms.int/en/species/milvus-milvus
Mycteria ibis	Yellow-billed Stork	0	www.cms.int/en/species/mycteria-ibis
Necrosyrtes monachus	Hooded Vulture	0	www.cms.int/en/species/necrosyrtes-monachus
Neophron percnopterus	Egyptian Vulture	0	www.cms.int/en/species/neophron-percnopterus
Netta erythrophthalma	Southern Pochard	0	www.cms.int/en/species/netta-erythrophthalma
Netta rufina	Red-crested Pochard	0	www.cms.int/en/species/netta-rufina
Nettapus auritus	African Pygmy-Goose	0	www.cms.int/en/species/nettapus-auritus
Ninox scutulata	Brown Boobook	0	www.cms.int/en/species/ninox-scutulata
Nisaetus nipalensis	Mountain Hawk-eagle	0	www.cms.int/en/species/nisaetus-nipalensis
Numenius arquata	Eurasian Curlew	0	www.cms.int/en/species/numenius-arquata
Numenius borealis	Eskimo Curlew	0	www.cms.int/en/species/numenius-borealis
Numenius madagascariensis	Far Eastern Curlew	0	www.cms.int/en/species/numenius-madagascariensis
Numenius phaeopus	Whimbrel	0	www.cms.int/en/species/numenius-phaeopus
Numenius tahitiensis	Bristle-thighed Curlew	0	www.cms.int/en/species/numenius-tahitiensis
Numenius tenuirostris	Slender-billed Curlew	0	www.cms.int/en/species/numenius-tenuirostris
Otis tarda	Great Bustard	0	www.cms.int/en/species/otis-tarda
Otus brucei	Pallid Scops-owl	0	www.cms.int/en/species/otus-brucei
Otus scops	Eurasian Scops-owl	0	www.cms.int/en/species/otus-scops
Otus sunia	Oriental Scops-owl	0	www.cms.int/en/species/otus-sunia
Oxyura leucocephala	White-headed Duck	0	www.cms.int/en/species/oxyura-leucocephala
Oxyura maccoa	Maccoa Duck	0	www.cms.int/en/species/oxyura-maccoa
Pandion haliaetus	Osprey	0	www.cms.int/en/species/pandion-haliaetus
Pelecanoides garnotii	Peruvian Diving-petrel	0	www.cms.int/en/species/pelecanoides-garnotii
Pelecanus crispus	Dalmatian Pelican	0	www.cms.int/en/species/pelecanus-crispus
Pelecanus onocrotalus	Great White Pelican	0	www.cms.int/en/species/pelecanus-onocrotalus
Pernis apivorus	**European Honey-buzzard**	**1**	**www.cms.int/en/species/pernis-apivorus**

Pernis ptilorhynchus	**Oriental Honey-buzzard**	**1**	**www.cms.int/en/species/pernis-ptilorhynchus**
Phalacrocorax nigrogularis	Socotra Cormorant	0	www.cms.int/en/species/phalacrocorax-nigrogularis
Phalaropus fulicaria	Grey Phalarope	0	www.cms.int/en/species/phalaropus-fulicaria
Phalaropus lobatus	Red-necked Phalarope	0	www.cms.int/en/species/phalaropus-lobatus
Phoebastria albatrus	Short-tailed Albatross	0	www.cms.int/en/species/phoebastria-albatrus
Phoebastria immutabilis	Laysan Albatross	0	www.cms.int/en/species/phoebastria-immutabilis
Phoebastria irrorata	Waved Albatross	0	www.cms.int/en/species/phoebastria-irrorata
Phoebastria nigripes	Black-footed Albatross	0	www.cms.int/en/species/phoebastria-nigripes
Phoebetria fusca	Sooty Albatross	0	www.cms.int/en/species/phoebetria-fusca
Phoebetria palpebrata	Light-mantled Albatross	0	www.cms.int/en/species/phoebetria-palpebrata
Phoenicoparrus andinus	Andean Flamingo	0	www.cms.int/en/species/phoenicoparrus-andinus
Phoenicoparrus jamesi	Puna Flamingo	0	www.cms.int/en/species/phoenicoparrus-jamesi
Phoenicopterus minor	Lesser Flamingo	0	www.cms.int/en/species/phoenicopterus-minor
Phoenicopterus ruber	American Flamingo	0	www.cms.int/en/species/phoenicopterus-ruber
Platalea alba	African Spoonbill	0	www.cms.int/en/species/platalea-alba
Platalea leucorodia	Eurasian Spoonbill	0	www.cms.int/en/species/platalea-leucorodia
Platalea minor	Black-faced Spoonbill	0	www.cms.int/en/species/platalea-minor
Plectropterus gambensis	Spur-winged Goose	0	www.cms.int/en/species/plectropterus-gambensis
Plegadis falcinellus	Glossy Ibis	0	www.cms.int/en/species/plegadis-falcinellus
Pluvialis apricaria	**Eurasian Golden Plover**	**1**	**www.cms.int/en/species/pluvialis-apricaria**
Pluvialis squatarola	Grey Plover	0	www.cms.int/en/species/pluvialis-squatarola
Podiceps auritus	Horned Grebe	0	www.cms.int/en/species/podiceps-auritus
Podiceps grisegena (Podiceps grisegena grisegena)	Red-necked Grebe	0	www.cms.int/en/species/podiceps-grisegena-grisegena
Polysticta stelleri	Steller's Eider	0	www.cms.int/en/species/polysticta-stelleri
Polystictus pectoralis (Polystictus pectoralis pectoralis)	**Bearded Tachuri**	**1**	**www.cms.int/en/species/polystictus-pectoralis-pectoralis**
Porzana porzana	Spotted Crake	0	www.cms.int/en/species/porzana-porzana
Procellaria aequinoctialis	White-chinned Petrel	0	www.cms.int/en/species/procellaria-aequinoctialis
Procellaria cinerea	Grey Petrel	0	www.cms.int/en/species/procellaria-cinerea
Procellaria conspicillata	Spectacled Petrel	0	www.cms.int/en/species/procellaria-conspicillata
Procellaria parkinsoni	Black Petrel	0	www.cms.int/en/species/procellaria-parkinsoni
Procellaria westlandica	Westland Petrel	0	www.cms.int/en/species/procellaria-westlandica

Pseudocolopteryx dinellianus	Dinelli's Doradito	0	www.cms.int/en/species/pseudocolopteryx-dinellianus
Pterodroma atrata	Henderson Petrel	0	www.cms.int/en/species/pterodroma-atrata
Pterodroma cahow	Bermuda Petrel	0	www.cms.int/en/species/pterodroma-cahow
Pterodroma phaeopygia	Galapagos Petrel	0	www.cms.int/en/species/pterodroma-phaeopygia
Pterodroma sandwichensis	Hawaiian Petrel	0	www.cms.int/en/species/pterodroma-sandwichensis
Puffinus mauretanicus	Balearic Shearwater	0	www.cms.int/en/species/puffinus-mauretanicus
Recurvirostra avosetta	Pied Avocet	0	www.cms.int/en/species/recurvirostra-avosetta
Rynchops flavirostris	African Skimmer	0	www.cms.int/en/species/rynchops-flavirostris
Sarcogyps calvus	Red-headed Vulture	0	www.cms.int/en/species/sarcogyps-calvus
Sarcoramphus papa	King vulture	0	www.cms.int/en/species/sarcoramphus-papa
Sarkidiornis melanotos	African Comb Duck	0	www.cms.int/en/species/sarkidiornis-melanotos
Sarothrura ayresi	Whitewinged Flufftail	0	www.cms.int/en/species/sarothrura-ayresi
Sarothrura boehmi	Streaky-breasted Flufftail	0	www.cms.int/en/species/sarothrura-boehmi
Saundersilarus saundersi	Saunders's Gull	0	www.cms.int/en/species/saundersilarus-saundersi
Serinus syriacus	Syrian Serin	0	www.cms.int/en/species/serinus-syriacus
Setophaga cerulea	**Cerulean Warbler**	**1**	**www.cms.int/en/species/setophaga-cerulea**
Setophaga kirtlandii	Kirtland's Warbler	0	www.cms.int/en/species/setophaga-kirtlandii
Sibirionetta formosa	Baikal Teal	0	www.cms.int/en/species/sibirionetta-formosa
Somateria mollissima	Common Eider	0	www.cms.int/en/species/somateria-mollissima
Somateria spectabilis	King Eider	0	www.cms.int/en/species/somateria-spectabilis
Spatula clypeata (Anas clypeata)	Northern Shoveler	0	www.cms.int/en/species/anas-clypeata
Spatula hottentota (Anas hottentota)	Hottentot Teal	0	www.cms.int/en/species/anas-hottentota
Spatula querquedula (Anas querquedula)	Garganey	0	www.cms.int/en/species/anas-querquedula
Spheniscus demersus	African Penguin	0	www.cms.int/en/species/spheniscus-demersus
Spheniscus humboldti	Humboldt Penguin	0	www.cms.int/en/species/spheniscus-humboldti
Sporophila cinnamomea	Chestnut Seedeater	0	www.cms.int/en/species/sporophila-cinnamomea
Sporophila hypochroma	Rufous-rumped Seedeater	0	www.cms.int/en/species/sporophila-hypochroma
Sporophila palustris	Marsh Seedeater	0	www.cms.int/en/species/sporophila-palustris
Sporophila ruficollis	Dark-throated Seedeater	0	www.cms.int/en/species/sporophila-ruficollis
Sporophila zelichi (now listed on CMS Appendices under S. palustris)	Zelich's Seedeater	0	www.cms.int/en/species/sporophila-zelichi-now-listed-cms-appendices-under-s-palustris
Sterna dougallii	Roseate Tern	0	www.cms.int/en/species/sterna-dougallii

Sterna hirundo (Sterna hirundo hirundo)	Common Tern	0	www.cms.int/en/species/sterna-hirundo-hirundo
Sterna paradisaea	Arctic Tern	0	www.cms.int/en/species/sterna-paradisaea
Sterna repressa	White-cheeked Tern	0	www.cms.int/en/species/sterna-repressa
Sternula albifrons	Little Tern	0	www.cms.int/en/species/sternula-albifrons
Sternula balaenarum	Damara Tern	0	www.cms.int/en/species/sternula-balaenarum
Sternula lorata	Peruvian Tern	0	www.cms.int/en/species/sternula-lorata
Sternula saundersi	Saunders's Tern	0	www.cms.int/en/species/sternula-saundersi
Streptopelia turtur (Streptopelia turtur turtur)	European Turtle-dove	0	www.cms.int/en/species/streptopelia-turtur-turtur
Strix nebulosa	Great Grey Owl	0	www.cms.int/en/species/strix-nebulosa
Strix uralensis	Ural Owl	0	www.cms.int/en/species/strix-uralensis
Surnia ulula	Northern Hawk-owl	0	www.cms.int/en/species/surnia-ulula
Synthliboramphus wumizusume	Japanese Murrelet	0	www.cms.int/en/species/synthliboramphus-wumizusume
Tadorna cana	South African Shelduck	0	www.cms.int/en/species/tadorna-cana
Tadorna ferruginea	Ruddy Shelduck	0	www.cms.int/en/species/tadorna-ferruginea
Tadorna tadorna	Common Shelduck	0	www.cms.int/en/species/tadorna-tadorna
Tetrax tetrax	Little Bustard	0	www.cms.int/en/species/tetrax-tetrax
Thalassarche bulleri	Buller's Albatross	0	www.cms.int/en/species/thalassarche-bulleri
Thalassarche carteri	Indian Yellow-nosed Albatross	0	www.cms.int/en/species/thalassarche-carteri
Thalassarche cauta	Shy Albatross	0	www.cms.int/en/species/thalassarche-cauta
Thalassarche chlororhynchos	Atlantic Yellow-nosed Albatross	0	www.cms.int/en/species/thalassarche-chlororhynchos
Thalassarche chrysostoma	Grey-headed Albatross	0	www.cms.int/en/species/thalassarche-chrysostoma
Thalassarche eremita	Chatham Albatross	0	www.cms.int/en/species/thalassarche-eremita
Thalassarche impavida	Campbell Albatross	0	www.cms.int/en/species/thalassarche-impavida
Thalassarche melanophris	Black-browed Albatross	0	www.cms.int/en/species/thalassarche-melanophris
Thalassarche salvini	Salvin's Albatross	0	www.cms.int/en/species/thalassarche-salvini
Thalassarche steadi	White-capped Albatross	0	www.cms.int/en/species/thalassarche-steadi
Thalasseus bengalensis	Lesser Crested Tern	0	www.cms.int/en/species/thalasseus-bengalensis
Thalasseus bergii	Greater Crested Tern	0	www.cms.int/en/species/thalasseus-bergii
Thalasseus bernsteini	Chinese Crested Tern	0	www.cms.int/en/species/thalasseus-bernsteini
Thalasseus maximus (Thalasseus maximus albididorsalis)	Royal Tern	0	www.cms.int/en/species/thalasseus-maximus-albididorsalis
Thalasseus sandvicensis (Thalasseus sandvicensis sandvicensis)	Sandwich Tern	0	www.cms.int/en/species/thalasseus-sandvicensis-sandvicensis

Thalassornis leuconotus	White-Backed Duck	0	www.cms.int/en/species/thalassornis-leuconotus
Threskiornis aethiopicus	African Sacred Ibis	0	www.cms.int/en/species/torgos-tracheliotos
Torgos tracheliotos	Lappet-faced Vulture	0	www.cms.int/en/species/torgos-tracheliotos
Trigonoceps occipitalis	White-headed Vulture	0	www.cms.int/en/species/trigonoceps-occipitalis
Tringa erythropus	Spotted Redshank	0	www.cms.int/en/species/tringa-erythropus
Tringa glareola	Wood Sandpiper	0	www.cms.int/en/species/tringa-glareola
Tringa guttifer	Spotted Greenshank	0	www.cms.int/en/species/tringa-guttifer
Tringa nebularia	Common Greenshank	0	www.cms.int/en/species/tringa-nebularia
Tringa ochropus	Green Sandpiper	0	www.cms.int/en/species/tringa-ochropus
Tringa stagnatilis	Marsh Sandpiper	0	www.cms.int/en/species/tringa-stagnatilis
Tringa totanus	Common Redshank	0	www.cms.int/en/species/tringa-totanus
Vanellus albiceps	White-Headed Lapwing	0	www.cms.int/en/species/vanellus-albiceps
Vanellus coronatus	Crowned Lapwing	0	www.cms.int/en/species/vanellus-coronatus
Vanellus gregarius	**Sociable Lapwing**	**1**	**www.cms.int/en/species/vanellus-gregarius**
Vanellus leucurus	**White-tailed Lapwing**	**1**	**www.cms.int/en/species/vanellus-leucurus**
Vanellus lugubris	**Senegal Lapwing**	**1**	**www.cms.int/en/species/vanellus-lugubris**
Vanellus melanopterus	Black-Winged Lapwing	0	www.cms.int/en/species/vanellus-melanopterus
Vanellus senegallus	Senegal Lapwing	0	www.cms.int/en/species/vanellus-senegallus
Vanellus spinosus	**Spur-winged Lapwing**	**1**	**www.cms.int/en/species/vanellus-spinosus**
Vanellus superciliosus	**Brown-chested Lapwing**	**1**	**www.cms.int/en/species/vanellus-superciliosus**
Vanellus vanellus	**Northern Lapwing**	**1**	**www.cms.int/en/species/vanellus-vanellus**
Vultur gryphus	Andean Condor	0	www.cms.int/en/species/vultur-gryphus
Xanthopsar flavus	Saffron-Cowled Blackbird	0	www.cms.int/en/species/xanthopsar-flavus
Xenus cinereus (Tringa cinerea)	**Terek Sandpiper**	**1**	**www.cms.int/en/species/tringa-cinerea**
Zapornia parva	Little Crake	0	www.cms.int/en/species/zapornia-parva
Zapornia pusilla (Zapornia pusilla intermedia)	Baillon's Crake	0	www.cms.int/en/species/zapornia-pusilla-intermedia

S2 Bats of the CMS Species List and Insectivorous Categorisation

Supplement 2 List of migratory bat species of the CMS species list (www.cms.int/en/species). Migratory insectivorous bat species are marked in bold. The assessment of insectivorous feeding of bats is based on www.iucnredlist.org (IUCN 2023b) and Facility www.gbif.org (GBIF 2023). Synonymous species names are put in parentheses.

Scientific name	English name	Report List	Further Information
Condition/Filter		*Insectivore*	
Reference	IUCN (2023b)	IUCN (2023b) GBIF (2023)	
Sum of Species		***55***	
Barbastella barbastellus	**Western Barbastelle**	**1**	**https://www.cms.int/en/species/barbastella-barbastellus**
Barbastella leucomelas	**Eastern Barbastelle**	**1**	**https://www.cms.int/en/species/barbastella-leucomelas**
Eidolon helvum	Straw-Coloured Fruit Bat	0	https://www.cms.int/en/species/eidolon-helvum
Eptesicus bottae	**Botta's Serotine**	**1**	**https://www.cms.int/en/species/eptesicus-bottae**
Eptesicus nilssonii	**Northern Bat**	**1**	**https://www.cms.int/en/species/eptesicus-nilssonii**
Eptesicus serotinus	**Serotine**	**1**	**https://www.cms.int/en/species/eptesicus-serotinus**
Hypsugo savii	**Savi's Pipistrelle Bat**	**1**	**https://www.cms.int/en/species/hypsugo-savii**
Lasiurus blossevillii	**Southern Red Bat**	**1**	**https://www.cms.int/en/species/lasiurus-blossevillii**
Lasiurus borealis	**Eastern Red Bat**	**1**	**https://www.cms.int/en/species/lasiurus-borealis**
Lasiurus cinereus	**Hoary Bat**	**1**	**https://www.cms.int/en/species/lasiurus-cinereus**
Lasiurus ega	**Southern Yellow Bat**	**1**	**https://www.cms.int/en/species/lasiurus-ega**
Miniopterus majori	**Major's Long-fingered Bat**	**1**	**https://www.cms.int/en/species/miniopterus-majori**
Miniopterus natalensis	**Natal Long-fingered Bat**	**1**	**https://www.cms.int/en/species/miniopterus-natalensis**
Miniopterus schreibersii	**Schreiber's Bent-winged Bat**	**1**	**https://www.cms.int/en/species/miniopterus-schreibersii**
Myotis alcathoe	**Alcathoe Myotis**	**1**	**https://www.cms.int/en/species/myotis-alcathoe**
Myotis aurascens	**Steppe Whiskered Bat**	**1**	**https://www.cms.int/en/species/myotis-aurascens**
Myotis bechsteinii	**Bechstein's Myotis**	**1**	**https://www.cms.int/en/species/myotis-bechsteinii**
Myotis blythii	**Lesser Mouse-eared Myotis**	**1**	**https://www.cms.int/en/species/myotis-blythii**
Myotis brandtii	**Brandt's Myotis**	**1**	**https://www.cms.int/en/species/myotis-brandtii**
Myotis capaccinii	**Long-fingered Bat**	**1**	**https://www.cms.int/en/species/myotis-capaccinii**

Myotis dasycneme	**Pond Bat**	**1**	**https://www.cms.int/en/species/myotis-dasycneme**
Myotis daubentoni	**Daubenton's Myotis**	**1**	**https://www.cms.int/en/species/myotis-daubentonii**
Myotis emarginatus	**Geoffroy's Bat**	**1**	**https://www.cms.int/en/species/myotis-emarginatus**
Myotis hajastanicus	**Armenian Whiskered Bat**	**1**	**https://www.cms.int/en/species/myotis-hajastanicus**
Myotis myotis	**Greater Mouse-eared Bat**	**1**	**https://www.cms.int/en/species/myotis-myotis**
Myotis mystacinus	**Whiskered Myotis**	**1**	**https://www.cms.int/en/species/myotis-mystacinus**
Myotis nattereri	**Natterer's Bat**	**1**	**https://www.cms.int/en/species/myotis-nattereri**
Myotis nipalensis	**Nepal Myotis**	**1**	**https://www.cms.int/en/species/myotis-nipalensis**
Myotis punicus	**Felton's Myotis**	**1**	**https://www.cms.int/en/species/myotis-punicus**
Myotis schaubi	**Schaub's Myotis**	**1**	**https://www.cms.int/en/species/myotis-schaubi**
Nyctalus lasiopterus	**Giant Noctule**	**1**	**https://www.cms.int/en/species/nyctalus-lasiopterus**
Nyctalus leisleri	**Lesser Noctule**	**1**	**https://www.cms.int/en/species/nyctalus-leisleri**
Nyctalus noctula	**Noctule**	**1**	**https://www.cms.int/en/species/nyctalus-noctula**
Otomops madagascariensis	**Madagascar Free-tailed Bat**	**1**	**https://www.cms.int/en/species/otomops-madagascariensis**
Otomops martiensseni	**Large-eared Free-tailed Bat**	**1**	**https://www.cms.int/en/species/otomops-martiensseni**
Otonycteris hemprichii	**Desert Long-eared Bat**	**1**	**https://www.cms.int/en/species/otonycteris-hemprichii**
Pipistrellus kuhlii	**Kuhl's Pipistrelle**	**1**	**https://www.cms.int/en/species/pipistrellus-kuhlii**
Pipistrellus nathusii	**Nathusius' Pipistrelle**	**1**	**https://www.cms.int/en/species/pipistrellus-nathusii**
Pipistrellus pipistrellus	**Common Pipistrelle**	**1**	**https://www.cms.int/en/species/pipistrellus-pipistrellus**
Pipistrellus pygmaeus	**Soprano pipistrelle**	**1**	**https://www.cms.int/en/species/pipistrellus-pygmaeus**
Plecotus auritus	**Brown Long-eared Bat**	**1**	**https://www.cms.int/en/species/plecotus-auritus**
Plecotus austriacus	**Grey Long-Eared Bat**	**1**	**https://www.cms.int/en/species/plecotus-austriacus**
Plecotus kolombatovici	**Kolombatovic's Long-eared Bat**	**1**	**https://www.cms.int/en/species/plecotus-kolombatovici**
Plecotus macrobullaris	**Alpine Long-eared Bat**	**1**	**https://www.cms.int/en/species/plecotus-macrobullaris**
Plecotus sardus	**Sardinian long-eared bat**	**1**	**https://www.cms.int/en/species/plecotus-sardus**
Rhinolophus blasii	**Blasius' Horseshoe Bat**	**1**	**https://www.cms.int/en/species/rhinolophus-blasii**
Rhinolophus euryale	**Mediterranean Horseshoe Bat**	**1**	**https://www.cms.int/en/species/rhinolophus-euryale**
Rhinolophus ferrumequinum	**Greater Horseshoe Bat**	**1**	**https://www.cms.int/en/species/rhinolophus-ferrumequinum**
Rhinolophus hipposideros	**Lesser Horseshoe Bat**	**1**	**https://www.cms.int/en/species/rhinolophus-hipposideros**
Rhinolophus mehelyi	**Mehely's Horseshoe Bat**	**1**	**https://www.cms.int/en/species/rhinolophus-mehelyi**
Rousettus aegyptiacus	Egyptian Fruit Bat	0	https://www.cms.int/en/species/rousettus-aegyptiacus

Tadarida brasiliensis	**Mexican free-tailed Bat**	**1**	**https://www.cms.int/en/species/tadarida-brasiliensis**
Tadarida insignis	**Oriental Free-tailed Bat**	**1**	**https://www.cms.int/en/species/tadarida-insignis**
Tadarida latouchei	**La Touche's Free-tailed Bat**	**1**	**https://www.cms.int/en/species/tadarida-latouchei**
Tadarida teniotis	**European Free-tailed Bat**	**1**	**https://www.cms.int/en/species/tadarida-teniotis**
Taphozous nudiventris	**Naked-rumped Tomb Bat**	**1**	**https://www.cms.int/en/species/taphozous-nudiventris**
Vespertilio murinus	**Particoloured Bat**	**1**	**https://www.cms.int/en/species/vespertilio-murinus**

S3 Fish of the CMS Species List and Insectivorous Categorisation

Supplement 3 List of migratory fish species of the CMS species list (www.cms.int/en/species). Migratory insectivorous fish species are marked in bold. The assessment of insectivorous feeding of fish is based on www.fishbase.se *(Froese & Pauly 2023)*. Synonymous species names are put in parentheses.

Scientific name	English name	Report List	Further Information
Condition/Filter		*Insectivore*	
Reference	CMS (2023)	Froese & Pauly (2023)	
Sum of Species		***4***	
Acipenser baerii (Acipenser baerii baicalensis)	**Siberian Sturgeon**	**1**	**www.cms.int/en/species/acipenser-baerii-baicalensis**
Acipenser fulvescens	**Lake Sturgeon**	**1**	**www.cms.int/en/species/acipenser-fulvescens**
Acipenser gueldenstaedtii	Russian Sturgeon	0	www.cms.int/en/species/acipenser-gueldenstaedtii
Acipenser medirostris	Green Sturgeon	0	www.cms.int/en/species/acipenser-medirostris
Acipenser mikadoi	Sakhalin Sturgeon	-	www.cms.int/en/species/acipenser-mikadoi
Acipenser naccarii	Adriatic Sturgeon	0	www.cms.int/en/species/acipenser-naccarii
Acipenser nudiventris	**Ship Sturgeon**	**1**	**www.cms.int/en/species/acipenser-nudiventris**
Acipenser persicus	Persian Sturgeon	0	www.cms.int/en/species/acipenser-persicus
Acipenser ruthenus	Sterlet	0	www.cms.int/en/species/acipenser-ruthenus
Acipenser schrenckii	**Amur Sturgeon**	**1**	**www.cms.int/en/species/acipenser-schrenckii**
Acipenser sinensis	Chinese Sturgeon	0	www.cms.int/en/species/acipenser-sinensis
Acipenser stellatus	Stellate Sturgeon	0	www.cms.int/en/species/acipenser-stellatus
Acipenser sturio	Common Sturgeon	0	www.cms.int/en/species/acipenser-sturio
Anguilla anguilla	European Eel	0	www.cms.int/en/species/anguilla-anguilla
Huso dauricus	Kaluga Sturgeon	0	www.cms.int/en/species/huso-dauricus
Huso huso	Giant Sturgeon	0	www.cms.int/en/species/huso-huso
Pangasianodon gigas	Giant Catfish	0	www.cms.int/en/species/pangasianodon-gigas
Psephurus gladius	Chinese Paddlefish	0	www.cms.int/en/species/psephurus-gladius
Pseudoscaphirhynchus fedtschenkoi	Syr Darya Sturgeon	-	www.cms.int/en/species/pseudoscaphirhynchus-fedtschenkoi
Pseudoscaphirhynchus hermanni	Dwarf Sturgeon	-	www.cms.int/en/species/pseudoscaphirhynchus-hermanni
Pseudoscaphirhynchus kaufmanni	Amu Darya Sturgeon	-	www.cms.int/en/species/pseudoscaphirhynchus-kaufmanni

-: Not listed in the reference.

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