Risk assessment template developed under the "Study on Invasive Alien Species – Development of risk assessments to tackle priority species and enhance prevention"
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Name of organism: *Acridotheres cristatellus* (Linnaeus, 1758)

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Risk Assessment Area: The risk assessment area is the territory of the European Union 27 and the United Kingdom, excluding the EU-outermost regions.

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[1] This template is based on the Great Britain non-native species risk assessment scheme (GBNNRA). A number of amendments have been introduced to ensure compliance with Regulation (EU) 1143/2014 on IAS and relevant legislation, including the Delegated Regulation (EU) 2018/968 of 30 April 2018, supplementing Regulation (EU) No 1143/2014 of the European Parliament and of the Council with regard to risk assessments in relation to invasive alien species (see https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32018R0968).

Contents

SECTION A – Organism Information and Screening

A1. Identify the organism. Is it clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?
including the following elements: ● the taxonomic family, order and class to which the species belongs; ● the scientific name and author of the species, as well as a list of the most common synonym names; ● names used in commerce (if any) ● a list of the most common subspecies, lower taxa, varieties, breeds or hybrids As a general rule, one risk assessment should be developed for a single species. However, there may be cases where it may be justified to develop one risk assessment covering more than one species (e.g. species belonging to the same genus with comparable or identical features and impact). It shall be clearly stated if the risk assessment covers more than one species, or if it excludes or only includes certain subspecies, lower taxa, hybrids, varieties or breeds (and if so, which subspecies, lower taxa, hybrids, varieties or breeds). Any such choice must be properly justified.

The present risk assessment covers the species crested myna (*Acridotheres cristatellus*) (Linnaeus, 1758), including the three known subspecies and any possible hybrids with the species of the same genus (see descriptions below).

Taxonomy:

Class: Aves (birds)

Order: Passeriformes (perching birds)

Family: Sturnidae (starlings) Rafinesque, 1815

Genus: *Acridotheres* Vieillot, 1816

Synonyms: *Gracula cristatellus* Linnaeus, 1758, *Aethiopsar cristatellus*

Common name (IUCN Red List): Crested myna

Other common names in English: Chinese crested myna, Chinese jungle myna, tufted myna, Chinese starling, Japanese starling. Note that myna may also be spelt 'mynah'.

Common names in other EU languages: majna chocholatá (CZ), Haubenmaina (DE), Topmaina (DK), Miná crestado, mainá crestado, mainá chino (ES), riisimaina (FI), Martin huppé (FR), Bivalymajna (HU), Maina crestata (IT), Kuifmaina (NL), majna czubata (PL), Mainá-de-crista, Mainato-de-poupa (PT), kinesisk majna (SE), škorec chochlatý (SK)

No varieties or breeds are known, while hybrids of common mynas (*Acridotheres tristis*) and crested mynas are documented both in captivity (Phillips 1898, Prestwich 1969, McCarthy 2006) and in the wild. For example, in Portugal, a photograph taken in Oeiras in 2008 showed an intermediate phenotype between common myna and crested myna, potentially representing the natural hybridization of these species in the area (Saavedra et al. 2015).

The species includes the following subspecies:

- *Acridotheres cristatellus cristatellus* (Linnaeus, 1758): This subspecies occurs in South-eastern and central China (S and SE China (S from S Shaanxi)). It has also been recorded in eastern Myanmar but its status there is currently unclear (Robson 2000).
- *Acridotheres cristatellus brevipennis* (Hartert, 1910): This subspecies occurs in Northern Indochina (C and S Laos and Vietnam, except S) and southern China (Hainan)).
- *Acridotheres cristatellus formosanus* (Hartert, 1912): This subspecies is a rare, local resident of lowland Taiwan (introduced Javan mynas (*Acridotheres javanicus*) are much more common on mainland Taiwan and commonly mistaken for crested mynas), more numerous on Kinmen (Brazil 2009).

A2. Provide information on the existence of other species that look very similar [that may be detected in the risk assessment area, either in the environment, in confinement or associated with a pathway of introduction]

Include both native and non-native species that could be confused with the species being assessed, including the following elements:

- other alien species with similar invasive characteristics, to be avoided as substitute species (in this case preparing a risk assessment for more than one species together may be considered);
- other alien species without similar invasive characteristics, potential substitute species;
- native species, potential misidentification and mis-targeting

The crested myna is a large starling-like bird (22-25 cm long), that can be confused with the common starling (*Sturnus vulgaris*), as well as other species of the genus *Acridotheres* (typical mynas), some of which have already been recorded in Europe (or are frequently kept in captivity). In addition to the common myna, that was introduced in Europe in several countries, a third similar species, the bank myna (*Acridotheres ginginianus*), was recorded in Italy and Belgium. The breeding of a pair of the bank myna in Italy was documented in 2003 (Puglisi et al. 2009), and in Zuid-Beveland in the Netherlands in 1985 (Vergeer and van Zuylen 1994). Casual records of the bank myna are known for Portugal and Spain, including in the Canary Islands (Saavedra et al. 2015), Germany (one observation in 1937 and one in 1999) (Nehring and Rabitsch 2015), the Netherlands (Vergeer and van Zuylen 1994) and several observations in Belgium at a single location in 2009 and several locations in 2016 (www.waarnemingen.be). A fourth species that could be confused with the crested myna is the jungle myna (*Acridotheres fuscus*). This species was observed in Germany in the wild in 1976 for a short period of time (Nehring and Rabitsch 2015). Other species that can be confused with crested myna are the great myna (*Acridotheres grandis*) and Javan myna. Both the great myna and the Javan myna are also known as white-vented myna, which may add some confusion to the overall species identification.

The crested myna can be distinguished from the species mentioned above through the characteristic short frontal crest and pale ivory-white bill with a reddish base (Feare and Craig 1999, Brazil 2009). Its plumage is almost entirely black, with conspicuous white wing patches and white scalloping on the vent, white corners on the rounded tail, narrow tips on its rectrices and yellow-orange legs (Feare and Craig 1999, Brazil 2009). In flight adult birds show very large white wing patches and narrow white tips to outer tail feathers. Juveniles can be confused with the great myna but the wing patch of crested myna is larger, the legs and feet are paler and duller and the undertail covers are darker. The Javan myna differs from the crested myna in being slightly smaller with a shorter crest, greyer body, larger white tail patches, narrower white wing spots and yellower bill. The crested myna (25-27 cm) is slightly smaller than a Eurasian jackdaw (*Corvus monedula*) (35-39 cm) and has prominent eyes with a characteristic dull orange iris. Young birds are duller and browner, with a blue iris and a smaller, undeveloped crest (Restall 1968). The sexes are similar. Three subspecies can be distinguished (Craig and Feare 2009):

- *Acridotheres cristatellus cristatellus* (Linnaeus, 1758)
- *Acridotheres cristatellus brevipennis* (Hartert, 1910): similar to the nominate subspecies but with narrower forehead feathers.
- *Acridotheres cristatellus formosanus* (Hartert, 1912): smaller than the nominate subspecies, with a green sheen on its crown and back, a notably longer frontal crest, sometimes broader white tips on its undertail-coverts, and a greenish-yellow bill.

A3. Does a relevant earlier risk assessment exist? Give details of any previous risk assessment, including the final scores and its validity in relation to the risk assessment area.

No specific risk assessments are known for the crested myna in Europe. However, a global assessment of the environmental impacts of the crested myna, undertaken using the Environmental Impact Classification for Alien Taxa (EICAT), classified these impacts as Minor (MN). This means that the crested myna caused a reduction in the fitness of individuals of one or more native taxa but it did not cause declines in populations of native taxa (Hawkins et al. 2015). The identified impact mechanisms were Competition and Predation, both with a Medium confidence rating (Evans et al. 2016).

An assessment of invasiveness of the crested myna was carried out in Mexico (where the species is not present): the species was categorised as being of "high" risk (CONABIO 2017).

According to the Invasive Species Pathway Risk Analysis for California (USA), the crested myna was listed among the species that could enter the country as a non-pet animal (through accidental introduction or escape from captivity), although the risk of introduction was considered "low" (Conser 2013).

In Australia, the necessity of a risk assessment is addressed by Massam et al. (2010), as the species was detected entering the region at the time.

The results of the above assessments may be of relevance to introductions to the EU (depending on the climatic conditions of the areas in the EU to which the species was introduced and/or may be introduced in the future). The Species Distribution Model (SDM) (Annex VIII) suggests that suitability for the crested myna is most strongly determined by Minimum temperature of the coldest month (Bio6) (<-15°C), Human influence index (HII) and Mean temperature of the warmest quarter (Bio10) (>15°C). These conditions are present throughout most of Europe (Annex VIII).

A4. Where is the organism native?

including the following elements:

- an indication of the continent or part of a continent, climatic zone and habitat where the species is naturally occurring
- if applicable, indicate whether the species could naturally spread into the risk assessment area

The crested myna is native to Southern China and South Eastern Asia (Brazil 2009). It is present in central and southern China (PRC), Lao People's Democratic Republic, Myanmar, Taiwan (ROC), and Vietnam. It is considered vagrant in Thailand (BirdLife International 2016). The areas where the species is native fall within the tropical (A), arid (B), temperate (C) and continental (D) climatic zones (Köppen-Geiger climate classification, Beck et al. 2018).

The crested myna naturally occurs in lowland habitats, such as open areas and plains, scrubland, rice paddies and other cultivated areas, lowland forest edges, human settlements, harbours, gardens, orchards and suburban parks (Robson 2000, Yap and Sodhi 2004, Brazil 2009, Craig and Feare 2009, Del Hoyo and Christie 2009). In general, the crested myna is known to avoid woodland (Craig and Feare 2009). However subspecies *Acridotheres cristatellus formosanus* seems to have been displaced to mountain forests by the introduced Javan myna in Taiwan (BirdForum Opus Contributors, 2020).

The crested myna is a characteristic bird of the cultivated plains and lowlands of southern China. According to Restall (1968): "It is as familiar a bird on the ploughed fields and tilled soil as rooks and black-headed gulls are in Britain". They forage in small or large flocks on agricultural land and often alongside other introduced species (Brazil 2009). After the farmer has worked the land, crested mynas gather in substantial numbers to take the spoils. They are a familiar sight on pasture land as well, where they walk about in the long grass and grab insects disturbed by the movements of the grazing animals. They can regularly be seen using the backs of cattle as perching spots, whilst also eating ticks and other parasites residing on the cattle.

A5. What is the global non-native distribution of the organism outside the risk assessment area?

The crested myna has been introduced in many countries beyond its native range in Asia, e.g. Brunei, Malaysia, Singapore, Philippines, Sabah, Japan – as well as in North, South and Central America (BirdLife International 2016, Craig and Feare 2009, Brazil 2009, Rodriguez Castaneda et al. 2017). It has also been detected entering Australia (Massam et al. 2010), although it is not considered established in the country. One unconfirmed 2018 record of crested myna in New-Zealand from the citizen science platform naturgucker.de, mentioned on GBIF, was excluded from the modelling. In Africa, the status of the crested myna, for which reports exist for South Africa and Zimbabwe, is not clear. Introduced populations probably belong to the subspecies *Acridotheres cristatellus brevipennis* (Craig and Feare 2009).

Details of the introduced populations in each country are provided below:

- Philippines: the crested myna has been present in north and central Philippines since 1849 and 1852 (Lever 2005), and in particular in Luzon, Cebu, Negros and possibly in Panay (Gonzalez 2006, Craig and Feare 2009).

- Malaysia: the crested myna was introduced in or before 1920 on Penang Island, in Peninsular Malaysia, where it was reasonably common, and Sandakan. It has been present near Kuala Lumpur but its status is unknown (Lever 2005). In addition, the crested myna was introduced in Kota Kinabalu, Likas Lagoon, Papar, Tamparuli, and Tanjung Aru, where it was considered locally common, at least since 1978 (Mann 1987, Sheldon et al. 2001) (see also Ahmad bin Darus and Stuebing 1986; Smythies 2000).
- Brunei: the crested myna was considered present in Bandar Seri Begawan from January 1983 until February 1986 (Mann 1987).
- Japan: the crested myna was introduced in Tokyo in or before 1978 (Lever 2005, Craig and Feare 2009). It was reported breeding in Tokyo, where it lives around human habitation, reed beds, riparian grasslands and grassland (Eguchi and Amano 2004b, Narusue 1981). It has also been introduced in Osaka (Craig and Feare 2020) and in urban areas of the Hyogo Prefecture, where it is rapidly increasing (Eguchi and Amano 2004a) with a total of about 100–10000 breeding pairs in Japan (BirdLife International 2016, Brazil 2009). The species was also recorded in other prefectures, e.g. Kanagawa, Kagoshima, Izumi, Osaka, Okayama and the Senkaku Islands (Lever 2005). The only breeding in eastern Japan was observed in the Kanagawa Prefecture, although it is possible that some birds were able to breed in 2019 in the Nara and Kyoto Prefectures (Takeshi Wada, pers. comm.).
- Singapore: the crested myna was introduced in St. John's Island probably in the early 1980s, where after initial success, numbers declined until it disappeared as a breeding species in 1995 (OwYong 2015, Craig and Feare 2009).
- Argentina: the crested myna has been recorded in several locations in the province of Buenos Aires (in the north and south-east) since 1982 (Chiurla 1997, Di Giácomo et al. 1993, Gimena Aguerre et al. 2008). Some populations spread and increased in numbers, and by 1995, flocks of more than 100 individuals were reported (Craig and Feare 2009, Bassó et al. 2012). Crested mynas were also recorded in other parts of the country, including in Cordoba (Robino Gómez 2011), Santa Fe (Bassó et al. 2012), and Bahía Blanca (Rodrigo 2017).
- Canada: the crested myna was introduced to the city of Vancouver in 1897 where the population was present for over a century before its extinction in 2003 (Wood 1924, Scheffer and Cottam 1935, Simberloff and Gibbons 2004, Banks et al. 2005, Johnson and Campbell 1995, Craig and Feare 2009, Long 1981, CWS 2003). This introduction was characterised by an impressive growth and spread of the population, which started with just 1-2 pairs in 1897 (Johnson and Campbell 1995), and rapidly reached an estimated number of about 20000 birds by the early 1930s spreading in British Columbia and the adjacent USA (Feare and Craig 1999, Campbell et al. 2007), with about 6000–7000 birds in Vancouver alone. The birds were concentrated in urban heat islands and selected warmer microclimates during colder periods (Campbell et al. 2007). However, after reaching its peak in 1920, the population started a gradual decline until the total numbers dropped steadily in the 1950s (only 2000–3000 individuals were left). The population further crashed with only 906 individuals in 1971 and less than one hundred between 1980 and 1985. By 2002, only 5–7 individuals were left (Guiaşu 2016). The crested myna eventually disappeared in the region in 2003 (Craig and Feare 2009, Colautti and MacIsaac 2004, Self 2003) (See also Scheffer and Cottam 1935, Ehrlich et al. 1988, Johnson and Campbell 1995, American Ornithologists' Union 1998, Feare and Craig 1999). The reasons for their decline remain largely unknown but several hypotheses illustrate the adaptability of the species and how this (sub)tropical bird was able to survive the

conditions of British Columbia. The decline has been attributed to several factors: suboptimal climate and habitat (which may have restricted mynas to a single brood annually), changes in building structures (fewer ledges and crevices), urbanization of former agricultural land where the birds fed, reduction in nest-site availability through remodelling of older homes, decrease in urban roosting sites as well as increased competition for nesting sites with common starlings (which invaded British Columbia in the early 1950s) and increased cat predation (Lever 2005, Simberloff and Gibbons 2004, Johnson and Campbell 1995, Craig and Feare 2009, Scheffer and Cottam 1935). Campbell et al. (2007) further reported the vanishing of horses from Vancouver and with them the tons of manure which provided insect food to the mynas and the better insulation of buildings causing loss of nesting sites and artificial warmth during winter. Also, the grain handling technology in the port of Vancouver became more efficient with less spillage.

- Puerto Rico: the crested myna was reported in the country but its status is uncertain (Banks et al. 2005). As a remark, the species is not mentioned in avibase in current avifauna so it is probably extinct (https://avibase.bsc-eoc.org/checklist.jsp?region=PR&list=howardmoore).
- Cuba: the crested myna (one specimen captured and kept in captivity) was found in Nueva Paz, Mayabeque Province, in 2013 (Rodriguez Castaneda et al. 2017), where it was considered vagrant but not established (Pacheco 2018, Pacheco and Mouriño 2017).
- USA: the crested myna was recorded in northwestern Washington and Portland, Oregon in 1922 (Banks et al. 2005, American Ornithologists' Union 1998, Gabrielson and Jewett 1940, Marshall et al. 2003). These were possibly escaped birds, and were considered casual. Lever (2005) mentions that occasionally, individuals have been recorded near Seattle in Washington and Oregon. In Florida, the species is considered as "present, not established" (see https://myfwc.com/wildlifehabitats/nonnatives/birds/perching-birds/). Some breeding pairs were observed in Miami-Dade County, Florida (Banks et al. 2005), but these may have been extinct by 2003 (Florida Fish and Wildlife Conservation Commission 2003).
- South Africa: a record of a preserved specimen collected in 2010 in Cape of Good Hope is available in GBIF, see https://www.discoverlife.org/mp/20l?id=GBIF241997809
- Zimbabwe: a record of a preserved specimen collected in 1928 in Mashonaland East is available in GBIF, see https://www.discoverlife.org/mp/20l?id=GBIF735628106
- United Arab Emirates: the crested myna is not considered present (Soorae 2015). However, there has probably been a breeding population in the past (Lever 2005).

A6. In which biogeographic region(s) or marine subregion(s) in the risk assessment area has the species been recorded and where is it established? The information needs be given separately for recorded (including casual or transient occurrences) and established occurrences. "Established" means the process of an alien species successfully producing viable offspring with the likelihood of continued survival[2].

A6a. Recorded: List regions

[2] Convention on Biological Diversity, Decision VI/23

A6b. Established: List regions

Freshwater / terrestrial biogeographic regions:

- Alpine, Atlantic, Black Sea, Boreal, Continental, Mediterranean, Pannonian, Steppic

Marine regions:

- Baltic Sea, North-east Atlantic Ocean, Mediterranean Sea, Black Sea

Marine subregions:

- Greater North Sea, incl. the Kattegat and the English Channel, Celtic Seas, Bay of Biscay and the Iberian Coast, Western Mediterranean Sea, Adriatic Sea, Ionian Sea, Central Mediterranean Sea, Aegean-Levantine Sea.

Comment on the sources of information on which the response is based and discuss any uncertainty in the response.

For delimitation of EU biogeographical regions please refer to https://www.eea.europa.eu/data-and-maps/figures/biogeographical-regions-in-europe-2 (see also Annex VI).

For delimitation of EU marine regions and subregions consider the Marine Strategy Framework Directive areas; please refer to https://www.eea.europa.eu/data-and-maps/data/msfd-regions-and-subregions/technical-document/pdf (see also Annex VI).

For more information on occurrences, see Qu. A8.

Response (6a): Atlantic, Continental, Mediterranean

Response (6b): Mediterranean

A7. In which biogeographic region(s) or marine subregion(s) in the risk assessment area could the species establish in the future under current climate and under foreseeable climate change? The information needs be given separately for current climate and under foreseeable climate change conditions.

A7a. Current climate: List regions

A7b. Future climate: List regions

With regard to EU biogeographic and marine (sub)regions, see above.

With regard to climate change, provide information on

- the applied timeframe (e.g. 2050/2070)
- the applied scenario (e.g. RCP 4.5)
- what aspects of climate change are most likely to affect the risk assessment (e.g. increase in average winter temperature, increase in drought periods)

The assessment does not have to include a full range of simulations on the basis of different climate change scenarios, as long as an assessment with a clear explanation of the assumptions is provided. However, if new, original models are executed for this risk assessment, the following RCP pathways shall be applied: RCP 2.6 (likely range of 0.4-1.6°C global warming increase by 2065) and RCP 4.5

(likely range of 0.9-2.0°C global warming increase by 2065). Otherwise, the choice of the assessed scenario has to be explained.

Response (7a): According to the SDM (Annex VIII), under current climate conditions, the crested myna can establish in all biogeographical regions within the risk assessment area. Sorted from highest to lowest percentage suitable area: Mediterranean (100), Pannonian (100), Black Sea (93), Continental (87), Atlantic (83) Steppic (59), Alpine (27) and Boreal (23). The percentage suitable area for the Anatolian biogeographical region, which is outside the risk assessment area, is 84%.

Response (7b): According to the SDM (Annex VIII), under climate change scenario RCP2.6, the crested myna can establish in all biogeographical regions within the risk assessment area. Sorted from highest to lowest percentage suitable area: Mediterranean (100), Pannonian (100), Black Sea (99), Continental (98), Atlantic (90), Steppic (71), Boreal (41) and Alpine (37). The percentage suitable area for the Anatolian biogeographical region, which is outside the risk assessment area, is 96%.

According to the SDM (Annex VIII), under climate change scenario RCP4.5, the crested myna can establish in all biogeographical regions within the risk assessment area. Sorted from highest to lowest percentage suitable area: Pannonian (100), Black Sea (100), Continental (99), Mediterranean (99), Atlantic (92), Steppic (76), Boreal (45) and Alpine (41). The percentage suitable area for the Anatolian biogeographical region, which is outside the risk assessment area, is 98%.

Under both climate change scenarios, most biogeographic regions are increasingly suitable for the crested myna, and establishment of this species will become more likely in the future.

A8. In which EU Member States has the species been recorded and in which EU Member States has it established? List them with an indication of the timeline of observations. The information needs be given separately for recorded and established occurrences.

A8a. Recorded: List Member States

A8b. Established: List Member States

Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden

The description of the invasion history of the species shall include information on countries invaded and an indication of the timeline of the first observations, establishment and spread.

Response (8a): Austria, Belgium, Germany, Portugal, Spain, The Netherlands

In Austria, a short-lived breeding group of crested mynas was present in Graz, from 1983 to 1991 (Lever 2005, Craig and Feare 2009). According to Kresse and Kepka (1988), the birds were former cage birds that escaped or were released. Four birds were observed in July 1983 in a residential area with fruit trees, flowers, vegetables and a park with high trees (both pine and deciduous trees). The year after, six individuals were seen, two of which made a nest in a former woodpecker hole, and by 1985, the population consisted of 9 or 10 individuals. By autumn, there were 15 birds, but the harsh winter of 1985/1986 took its toll and afterwards, only 6 individuals were seen. However, the birds managed to raise three nests and by the end of 1986, the population reached 14 again. By 1991, however, no more birds were seen in the area.

In Belgium, in addition to casual observations, some crested mynas were observed breeding (Prosperpolder, Doel) for several years (2004–2006). These birds were captured and removed in 2011 (Vermeersch et al. 2006; Bosmans 2009).

In Germany, Bauer and Woog (2008) report the crested myna as one of the non-indigenous species that are present but not breeding in the country. They do not provide any additional information.

In Portugal, crested myna has been recorded in the Lisbon metropolitan area in Corroios (Seixal) since 1997 and Oeiras since 1999 (Matias 2002). Colonies were found in Corroios and Santo Antonio da Caparica, and the species is also present in Cascais (Monticelli 2008). According to Saavedra et al. (2015), there were also records of single individuals in other areas, e.g. Evora (in 2006), Porto (in 2012), and Braga (in 2012).

In Spain there are three records of single individuals in Santander in 2004 and 2007–2008 (see record reported here: https://naturalezayavesencantabria.blogspot.com/2008/02/min-crestado-acridotheres-cristatellus.html), and one in Mallorca, Balearic Islands, in 2002 (Saavedra et al. 2015). In 2018 there was a confirmed record for crested myna in the Jardins del Real (Valencia) (see here http://grupodeavesexoticas.blogspot.com/2018/10/acridotheres-cristatellus-valencia.html) which was published on e-bird (Levatich and Ligocki 2020). So far, reproduction in Spain has not been confirmed.

In The Netherlands, between 2000 and 2021, 30 observations were reported on the citizen science platform waarneming.nl of several individual birds, including of a group of six escaped crested myna that were foraging on earthworms and apples. Some birds were wearing coloured rings (e.g. https://waarneming.nl/observation/201133251/, https://waarneming.nl/observation/207007371/) and therefore were clearly of captive origin.

Response (8b): Portugal

The species was first recorded in Portugal in 1997 (Saavedra et al. 2015). The population of mynas in Portugal is suspected to originate from accidental escapes of wild–caught birds that were traded from their native ranges to cage–bird markets until the European trade ban on wild birds in 2005 (Saavedra et al. 2015). Breeding colonies are present in Lisbon, the Setubal region and in the surroundings of the Tagus Estuary (Craig and Feare 2009, Saavedra et al. 2015), in particular in Corroios, Caparica, Cascais, Carcavelos, Oeiras, Belem, and Estoril (Monticelli 2008, Saavedra et al. 2015). The species has undergone an exponential population growth in the last decade, in the same area where the common myna occurs yet most records of crested mynas came from the surroundings of the Tagus Estuary (Saavedra et al. 2015). For example, in Corroios, the population increased from around 10 birds in 1997 to over 100 in 2002 (de Juana and Garcia 2015). In June 2011 the population was estimated at minimum 239 birds and the true population size was suspected to be larger (Saavedra et al. 2015). In 2022, the Portuguese population was estimated at a minimum of 500 birds (eBird Basic Dataset 2023). The species has been increasing in number and distribution area on both banks of the Tagus estuary. This increase is particularly clear on the southern bank, where the area has expanded by at least 3 km each year over the last decade (eBird Basic Dataset 2023).

A9. In which EU Member States could the species establish in the future under current climate

and under foreseeable climate change? The information needs be given separately for current climate and under foreseeable climate change conditions.

A9a. Current climate: List Member States

A9b. Future climate: List Member States

With regard to EU Member States, see above.

With regard to climate change, provide information on

- the applied timeframe (e.g. 2050/2070)
- the applied scenario (e.g. RCP 4.5)
- what aspects of climate change are most likely to affect the risk assessment (e.g. increase in average winter temperature, increase in drought periods)

The assessment does not have to include a full range of simulations on the basis of different climate change scenarios, as long as an assessment with a clear explanation of the assumptions is provided. However, if new, original models are executed for this risk assessment, the following RCP pathways shall be applied: RCP 2.6 (likely range of 0.4-1.6°C global warming increase by 2065) and RCP 4.5 (likely range of 0.9-2.0°C global warming increase by 2065). Otherwise, the choice of the assessed scenario has to be explained.

Response (9a): According to the SDM (Annex VIII), under current climate, the crested myna could establish in all EU Member States and in the United Kingdom (UK). Member States listed from highest to lowest percentage of suitability (indicating the proportion of grid cells in each country classified as suitable): Belgium (100), Croatia (100), Cyprus (100), Denmark (100), Germany (100), Greece (100), Hungary (100), Latvia (100), Lithuania (100), Luxembourg (100), Netherlands (100), Portugal (100), Ireland (99), Poland (99), Spain (98), Czech Rep. (96), France (96), Bulgaria (96), Slovenia (95), Estonia (94), Italy (92), Romania (92), Slovakia (91), UK (82), Austria (55), Sweden (29) and Finland (12).

Response (9b): According to the SDM (Annex VIII), under climate change scenario RCP2.6, the crested myna could establish in all EU Member States and the UK. Member States listed from highest to lowest percentage of suitability: Belgium (100), Croatia (100), Cyprus (100), Czech Rep. (100), Denmark (100), Germany (100), Greece (100), Hungary (100), Latvia (100), Lithuania (100), Luxembourg (100), Netherlands (100), Poland (100), Portugal (100), Romania (100), Slovakia (100), Slovenia (100), Bulgaria (99), Ireland (99), Spain (99), France (98), UK (98), Estonia (96), Italy (95), Austria (83), Sweden (44) and Finland (41).

According to the SDM (Annex VIII), under climate change scenario RCP4.5, the crested myna could establish in all EU Member States and the UK. Member States listed from highest to lowest percentage of suitability: Belgium (100), Bulgaria (100), Croatia (100), Czech Rep. (100), Denmark (100), Germany (100), Hungary (100), Latvia (100), Lithuania (100), Luxembourg (100), Netherlands (100), Poland (100), Portugal (100), Romania (100), Slovakia (100), Slovenia (100), UK (100), France (99), Greece (99), Ireland (99), Spain (98), Italy (97), Estonia (96), Austria (92), Cyprus (88), Sweden (47) and Finland (46).

Under both climate change scenarios, most EU Member States are increasingly suitable for the crested myna, and establishment of this species will become more likely in the future.

A10. Is the organism known to be invasive (i.e. to threaten or adversely impact upon biodiversity and related ecosystem services) anywhere outside the risk assessment area?

Most sources report crop damage and competition with native species as adverse impacts of the crested myna outside the risk assessment area (Bent 1950, Zelaya et al. 2001, Navas 2002, Eguchi and Amano 2004a).

Craig and Feare (2009) report crop damage in the Philippines and Malaysia. In its introduced range in Vancouver (Canada), the crested myna was initially considered as having an important impact to production of fruit, such as cherries, blackberries, apples and similar crops (Wood 1924), however no serious "depredations" were reported in later years (Lever 2005). A study published by Phillips (1928) noted that the population of crested mynas in Vancouver had begun to destroy a good deal of fruit, especially cherries, blackberries, and apples. In the summer, the crested mynas in that area spread out into rural districts and feed on grain in horse droppings.

The main impacts on biodiversity reported outside the risk assessment area are competition with native species for food and nesting holes, predation on a variety of species and possibly seed dispersal of invasive introduced plants (Wood 1924, Chiurla 1997, Craig and Feare 2009). Phillips (1928) describes the crested myna as pugnacious, stating that it drives away native species, attacking American robins (*Turdus migratorius*) and other birds. It also competes for nesting places with the house sparrow (*Passer domesticus*), although it seems to be able to nest in any sort of cavity in old fir and hemlock trees outside cities, wherever dead trees are left standing. See also Qu. 4.1.

In Japan, the crested myna has been observed competing for nest sites with the white-cheeked starling (*Spodiopsar cineraceus*), which has a very similar ecology and is a natural competitor (Takeshi Wada, pers. comm.).

A11. In which biogeographic region(s) or marine subregion(s) in the risk assessment area has the species shown signs of invasiveness? Indicate the area endangered by the organism as detailed as possible.

Freshwater / terrestrial biogeographic regions:

- Alpine, Atlantic, Black Sea, Boreal, Continental, Mediterranean, Pannonian, Steppic

Marine regions:

- Baltic Sea, North-east Atlantic Ocean, Mediterranean Sea, Black Sea

Marine subregions:

Greater North Sea, incl. the Kattegat and the English Channel, Celtic Seas, Bay of Biscay and the Iberian Coast, Western Mediterranean Sea, Adriatic Sea, Ionian Sea, Central Mediterranean Sea, Aegean-Levantine Sea

Response: Mediterranean

According to Saavedra et al. (2015), the crested myna has dramatically increased in numbers in Portugal during the last decade. It is now widely distributed throughout the Tagus Estuary. Given the typical lag in introduced alien bird population growth (Aagaard and Lockwood 2014), a continued growth and spread of the crested myna is expected throughout the Iberian Peninsula in the absence of appropriate management action (Saavedra et al. 2015).

Regarding its invasiveness, as reported by Saavedra et al. (2015), the crested myna has been observed acting aggressively towards several native species, from smaller species (barn swallow (*Hirundo rustica*), white wagtail (*Motacilla alba*) and house sparrow) to species of a similar size (spotless starling (*Sturnus unicolor*), Eurasian blackbird (*Turdus merula*)) and larger species (common kestrel (*Falco tinnunculus*) and yellow-legged gull (*Larus michahellis*)).

A12. In which EU Member States has the species shown signs of invasiveness? Indicate the area endangered by the organism as detailed as possible.

Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden

Response: Portugal.

See reply under Qu. A11.

A13. Describe any known socio-economic benefits of the organism.

including the following elements:

- Description of known uses for the species, including a list and description of known uses in the risk assessment area and third countries, if relevant.
- Description of social and economic benefits deriving from those uses, including a description of the environmental, social and economic relevance of each of those uses and an indication of associated beneficiaries, quantitatively and/or qualitatively depending on what information is available.

If the information available is not sufficient to provide a description of those benefits for the entire risk assessment area, qualitative data or different case studies from across the risk assessment area or third countries shall be used, if available.

No socio-economic benefits are known in the risk assessment area other than the value of the species as a cage bird and as a zoo attraction. Crested mynas are for sale online for €180 (www.marktplaats.nl), but we found no information on numbers in captivity to calculate economic relevance. Similarly, it was not possible to establish the economic relevance of the species kept in zoos and other exhibitions.

According to www.zootierliste.de *A. cristellatus* is on display in 14 exhibitions only, although not all zoological institutions are listed on this website. In the private sector, the crested myna is not frequently distributed. The offspring statistics of the German society AZ Vogelzucht lists one breeding pair for the years 2004, 2008 and 2016 and between 1 and 3 offspring for these years on their webpage. In another German Society dedicated to the husbandry and protection of birds (VDW), three offspring were listed for 2019 but zero offspring for the previous years (BNA, pers. comm. to the Commission, 2022).

As frugivores, crested mynas can also disperse seeds of native plants, as has been reported in the closely related common myna (Clout and Hay 1989), but details on this regard are not available for crested mynas.

There are other possible socio-economic benefits known outside the risk assessment area that might become relevant in the future in the risk assessment area. For example, it may have an aesthetic appeal for bird-watchers and members of the wider general public.

SECTION B – Detailed assessment

Important instructions:
• In the case of lack of information the assessors are requested to use a standardized answer: "No information has been found." • With regard to the scoring of the likelihood of events or the magnitude of impacts see Annexes I and II. • With regard to the confidence levels, see Annex III. • Highlight the selected response score and confidence level in **bold** but keep the other scores in normal text (so that the selected score is evident in the final document).

1 PROBABILITY OF INTRODUCTION AND ENTRY

Important instructions:
• **Introduction** is the movement of the species into the risk assessment area (it may be either in captive conditions and/or in the environment, depending on the relevant pathways). • **Entry** is the release/escape/arrival in the environment, i.e. occurrence in the wild • Introduction and entry may coincide for species entering through pathways such as "corridor" or "unaided", but it also may differ. If different, please consider all relevant pathways, both for the introduction into the risk assessment area and the entry in the environment. • The classification of pathways developed by the Convention of Biological Diversity (CBD) should be used (see Annex IV). For detailed explanations of the CBD pathway classification scheme consult the IUCN/CEH guidance document[3] and the provided key to pathways[4]. • For organisms which are already present (recorded or established) in the risk assessment area, the likelihood of introduction and entry should be scored as "very likely" by default. • Repeated (independent) introductions and entries at separate locations in the risk assessment area should be considered here (see Qu. 1.7).

Qu. 1.1. List relevant pathways through which the organism could be introduced into the risk assessment area and/or enter into the environment. Where possible give details about the specific origins and end points of the pathways as well as a description of any associated commodities.
For each pathway answer questions 1.2 to 1.7 (copy and paste additional rows at the end of this section as necessary). Please attribute unique identifiers to each question if you consider more than one pathway, e.g. 1.2a, 1.3a, etc. and then 1.2b, 1.3b etc. for the next pathway.   In this context a pathway is the route or mechanism of introduction and/or entry of the species.   The description of commodities with which the introduction of the species is generally associated shall include a list and description of commodities with an indication of associated risks (e.g. the volume of

[3] https://circabc.europa.eu/sd/a/738e82a8-f0a6-47c6-8f3b-aeddb535b83b/TSSR-2016-010%20CBD%20categories%20on%20pathways%20Final.pdf
[4] https://circabc.europa.eu/sd/a/0aeba7f1-c8c2-45a1-9ba3-bcb91a9f039d/TSSR-2016-010%20CBD%20pathways%20key%20full%20only.pdf

trade; the likelihood of a commodity being contaminated or acting as vector).

If there are no active pathways or potential future pathways this should be stated explicitly here, and there is no need to answer the questions 1.2-1.9.

Pathways:

- Pet/aquarium/terrarium species (escape from confinement)
- Botanical garden/zoo/aquaria (escape from confinement)
- Biological control (release in nature)
- Other means of transport (transport stowaway)
- Natural dispersal (unaided)

According to Feare and Craig (1999), established alien populations of crested mynas probably resulted from birds that escaped or were deliberately released from captivity. This is likely to have been the case in the Philippines (Gonzalez 2006), Malaysia (Jeyarajasingam and Pearson 2012), Japan (Eguchi and Amano 2004a), the USA (Florida) (Banks et al. 2005) and Argentina (Bassó et al. 2012). The crested myna was also introduced to Portugal and Spain, possibly as a result of accidental escapes of captive birds en-route to cage-bird markets in other countries (Saavedra et al. 2015, Craig and Feare 2009). In Argentina, the crested mynas observed several times free in the Cordoba Zoo were considered as escapes from this facility (Robino Gómez 2011).

In several countries beyond the risk assessment area, the crested myna has been introduced intentionally as a biological control agent. For example, in the Philippines and Malaysia, it was introduced between 1849 and 1852 to control migratory locusts (Lever 2005, Yap and Sodhi 2004, Gonzalez 2006, Wood 1924, Bartlett and Clausen 1978). However, this pathway is not considered active in the EU and is not further discussed in this risk assessment.

According to Lever (2005), the introduction of the species in Vancouver, Canada, was possibly a consequence of "birds escaped from some ship touching at this port". However, it seems unlikely that these individuals were transport stowaways, but rather were destined for trade as caged birds (Scheffer and Cottam 1935).

In Japan, the presence of the crested myna on the Sakishima Islands may be the result of natural dispersion from Taiwan, although it is possible that these populations originate from deliberately released or escaped cage birds, as is the case in the rest of Japan (Lever 2005, see also https://www.nies.go.jp/biodiversity/invasive/DB/detail/20370e.html).

Of the pathways listed above, the main pathway for the crested myna is the "pet/aquarium/terrarium species (escape from confinement)". Another pathway considered in this RA is "botanical garden/zoo/aquaria (escape from confinement)". As no specific introductions were documented in the EU in relation to biological control, transport stowaways or natural dispersal, these pathways are not considered active for the time being or for the near future, and are not considered in this risk assessment. This is considered valid for the risk of introduction/entry, but see difference with the spread section.

(a) PATHWAY: Pet/aquarium/terrarium species (escape from confinement)

Qu. 1.2a. Is introduction and/or entry along this pathway intentional (e.g. the organism is imported for trade) or unintentional (e.g. the organism is a contaminant of imported goods)?

RESPONSE	**intentional** unintentional	**CONFIDENCE**	low medium **high**

The crested myna is imported for the pet trade and as such the introduction pathway is intentional. The entry into the environment can be either intentional or unintentional, depending on whether it is the result of deliberate releases or accidental escapes.

Qu. 1.3a. How likely is it that large numbers of the organism will be introduced and/or enter into the environment through this pathway from the point(s) of origin over the course of one year?

including the following elements:

- discuss how likely the organism is to get onto the pathway in the first place. Also comment on the volume of movement along this pathway.
- an indication of the propagule pressure (e.g. estimated volume or number of individuals / propagules, or frequency of passage through pathway), including the likelihood of reinvasion after eradication
- if relevant, comment on the likelihood of introduction and/or entry based on propagule pressure (i.e. for some species low propagule pressure (1-2 individuals) could result in subsequent establishment whereas for others high propagule pressure (many thousands of individuals) may not.

RESPONSE	very unlikely unlikely **moderately likely** likely very likely	**CONFIDENCE**	low **medium** high

The crested myna is a popular cage bird in its native range (Yap and Sodhi 2004), mainly due to its ability to mimic and imitate the human voice (Johnson and Campbell 1995, Feare and Craig 1999). For this reason, birds are still caught in the wild and kept as pets, both in their native and introduced range, e.g. in the Philippines (Gonzalez 2006, van den Top G. 2004). Large numbers of the crested myna are thus moved between countries through the international bird trade (Wai 2006). It has been a popular cage bird among Japanese and Chinese inhabitants in the USA since the 1920s (Wood 1924), and is still occasionally found in bird stores today. From 1968 until 1980, it was imported to the USA in low to moderate numbers (0–563 annually), becoming increasingly common in later years (Rodriguez Castaneda et al. 2017, Banks 1970, Banks and Clapp 1972, Clapp and Banks 1973a, 1973b, Clapp 1975, Nilsson 1981).

Also in the risk assessment area, the crested myna is a popular cage bird. As an example, on a Dutch website (https://www.marktplaats.nl/l/dieren-en-toebehoren/vogels-overige-vogels/q/kuifmaina/) that does not even specialize in selling birds, four individual crested mynas were listed for sale in May 2020. Also, a pair of crested mynas was found on sale in August 2022 on a peer-to-peer platforms in Italy (https://www.subito.it/animali/maina-crestata-cinese-trapani-440603079.htm).

Therefore, it is considered very likely that the crested myna could be introduced through this pathway. Given that in one month, on only one website, in one country within the risk assessment area, four birds were listed for sale, there are clues that the actual volume of crested mynas introduced into the risk assessment area may be significant. Even if the birds would be eradicated after introduction to the wild, chances are high that new birds would enter again, given that the number of pet birds present in the risk assessment area remains equally high.

As a remark, it is important to consider that the EU adopted a ban on the importation of wild birds in response to avian influenza in October 2005 which was then made permanent from July 2007 (Commission Regulation (EC) No 318/2007). This has had an impact on the risk of introduction of invasive birds by shifting the trade to captive-bred birds, which have lower invasive potential than wild-caught birds (Cardador et al. 2019) but despite this, crested mynas are still present in trade. It should also be noted that should this ban, issued under sanitary legislative regimes, be lifted, the situation would probably return to pre-ban levels (also, note that some individuals recorded on bird observation platforms do not have closed rings, so looks like there may still be breeding and keeping outside of the official circuits).

When it comes to propagule pressure, it seems that a very small number of birds is sufficient to establish a new population. This was likely the case of the populations in Portugal, where the population in Corroios increased from around 10 birds in 1997 to over 100 in 2002 (de Juana and Garcia 2015; Saavedra et al. 2015), see also Qu. A8b. The most striking example is the invasion in Vancouver, Canada, where the introduction of only one or two pairs in 1897 resulted in some 20000 birds in the early 1930s (spreading from British Columbia to the adjacent USA, as far south as northwestern Washington and possibly to Oregon). For more information on the course of the Vancouver population and its subsequent decline, see Qu. A5.

Therefore, at present, it is still very likely that large numbers (enough to lead to the risk of new populations getting established) will be introduced into the risk assessment area through this pathway, but less so that large numbers will escape or will be deliberately released, hence we score moderately likely. No information was found on any illegal trade of the species.

Qu. 1.4a. How likely is the organism to survive, reproduce, or increase during transport and storage along the pathway (excluding management practices that would kill the organism)?

RESPONSE	very unlikely unlikely moderately likely **likely** very likely	**CONFIDENCE**	**low** medium high

Despite the lack of figures on number of birds traded, it is possible to assume that the intention of pet shop dealers is to bring live animals with the aim to keep them and make them reproduce in captivity. Likewise, in the case of exchange/trade between hobbyists, their intention is to keep the birds alive and well during transport to deliver them, so survival is likely. Moreover, reproduction is possible also while the species is kept as a cage bird by amateurs. Since no official records are available on this matter, confidence is low. No information was found on any illegal trade of the species.

Qu. 1.5a. How likely is the organism to survive existing management practices before and during transport and storage along the pathway?

RESPONSE	very unlikely unlikely moderately likely likely **very likely**	**CONFIDENCE**	**low** medium high

There are no management practices along this pathway that may represent a threat for the species, as the purpose is to keep them alive both during transport by pet shop dealers, and while kept as a cage bird by pet amateurs. No information was found on any illegal trade of the species.

Qu. 1.6a. How likely is the organism to be introduced into the risk assessment area or entry into the environment undetected?

RESPONSE	very unlikely **unlikely** moderately likely likely very likely	**CONFIDENCE**	low **medium** high

Undetected introduction into the risk assessment area along the pet pathway is unlikely. The species is a popular cage bird and is imported intentionally, including through sale on several websites (see Qu. 1.3a).

Regarding the entry into the environment, after escape/release events from confinement, it is also unlikely that the bird will remain undetected, as it is quite vocal and former pet birds will likely not be afraid of humans. Restall (1968) notes that in its native range, the crested myna can frequently be seen walking around villages and back doorsteps, even though it is a wary and shy bird, much like the house sparrow. It can be easily detected by the widespread community of bird watchers and wildlife amateurs, particularly with the increased popularity of citizen science initiatives in EU countries. In addition, crested mynas gather by night to roost, singing and whistling loudly, further increasing their chance of being detected (Chébez and Rodriguez 2013).

Qu. 1.7a. How isolated or widespread are possible points of introduction and/or entry into the environment in the risk assessment area?

RESPONSE	isolated **widespread** ubiquitous	**CONFIDENCE**	low medium **high**

As the crested myna is kept by bird enthusiasts all over Europe, possible points of introduction and subsequent entry are widespread. This is supported by the fact that the crested myna has already escaped (or been deliberately released) in some EU Member States possibly as a consequence of the pet trade (see Qu. A8, Qu.1.1 and Qu.1.3a).

Qu. 1.8a. Estimate the overall likelihood of introduction into the risk assessment area and/or entry into the environment based on this pathway?

RESPONSE	very unlikely unlikely moderately likely likely **very likely**	**CONFIDENCE**	low **medium** high

Even though it is difficult to determine whether introduced crested mynas have escaped or have been deliberately released, it is very likely that the introduction of birds kept as pets has occurred in the past, as documented in many countries around the world, including countries within the risk assessment area (see Qu A8). Based on the incidences of escapes / deliberate releases in the past, it is very likely that escapes / releases of crested mynas will continue to occur in the risk assessment area.

The crested myna is relatively valuable: for example, on a Dutch website it is offered for sale for €180 (www.marktplaats.nl). This may suggest that traders are more likely to sell crested mynas rather than release them if they no longer want to keep them. However, it is not possible to rule-out that some people will want to give crested mynas their freedom, as has been documented for many cage birds in general.

(b) PATHWAY: Botanical garden / zoo / aquaria (escape from confinement)

Qu. 1.2b. Is introduction and/or entry along this pathway intentional (e.g. the organism is imported for trade) or unintentional (e.g. the organism is a contaminant of imported goods)?

RESPONSE	**intentional** unintentional	**CONFIDENCE**	low medium **high**

The crested myna is introduced to be exhibited in a zoological collection, and as such the pathway is intentional. The entry into the environment can be either intentional or unintentional, depending on whether it is the result of a deliberate release or accidental escape (but the risk of intentional release is considered negligible).

Qu. 1.3b. How likely is it that large numbers of the organism will be introduced and/or enter into the environment through this pathway from the point(s) of origin over the course of one year? including the following elements: ● discuss how likely the organism is to get onto the pathway in the first place. Also comment on the volume of movement along this pathway. ● an indication of the propagule pressure (e.g. estimated volume or number of individuals / propagules, or frequency of passage through pathway), including the likelihood of reinvasion after eradication ● if relevant, comment on the likelihood of introduction and/or entry based on propagule pressure (i.e. for some species low propagule pressure (1-2 individuals) could result in subsequent establishment whereas for others high propagule pressure (many thousands of individuals) may not.

RESPONSE	very unlikely **unlikely** moderately likely likely very likely	**CONFIDENCE**	**low** medium high

According to the EAZA inventory of European zoos and public collections (http://www.zootierliste.de/), the crested myna is currently on display in several zoos in the risk assessment area, including the Czech Republic (three zoos), France (one), Germany (four), the Netherlands (three) and Sweden (two). This list comprises just a quarter of all zoological gardens and animal parks in Europe (www.zoos.media): there may be more crested mynas on public display elsewhere. However, reliable records may be available only for EAZA associated zoos (which are also those with high standards for biosecurity) because no registers are known for all other zoological collections in similar facilities. Therefore, it is difficult to assess to what extent the species is kept in captivity within the risk assessment area. Detailed information on the number of crested mynas that are imported to be kept in zoos is unavailable, but it is expected to be very low. Similarly, reliable data on the number of crested mynas that have escaped from zoos is generally lacking, but based on the lack of documented evidence the risk is considered very low. The risk of intentional release from zoos is considered negligible.

Therefore, it is considered unlikely that large numbers of individual crested mynas will be introduced via zoos and subsequently enter the environment by escaping from zoos within the Risk assessment area.

Qu. 1.4b. How likely is the organism to survive, reproduce, or increase during transport and

storage along the pathway (excluding management practices that would kill the organism)?

RESPONSE	very unlikely unlikely moderately likely **likely** very likely	CONFIDENCE	**low** medium high

Despite the lack of definitive figures on numbers of birds kept in zoos and/or escaped/released through this pathway, we can reasonably assume that the intention of zoos and bird keepers is to keep live animals and, if possible and appropriate, encourage them to breed in captivity. Since no official records are available on this matter, confidence is low.

Reproduction along this pathway will only be possible if two or more individuals are kept at the same time and place. It is reasonable to expect that zoos will generally keep their birds in pairs, so we consider it likely that the animals will survive and reproduce along this pathway.

Qu. 1.5b. How likely is the organism to survive existing management practices before and during transport and storage along the pathway?

RESPONSE	very unlikely unlikely moderately likely likely **very likely**	CONFIDENCE	low medium **high**

There are no management practices along this pathway that may represent a threat for the species, as the purpose is to keep them alive (and possibly to encourage them to breed).

Qu. 1.6b. How likely is the organism to be introduced into the risk assessment area or entry into the environment undetected?

RESPONSE	very unlikely **unlikely** moderately likely likely very likely	CONFIDENCE	low **medium** high

Undetected introduction into the risk assessment area along the zoo pathway is unlikely. The species is imported intentionally with the objective to be housed in collections and any missing escaped or released birds would probably be noticed (see Qu. 1.3a). After escape/release events from confinement, it is also unlikely that the bird will remain undetected, because of its specific behavioural and morphological features (See Qu. 1.6a).

Qu. 1.7b. How isolated or widespread are possible points of introduction and/or entry into the environment in the risk assessment area?

RESPONSE	isolated **widespread** ubiquitous	**CONFIDENCE**	low **medium** high

The crested myna is kept in several zoos spread across the risk assessment area, including the Czech Republic, France, Germany, the Netherlands and Sweden. As not all zoos are included in this list, there are probably more crested mynas being exhibited elsewhere. Possible points of introduction and/or entry into the environment through this pathway are therefore widespread.

Qu. 1.8b. Estimate the overall likelihood of introduction into the risk assessment area and/or entry into the environment based on this pathway?

RESPONSE	very unlikely **unlikely** moderately likely likely very likely	**CONFIDENCE**	**low** medium high

Even though the crested myna would easily find suitable environmental conditions after escape, the total number of birds currently present in zoos in the risk assessment area seems very low. Therefore the risk of the species being introduced in the risk assessment area and/or entering the environment, is unlikely.

Qu. 1.9. Estimate the overall likelihood of introduction into the risk assessment area or entry into the environment based on all pathways and specify if different in relevant biogeographical regions in current conditions. Provide a thorough assessment of the risk of introduction in relevant biogeographical regions in current conditions: providing insight into the risk of introduction into the risk assessment area.

RESPONSE	very unlikely unlikely moderately likely	**CONFIDENCE**	low medium **high**

	likely **very likely**		

The crested myna is a very popular cage bird and is probably kept throughout Europe in households. Moreover, release/escape events linked to the pathway category "pet/aquarium/terrarium species (escape from confinement)" have already occurred within the risk assessment area, as documented in Austria, Belgium, Germany, Portugal and Spain. In addition, according to the SDM (Annex VIII), suitable habitat / climatic conditions occur throughout the risk assessment area, in all of its biogeographical regions and in all countries. Therefore, even though the contribution of the other pathway ("botanical garden / zoo / aquaria (escape from confinement)") is likely to be lower, we consider it very likely that the crested myna will be introduced and enter into the risk assessment area in the future.

Qu. 1.10. Estimate the overall likelihood of introduction into the risk assessment area or entry into the environment based on all pathways in foreseeable climate change conditions?

Thorough assessment of the risk of introduction in relevant biogeographical regions in foreseeable climate change conditions: explaining how foreseeable climate change conditions will influence this risk.

With regard to climate change, provide information on

- the applied timeframe (e.g. 2050/2070)
- the applied scenario (e.g. RCP 4.5)
- what aspects of climate change are most likely to affect the likelihood of introduction (e.g. change in trade or user preferences)

The thorough assessment does not have to include a full range of simulations on the basis of different climate change scenarios, as long as an assessment of likely introduction within a medium timeframe scenario (e.g. 30-50 years) with a clear explanation of the assumptions is provided. However, if new, original models are executed for this risk assessment, the following RCP pathways shall be applied: RCP 2.6 (likely range of 0.4-1.6°C global warming increase by 2065) and RCP 4.5 (likely range of 0.9-2.0°C global warming increase by 2065). Otherwise, the choice of the assessed scenario has to be explained.

RESPONSE	very unlikely unlikely moderately likely likely **very likely**	**CONFIDENCE**	low medium **high**

The crested myna is a very popular cage bird and is probably kept as a pet throughout Europe. This is not expected to change as a result of future climate change. Release/escape events have already occurred within the risk assessment area and this is also not expected to change either as a result of future climate change.

In addition, according to the SDM (Annex VIII), there will be more environmentally suitable areas throughout the risk assessment area, in all of its biogeographical regions and in all countries, under both RCP2.6 and RCP4.5. Under RCP2.6, it is predicted that all regions will have a stable or increased habitat suitability for the crested myna. Under RCP4.5, the Mediterranean biogeographical region will become slightly less suitable (-0.01) for the crested myna.

Therefore, we consider it very likely that the crested myna will be introduced and enter into the risk assessment area in the future.

2 PROBABILITY OF ESTABLISHMENT

Important instructions:
● For organisms which are already established in parts of the risk assessment area or have previously been eradicated, the likelihood of establishment should be scored as "very likely" by default. ● Discuss the risk also for those parts of the risk assessment area, where the species is not yet established.

Qu. 2.1. How likely is it that the organism will be able to establish in the risk assessment area based on similarity of climatic and abiotic conditions in its distribution elsewhere in the world?

RESPONSE	very unlikely unlikely moderately likely likely **very likely**	**CONFIDENCE**	low medium **high**

The crested myna is already established in the risk assessment area in Portugal and there have been instances of breeding in other Member States. The climatic and biotic conditions occurring in the risk assessment area are compatible with the species requirements shown elsewhere in the world. This is supported by the results of the SDM (Annex VIII), which shows all countries and all biogeographical regions within the risk assessment area to be potentially at risk for establishment of the crested myna.

For most of the risk assessment area, the mean temperature of the warmest quarter (BIO10) is the most limiting factor for successful establishment. The model indicates BIO10 accounts for 25.9% of the variation with establishment potential increasing from a mean temperature of the warmest quarter of about 10°C (Annex VIII, figure 6). In some southern parts of the Mediterranean, the Climatic Moisture Index (CMI) or minimum temperature of the coldest month (BIO6) are more important. BIO6 is also the limiting factor in many northern parts of Finland, Norway and Sweden, as is the Human Influence Index (HII). The crested myna thrives in man-made environments, and the low HII in the remote north of Scandinavia makes this region less suitable for the species (Annex VIII, figure 6).

Qu. 2.2. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in the risk assessment area? Consider if the organism specifically requires another species to complete its life cycle.

RESPONSE	very isolated isolated moderately widespread **widespread** ubiquitous	**CONFIDENCE**	low medium **high**

Habitats occupied by the crested myna, as described under Qu. A4, are widespread in the risk assessment area (e.g. lowland habitats, such as open areas and plains, scrubland, rice paddies and other cultivated areas, lowland forest edges, human settlements, harbours, gardens, orchards and suburban parks).

No specific organisms are required by the crested myna to complete its life cycle. A stomach content analysis performed by Scheffer and Cottam (1935) suggests that the crested myna is a diet generalist, and can adapt to rapidly changing conditions. The number of different food items identified varied by month from 4.89 in July to 20.5 in November (average 11.5 per month). In months when few wild fruits, seeds or insects were available, the birds fed on garbage. This ecological flexibility enables the species to survive in a range of urban and agricultural environments.

Qu. 2.3. How likely is it that establishment will occur despite competition from existing species in the risk assessment area?

RESPONSE	very unlikely unlikely moderately likely likely **very likely**	**CONFIDENCE**	low medium **high**

The crested myna is an aggressive species and not easily outcompeted by other species (Saavedra et al. 2015). It can be compared to the common starling, another hardy, resourceful and omnivorous bird with a high degree of intelligence. In fact the common starling is likely to be a main competitor for the crested myna. Other native species that could limit establishment and spread of the crested myna include species of crow, magpies and gulls. However, in its native range, the crested myna consorts with rooks, jackdaws and common starlings, and even roosts with common starlings, especially in autumn and winter (Restall 1968). Therefore, common starlings are not expected to represent a major constraint to the establishment of crested mynas.

In Portugal, the species does not seem to be affected by competition from native species. In the Tagus Estuary, crested mynas have been observed aggressively interacting with small, medium and large birds including barn swallow, white wagtail, house sparrow, spotless starling, Eurasian blackbird, common kestrel and yellow-legged gull (Saavedra et al. 2015) .

However, it should be noted that in Canada, one of the factors contributing to the decline of this species (after being successfully established for over a century), was increased competition for nesting sites with common starlings, which invaded British Columbia in the early 1950s (Lever 2005, Simberloff and Gibbons 2004, Johnson and Campbell 1995, Craig and Feare 2009, Scheffer and Cottam 1935).

Qu. 2.4. How likely is it that establishment will occur despite predators, parasites or pathogens already present in the risk assessment area?

RESPONSE	N/A very unlikely unlikely moderately likely likely **very likely**	CONFIDENCE	low medium **high**

Despite naturally occurring predators, establishment has occurred in numerous countries outside and inside the risk assessment area (see Qu. A5 and A8).

Cats are present in large numbers in the risk assessment area and are a threat to many bird species: the crested myna would most-likely suffer from cat predation (Woods et al. 2003). Indeed, cat predation is believed to have contributed to the decline of the non-native population of the crested myna in Vancouver (Lever 2005, Simberloff and Gibbons 2004, Johnson and Campbell 1995, Craig and Feare 2009, Scheffer and Cottam 1935).

Given the high density of cats in some areas where the crested myna would establish, they may be a limiting factor in the establishment success of the crested myna. Nevertheless, this bird has successfully established in several areas around the world, including Portugal, where cat predation is high (Oliveira et al. 2008).

No information on specific pathogens and parasites which may affect the species establishment was found.

Qu. 2.5. How likely is the organism to establish despite existing management practices in the risk assessment area? Explain if existing management practices could facilitate establishment.

RESPONSE	very unlikely unlikely moderately likely likely **very likely**	CONFIDENCE	low medium **high**

In the risk assessment area, management practices may assist species establishment. The species persists in agricultural environments (for example, in Vancouver, the species fed on grain in horse dung (Campbell et al. 2007)) and is also likely to benefit from bird feeding in gardens. The presence of humans and human-influenced landscapes can therefore be expected to increase survival and establishment of the crested myna. This is corroborated by the SDM which shows the human influence index (HII) to be the second most important factor determining suitability for the species (accounting for 27% of the variation on the model (Annex VIII)).

Qu. 2.6. How likely is it that biological properties of the organism would allow it to survive

eradication campaigns in the risk assessment area?

RESPONSE	very unlikely unlikely **moderately likely** likely very likely	**CONFIDENCE**	**low** medium high

Eradication campaigns have proven to be highly effective when populations are still small (<50 individuals) (Saavedra et al. 2015). However, as the crested myna has an inquisitive nature (which is one of the reasons why it is such a popular pet bird), it is moderately likely that the bird could survive such eradication campaigns (e.g. shooting, netting, traps). It is also worth considering that as reported in Portugal, the crested myna is a largely urban bird and all nest/roost sites found during a brief visit to the Lisbon area in 2008 (Feare and Saavedra, pers. obs.) were in holes in the walls of buildings. In some cases, birds could be removed at times of day when few people were around, but in general their eradication would be likely to attract a lot of attention, and generate possible conflicts with the general public. In these situations it is certainly likely that birds could survive eradication attempts (Chris Feare, pers. comm. 2020). A recent eradication feasibility study categorized crested myna as medium priority for eradication in Europe (Booy et al. 2020).

Qu. 2.7. How likely are the biological characteristics of the organism to facilitate its establishment in the risk assessment area? including the following elements: ● a list and description of the reproduction mechanisms of the species in relation to the environmental conditions in the risk assessment area ● an indication of the propagule pressure of the species (e.g. number of gametes, seeds, eggs or propagules, number of reproductive cycles per year) of each of those reproduction mechanisms in relation to the environmental conditions in the risk assessment area. ● If relevant, comment on the likelihood of establishment based on propagule pressure (i.e. for some species low propagule pressure (1-2 individuals) could result in establishment whereas for others high propagule pressure (many thousands of individuals) may not. ● If relevant, comment on the adaptability of the organism to facilitate its establishment and if low genetic diversity in the founder population would have an influence on establishment.

RESPONSE	very unlikely unlikely moderately likely **likely** very likely	**CONFIDENCE**	low medium **high**

Several species characteristics have been linked to invasion success in birds (Sol et al. 2002; Cassey et al. 2004) and the crested myna has several of those. First, ecologically, the species is a habitat generalist and shows ecological flexibility, a tendency to discover unoccupied habitats and an ability to shift habitat preferences. Both in its native and invaded range the crested myna is reported to inhabit a wide range of different habitats, including open areas and plains, scrubland, rice paddies and other cultivated areas, lowland forest edges, human settlements, harbours, gardens, orchards, suburban parks (see Qu. A4). It is also flexible in its choice of nesting places. Nests can be made in natural holes in trees or rock faces, but also in disused nests of other birds (e.g. kingfishers (*Coraciiform spp.*), common magpie (*Pica pica*) or black-collared starling (*Gracupica nigricollis*)), as well as holes in man-made structures and nest boxes (Craig and Feare, 2009). In Portugal, nests are found in buildings, limestone cliffs in peri-urban areas (Saavedra et al. 2015), and in holes in *Platanus* or palm trees (eBird Basic Dataset 2023: checklists S37427510 and S37442702). In the Philippines, crevices on buildings and palm fronds are used as nest sites (Gonzalez 2006). Where sufficient holes for nesting are available, the crested myna may behave as a colonial breeder. Second, the species is a dietary generalist able to exploit a large range of food items. It has a generic, omnivorous diet, which includes insects and other invertebrates, fruits, grains, eggs, young birds but also dead fish and human discards (Wells 2010) (see Qu. 4.1). Third, the species has a good reproductive output, it has a long breeding season ranging from April to August depending on the region and double-broods have been observed (Craig and Feare, 2009) and clutch sizes ranging from four to seven eggs. According to studies carried out in Vancouver, hatching success of introduced populations ranged from 35–60%, and fledging success from 46–87%.

Additionally, introduction effort (propagule size or number) has been linked to invasion success of birds globally (Cassey et al. 2004). Invasion histories of crested myna have however shown that populations can originate from a very limited number of founders (see Qu 1.3a).

Qu. 2.8. If the organism does not establish, then how likely is it that casual populations will continue to occur?

Consider, for example, a species which cannot reproduce in the risk assessment area, because of unsuitable climatic conditions or host plants, but is present because of recurring introduction, entry and release events. This may also apply for long-living organisms.

RESPONSE	very unlikely unlikely moderately likely **likely** very likely	**CONFIDENCE**	**low** medium high

Escapes and releases from the discussed pathways of introduction/entry are likely to occur regularly (every year or so). Therefore it is likely that casual populations will continue to occur (particularly as the species is relatively long-lived: crested mynas are known to survive for up to 13 years in captivity (Flower 1938)).

Qu. 2.9. Estimate the overall likelihood of establishment in the risk assessment area under current climatic conditions. In addition, details of the likelihood of establishment in relevant

biogeographical regions under current climatic conditions should be provided. Thorough assessment of the risk of establishment in relevant biogeographical regions in current conditions: providing insight in the risk of establishment in (new areas in) the risk assessment area.

RESPONSE	very unlikely unlikely moderately likely likely **very likely**	**CONFIDENCE**	low medium **high**

The crested myna is already established in the risk assessment area in Portugal. Furthermore, according to the SDM (Annex VIII), the crested myna will be able to establish in all biogeographical regions within the risk assessment area. Under current climatic conditions, over 50% of the area of most biogeographical regions are suitable environmentally for establishment of the crested myna. Only two regions have less than 50% suitable area, i.e. the Alpine (27%) and the Boreal (23%) regions. The most limiting factor in these regions is the minimum temperature of the coldest month (BIO6), where the probability of crested myna establishment seems to decrease at BIO6 <-15°C (Annex VIII). Also see Qu. A7.

Qu. 2.10. Estimate the overall likelihood of establishment in the risk assessment area under foreseeable climate change conditions. In addition, details of the likelihood of establishment in relevant biogeographical regions under foreseeable climate change conditions should be provided. Thorough assessment of the risk of establishment in relevant biogeographical regions in foreseeable climate change conditions: explaining how foreseeable climate change conditions will influence this risk. With regard to climate change, provide information on ● the applied timeframe (e.g. 2050/2070) ● the applied scenario (e.g. RCP 4.5) ● what aspects of climate change are most likely to affect the likelihood of establishment (e.g. increase in average winter temperature, increase in drought periods) The thorough assessment does not have to include a full range of simulations on the basis of different climate change scenarios, as long as an assessment of likely establishment within a medium timeframe scenario (e.g. 30-50 years) with a clear explanation of the assumptions is provided. However, if new, original models are executed for this risk assessment, the following RCP pathways shall be applied: RCP 2.6 (likely range of 0.4-1.6°C global warming increase by 2065) and RCP 4.5 (likely range of 0.9-2.0°C global warming increase by 2065). Otherwise, the choice of the assessed scenario has to be explained.

RESPONSE	very unlikely unlikely moderately likely likely	**CONFIDENCE**	low medium **high**

	very likely		

Under RCP2.6, all biogeographical regions will become more suitable, or stay equally suitable (Mediterranean and Pannonian regions) for the establishment of the crested myna. Under RCP4.5, the percentage of suitable area will increase further, except for the Mediterranean region, where there will be 1% less habitat that is suitable for the species (100% to 99% suitable) (Annex VIII). Also see Qu. A7.

3 PROBABILITY OF SPREAD

Important instructions: ● Spread is defined as the expansion of the geographical distribution of an alien species within the risk assessment area. ● Repeated releases at separate locations do not represent continuous spread and should be considered in the probability of introduction and entry section (Qu. 1.7).

Qu. 3.1. How important is the expected spread of this organism within the risk assessment area by natural means? (List and comment on each of the mechanisms for natural spread.) including the following elements: ● a list and description of the natural spread mechanisms of the species in relation to the environmental conditions in the risk assessment area. ● an indication of the rate of spread discussed in relation to the species biology and the environmental conditions in the risk assessment area. The description of spread patterns here refers to the CBD pathway category “Unaided (Natural Spread)”. It should include elements of the species life history and behavioural traits able to explain its ability to spread, including: reproduction or growth strategy, dispersal capacity, longevity, dietary requirements, environmental and climatic requirements, specialist or generalist characteristics.

RESPONSE	minimal minor **moderate** major massive	**CONFIDENCE**	low **medium** high

Craig and Feare (2009) and Yap and Sodhi (2004) consider the crested myna to be a sedentary species, with only moderate dispersal capacity. The only information on the spread rate of the crested myna in the risk assessment area is available for Portugal (Saavedra et al. 2015). Here the crested myna has colonised the Tagus Estuary: the population was observed to increase until at least 2015. The colonized area has expanded eastwards and southwards by at least 3 km each year over the last decade (eBird Basic Dataset 2023). The species seems to have a medium dispersal ability, since in some cases, isolated individuals or small flocks have appeared in areas (eg., Sesimbra and Samora Correia) up to about 20km away from known colonies (Pedro Filipe Pereira, pers. comm. 2023). The population of crested myna in Portugal is still increasing nowadays (Pedro Filipe Pereira, pers. comm. 2023).

Information is also available for some countries outside the risk assessment area, where the species has also been introduced. For example, according to Phillips (1928), the crested myna spread rate was about two miles per year in Washington (USA) in the 1920s. In Japan in 2004, the crested myna was limited to a small region, but its numbers were rapidly increasing in urban areas of the Hyogo Prefecture (Eguchi and Amano 2004a).

Qu. 3.2a. List and describe relevant pathways of spread other than "unaided". For each pathway answer questions 3.3 to 3.9 (copy and paste additional rows at the end of this section as

necessary). Please attribute unique identifiers to each question if you consider more than one pathway, e.g. 3.3a, 3.4a, etc. and then 3.3b, 3.4b etc. for the next pathway.

including the following elements:

- a list and description of pathways of spread with an indication of their importance and associated risks (e.g. the likelihood of spread in the risk assessment area, based on these pathways; likelihood of survival, or reproduction, or increase during transport and storage; ability and likelihood of transfer from the pathway to a suitable habitat or host) in relation to the environmental conditions in the risk assessment area.
- an indication of the rate of spread for each pathway discussed in relation to the species biology and the environmental conditions in the risk assessment area.
- All relevant pathways of spread (except "Unaided (Natural Spread)", which is assessed in Qu. 3.1) should be considered. The classification of pathways developed by the Convention of Biological Diversity shall be used (see Annex IV).

The main pathways of spread (all within the transport-stowaway category) are:

- Vehicles (car, train,…)
- Hitchhikers on ship/boat (excluding ballast water and hull fouling).

(a) Vehicles (car, train,…)

Qu. 3.3a. Is spread along this pathway intentional (e.g. the organism is deliberately transported from one place to another) or unintentional (e.g. the organism is a contaminant of translocated goods within the risk assessment area)?

RESPONSE	intentional **unintentional**	**CONFIDENCE**	low medium **high**

The crested myna may potentially hitch-hike on trucks (but also other means of transport, such as vehicles, cargo trains, etc.) and as such transported as a stowaway of translocated goods within the risk assessment area, as documented for other birds (Lever 2005).

Qu. 3.4a. How likely is it that a number of individuals sufficient to originate a viable population will spread along this pathway from the point(s) of origin over the course of one year?

including the following elements:

- an indication of the propagule pressure (e.g. estimated volume or number of specimens, or frequency of passage through pathway), including the likelihood of reinvasion after eradication
- if appropriate, indicate the rate of spread along this pathway
- if appropriate, include an explanation of the relevance of the number of individuals for spread with regard to the biology of species (e.g. some species may not necessarily rely on large numbers of individuals).

RESPONSE	very unlikely **unlikely** moderately likely likely very likely	CONFIDENCE	**low** medium high

The crested myna established in the past even with low propagule pressure, e.g. in British Columbia and the USA, just 1-2 pairs were observed in 1897, but there were about 20000 birds by the early 1930s (Johnson and Campbell 1995). However, the chances of multiple birds all hitchhiking on the same transport mode (e.g. on a truck or train) within the risk assessment area is unlikely, and this kind of event has not been documented for this species in the risk assessment area, for example in Portugal where it is present in numbers for over 15 years. One possibility for the species to hitch-hike on trucks or other means of transport is if birds commence nest building in a vehicle that has been stationary for a long time but in general it is unlikely (Chris Feare, pers. comm. 2020).

Qu. 3.5a. How likely is the organism to survive, reproduce, or increase during transport and storage along the pathway (excluding management practices that would kill the organism)?

RESPONSE	very unlikely unlikely **moderately likely** likely very likely	CONFIDENCE	**low** medium high

If a crested myna would hitchhike on a truck or train and no water is present, it is likely that the individual would not survive transport. However, travelling distances in the risk assessment area are generally short, so the bird would only need to survive for a couple of hours or days, hence we score this outcome as moderately likely. It is very unlikely that the bird would reproduce, or increase its population size during transport.

Qu. 3.6a. How likely is the organism to survive existing management practices during spread?

RESPONSE	very unlikely unlikely moderately likely likely **very likely**	CONFIDENCE	**low** medium high

Other than any potential biosecurity measures, there are no existing management practices that may affect the likelihood of survival of stowaway birds. No information on biosecurity measures was found.

Qu. 3.7a. How likely is the organism to spread in the risk assessment area undetected?

RESPONSE	very unlikely unlikely **moderately likely** likely very likely	**CONFIDENCE**	**low** medium high

When the means of transport used as a vector (e.g. a truck) arrives at its destination, it is possible that the driver will notice if a trapped crested myna would fly out of the vehicle. However, it is also likely that the driver will not pay much attention to the bird or that it would simply be noticed flying out or be released and get introduced. Such events are also unlikely to get reported without specific awareness raising with transport carriers in risky areas which is unlikely to take place. Therefore we consider it moderately likely that crested myna stowaways can enter the risk assessment area undetected.

Qu. 3.8a. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host during spread?

RESPONSE	very unlikely unlikely moderately likely likely **very likely**	**CONFIDENCE**	low medium **high**

As reported under Qu 2.2, the natural habitat of the crested myna is widespread in the risk assessment area. This is supported by the results of the SDM (Annex VIII), according to which all biogeographical regions and all countries in the risk assessment area are predicted to provide areas with suitable environmental conditions for the crested myna, both under current and future climate conditions (RCP2.6 and RCP4.5). Therefore it is very likely that the species would be transferred to a suitable habitat along this pathway. For more information on suitable habitats for the crested myna, see Qu. A4.

Qu. 3.9a. Estimate the overall potential rate of spread based on this pathway in relation to the environmental conditions in the risk assessment area (please provide quantitative data where possible).

RESPONSE	**very slowly** slowly	**CONFIDENCE**	**low** medium

	moderately rapidly very rapidly		high

There have been no documented cases of crested myna being introduced as stowaway birds in the risk assessment area, despite the presence of one population in Portugal for over 20 years. Therefore, the spread of the crested myna as a transport stowaway (e.g. in trucks and trains) is considered to be very slow.

(b) Hitchhikers on ship/boat (excluding ballast water and hull fouling)

Qu. 3.3b. Is spread along this pathway intentional (e.g. the organism is deliberately transported from one place to another) or unintentional (e.g. the organism is a contaminant of translocated goods within the risk assessment area)?

RESPONSE	intentional **unintentional**	**CONFIDENCE**	low medium **high**

The crested myna may potentially hitch-hike on a ship, and be transported with a contaminant of goods within the risk assessment area, as has been documented for other bird species such as the house crow (*Corvus splendens*) (Cheke 2008), common myna (Iqbal et al. 2014), house sparrow and java sparrow (*Lonchura oryzivora*) (Lever 2005).

Qu. 3.4b. How likely is it that a number of individuals sufficient to originate a viable population will spread along this pathway from the point(s) of origin over the course of one year? including the following elements: ● an indication of the propagule pressure (e.g. estimated volume or number of specimens, or frequency of passage through pathway), including the likelihood of reinvasion after eradication ● if appropriate, indicate the rate of spread along this pathway ● if appropriate, include an explanation of the relevance of the number of individuals for spread with regard to the biology of species (e.g. some species may not necessarily rely on large numbers of individuals).

RESPONSE	very unlikely **unlikely** moderately likely likely very likely	**CONFIDENCE**	**low** medium high

The crested myna established in the past even with low propagule pressure, e.g. in Canada and the USA, just 1-2 pairs were observed in 1897, but there were about 20000 birds by the early 1930s (Johnson and Campbell 1995). However, the chances of multiple individuals all hitchhiking on the same vessel (eg. a ship) within the risk assessment area is unlikely, and this has not been documented for this species.

Qu. 3.5b. How likely is the organism to survive, reproduce, or increase during transport and storage along the pathway (excluding management practices that would kill the organism)?

RESPONSE	very unlikely unlikely **moderately likely** likely very likely	**CONFIDENCE**	**low** medium high

The species could be a stowaway on a ship within the risk assessment area. While being introduced as a stowaway on cars, lorries, trains is unlikely, transport by ship to islands might be feasible – thinking in particular of the Tagus estuary population, in Portugal (Chris Feare, pers. comm. 2020). If birds get blown out to sea they could settle on ships, where they could be cared for and fed by sympathetic sailors and fly to land when this is next approached (including in other coastal areas of Europe, and relevant islands. On a ship, the crested myna could receive food and water from the crew, and survive for considerable time. It is a gregarious bird that imitates a lot of noises (Restall 1968), making it likeable (perhaps increasing its chances of survival). It is considered very unlikely that the bird would reproduce, or increase its population size during transport along this pathway

Qu. 3.6b. How likely is the organism to survive existing management practices during spread?

RESPONSE	very unlikely unlikely moderately likely likely **very likely**	**CONFIDENCE**	**low** medium high

There are no management practices that may affect the likelihood survival of stowaway birds, other than any potential biosecurity measures. No information on biosecurity measures was found.

Qu. 3.7b. How likely is the organism to spread in the risk assessment area undetected?

RESPONSE	very unlikely	**CONFIDENCE**	**low**

	unlikely **moderately likely** likely very likely		medium high

The crested myna is a vocal, curious species. It is therefore unlikely that it will spread undetected on ships with a crew. However, its occurrence may be left unreported. This way, crested myna stowaways may enter a new area undetected.

Qu. 3.8b. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host during spread?

RESPONSE	very unlikely unlikely moderately likely likely **very likely**	**CONFIDENCE**	low medium **high**

As reported under Qu 2.2, the natural habitat of the crested myna is widespread in the risk assessment area. This is supported by the results of the SDM (Annex VIII), which predicts areas of all biogeographical regions and all countries in the risk assessment as suitable for crested myna establishment, both under current and future climate conditions (RCP2.6 and RCP4.5, see SDM, Annex VIII). Therefore, it is very likely that the species would be transferred to a suitable habitat along this pathway. For more information on suitable habitats for the crested myna, see Qu. A4, 1.4a and 2.2.

Qu. 3.9b. Estimate the overall potential rate of spread based on this pathway in relation to the environmental conditions in the risk assessment area (please provide quantitative data where possible).

RESPONSE	**very slowly** slowly moderately rapidly very rapidly	**CONFIDENCE**	**low** medium high

As far as we are aware, there have been no documented cases of crested myna being introduced as hitch-hiker on a ship in the risk assessment area, despite the presence of a population in Portugal for over 20 years. Therefore, even if it would happen, spread along this pathway is considered very slow.

Qu. 3.10. Within the risk assessment area, how difficult would it be to contain the organism in relation to these pathways of spread?

RESPONSE	very easy easy with some difficulty **difficult** very difficult	**CONFIDENCE**	**low** medium high

Given the inherent characteristic of this pathway, it is difficult to ensure no birds are given the chance to hitchhike (see also Qu. 3.7b), even despite the implementation of dedicated awareness campaigns specifically targeting transport companies and drivers of shipping transports (at least those active within risk areas for crested myna in the risk assessment area).

Qu. 3.11. Estimate the overall potential rate of spread in relevant biogeographical regions under current conditions for this organism in the risk assessment area (indicate any key issues and provide quantitative data where possible). Thorough assessment of the risk of spread in relevant biogeographical regions in current conditions, providing insight in the risk of spread into (new areas in) the risk assessment area.

RESPONSE	very slowly slowly **moderately** rapidly very rapidly	**CONFIDENCE**	low **medium** high

Based on other invasions elsewhere in the world (see Qu. A5), the potential rate of spread is considered to be moderate. In Portugal, although the number of records and individuals increased in the period 2001-2011 (Saavedra et al. 2015), the invaded area in the Tagus Estuary (~140 km^2) seems relatively small. In 2022, the colonized area in Portugal is at least 2.000km2 (eBird Basic Dataset 2023; III Portuguese Breeding Bird Atlas *in prep*.). The colonized area has expanded eastwards and southwards by at least 3 km each year over the last decade (eBird Basic Dataset 2023). In Vancouver, Canada, numbers of crested myna built up to 20.000 birds in in about 30 years after introduction and the species spread from British Columbia to the adjacent USA, as far south as northwestern Washington and possibly to Oregon. Scheffer and Cottam (1935) however noted that the increase of crested myna in Vancouver was rather slow and the spread gradually, with birds moving in small colonies and never far from the habitations of man. Considering the Vancouver case, we scored the spread moderately with medium confidence because quantitative data are lacking. Spread will mostly occur through natural means and not via one of the transport stowaway pathways listed above.

See also Qu. A8 and A11.

Qu. 3.12. Estimate the overall potential rate of spread in relevant biogeographical regions in foreseeable climate change conditions (provide quantitative data where possible).
Thorough assessment of the risk of spread in relevant biogeographical regions in foreseeable climate change conditions: explaining how foreseeable climate change conditions will influence this risk, specifically if rates of spread are likely slowed down or accelerated.

RESPONSE	very slowly slowly moderately **rapidly** very rapidly	**CONFIDENCE**	low **medium** high

Since a greater proportion of habitat will become suitable in the risk assessment area under both RCP2.6 and RCP4.5, the spread of the crested myna may be accelerated. Under current climate conditions, the most limiting factors are the minimum temperature of the coldest month (BIO6) and the mean temperature of the warmest quarter (BIO10). In particular, the alpine and boreal biogeographic regions, where it is currently too cold for this species to establish and spread, will become more suitable (see SDM, Annex VIII).

4 MAGNITUDE OF IMPACT

Important instructions:
● Questions 4.1-4.5 relate to biodiversity and ecosystem impacts, 4.6-4.8 to impacts on ecosystem services, 4.9-4.13 to economic impact, 4.14-4.15 to social and human health impact, and 4.16-4.18 to other impacts. These impacts can be interlinked, for example, a disease may cause impacts on biodiversity and/or ecosystem functioning that leads to impacts on ecosystem services and finally economic impacts. In such cases the assessor should try to note the different impacts where most appropriate, cross-referencing between questions when needed. ● Each set of questions starts with the impact elsewhere in the world, then considers impacts in the risk assessment area (=EU excluding outermost regions) separating known impacts to date (i.e. past and current impacts) from potential future impacts (including foreseeable climate change). ● Only negative impacts are considered in this section (socio-economic benefits are considered in Qu. A.7) ● In absence of specific studies or other direct evidence this should be clearly stated by using the standard answer "No information has been found on the issue". This is necessary to avoid confusion between "no information found" and "no impact found".

Biodiversity and ecosystem impacts

Qu. 4.1. How important is the impact of the organism on biodiversity at all levels of organisation caused by the organism in its non-native range excluding the risk assessment area?
including the following elements: ● Biodiversity means the variability among living organisms from all sources, including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems ● impacted chemical, physical or structural characteristics and functioning of ecosystems

RESPONSE	minimal **minor** moderate major massive	**CONFIDENCE**	**low** medium high

The main impacts on biodiversity reported outside the risk assessment area are competition with native species for food and nesting holes, predation on a variety of species and possibly seed dispersal of invasive introduced plants (Wood 1924, Chiurla 1997, Craig and Feare 2009).

The crested myna is considered to be an aggressive bird that destroys the eggs and kills the chicks of other cavity nesting bird species in Argentina (Chébez and Rodríguez 2013). Aggressive behaviour was also reported during feeding, e.g. towards the brown-and-yellow marshbird (*Pseudoleistes virescens*), domestic pigeon (*Columba livia*) and rufous-bellied thrush (*Turdus rufiventris*) (Chébez and Rodríguez 2013). The crested myna was considered a threat for native birds in Vancouver (Wood 1924), where it was observed attempting to usurp the nests of native insectivorous birds. Woodpeckers and wrens were most frequently affected, abandoning their nests. In the case of the wren, the crested myna was seen to first oust the occupant species and then enlarge the nesting hole. Usurped nests were often located in houses or barns, in telephone poles and other artificial cavities (Wood 1924). Campbell et al. (2007) note nesting was mostly confined to human-made sites, such as nest boxes, crevices, cavities, drainpipes, decorations of buildings etc. About 6% of the reported nest sites (N = 71) were natural cavities excavated by other species e.g. woodpeckers. In Buenos Aires, Argentina, the crested myna was observed forcing itself into a green-barred woodpecker (*Colaptes melanochloros*) nest in a poplar (Chiurla 1997).

With regards to impact on invertebrates through predation, Scheffer and Cottam (1935) performed stomach analysis of 142 birds near Vancouver (Canada) in 1925, 1931 and 1932. Prominent insects were Diptera, Lepidoptera and parasitic wasps. Earthworms (Lumbricidae) made up over 4% of food items in the stomach (N = 117) on average, Arachnids made up almost 3% of crested myna food, and terrestrial isopods (Oniscidae) made up about 1% of the diet in three of the eight months of stomach collection (May, June and October). Also, garbage (animal debris, table scraps of meat, bones and vegetable scraps) was an important food item (Scheffer and Cottam 1935). Food items in the stomach largely reflected their availability, and pest insects represented only a very small proportion of those. It is however not clear what the impact of predation by the crested myna was at population level of these arthropod species in British Columbia (Canada).

The crested myna has a generic, omnivorous diet, which is known to include a variety of items, from insects and other invertebrates (both adults and larvae), to fruits, grains, eggs and young birds (Wells 2010). It is also known to scavenge dead fish and human discards, and has been observed harassing a nestling Chinese pond-heron (*Ardeola bacchus*) until it regurgitated its food. In its native range in China, the species' diet is composed of 55% animal food and 45% vegetable matter, while in its introduced range in Canada, its diet was composed of 60% fruits and 40% insects and earthworms (Craig and Feare 2009).

In view of the crested myna's similarity, ecologically, with the common myna, we should probably not underestimate a capacity to disperse non-native and invasive vegetation (Chris Feare, pers. comm. 2020). Common mynas in some circumstances disperse seeds of invasives and may also be involved in pollination in others (Feare and Saavedra 2009). To give an idea of the varied diet of the species in relation to this threat, one may consider that fruits exploited by the crested myna in its native range include *Ficus retusa*, common lantana (*Lantana camara*), *Varronia cylindrostachya* and Chinese tallow (*Triadica sebifera*). The birds in the introduced Canadian population feed on cherry (*Prunus*), mountain ash (*Sorbus*), salmonberry (*Rubus spectabilis*), thimbleberry (*Rubus parviflorus*), black raspberry (*Rubus leucodermis*), currant (*Ribes*), crab apple (*Malus*), cotoneaster (*Cotoneaster*) and bog cranberry (*Vaccinium oxycoccos*) (Craig and Feare 2009).

To conclude, there is evidence of competition for food and nesting sites with several other bird species and for predation on eggs and chicks of other cavity nesters. Beside this, crested mynas predate on invertebrates and feed on fruits of various plant species (including some invasive plants). This might cause competitive displacement and affect fitness or breeding success of native birds in the long term. There is direct observational evidence of impact on a range of species but at a rather small spatial scale. However, there is currently no evidence of population level effects on, or extinction of these native species. Hence, we scored minor impact. This may not fully reflect the risk in case the species gets more widespread in the alien range and/or further evidence is collected on the species impact on biodiversity (namely on primary and secondary cavity nester birds, as a consequence of competition, or other vertebrates and invertebrates due to predation), hence medium confidence.

Qu. 4.2. How important is the current known impact of the organism on biodiversity at all levels of organisation (e.g. decline in native species, changes in native species communities, hybridisation) in the risk assessment area (include any past impact in your response)? Discuss impacts that are currently occurring or are likely occurring or have occurred in the past in the risk assessment area. Where there is no direct evidence of impact in the risk assessment area (for example no studies have been conducted), evidence from outside of the risk assessment area can be used to infer impacts within the risk assessment area.

RESPONSE	minimal **minor** moderate major massive	**CONFIDENCE**	**low** medium high

In Portugal, Saavedra et al. (2015) observed crested mynas aggressively interacting with a variety of native bird species in urban areas. These species include birds smaller than crested mynas (barn swallow, white wagtail, house sparrow), birds of a similar size (spotless starling, Eurasian blackbird) and larger birds (common kestrel, yellow-legged gull). These are all common species in Portugal. Also, an intermediate phenotype between common myna and crested myna was observed, suggesting hybridization of these non-native species in the area (see A1). Saavedra et al. (2015) concluded that more research is required to assess the actual and potential impacts of crested mynas to other bird species in Portugal. The proportion of colonized agricultural land and natural habitats has increased relative to urban or peri-urban areas during the last decade (eBird Basic Dataset 2023). Therefore, the potential impact of crested myna on natural ecosystems may also increase. Research is needed to prove this hypothesis (Pedro Filipe Pereira, pers. comm. 2023). In conclusion, despite the lack of documented evidence, we assume that the magnitude of impacts caused by the crested myna in the risk assessment area is likely to be at least as severe as elsewhere in its introduced range and therefore score minor with low confidence.

Qu. 4.3. How important is the potential future impact of the organism on biodiversity at all levels of organisation likely to be in the risk assessment area? See comment above. The potential future impact shall be assessed only for the risk assessment area.

RESPONSE	minimal minor **moderate** major massive	**CONFIDENCE**	low **medium** high

As stated in Qu. 4.2. the crested myna displays aggressive behaviour towards other bird species, mainly for food and nesting sites (Lindell 1996; Eguchi and Amano 2004a). The crested myna could exert competition on species that also feed on insects and other invertebrates (both adults and larvae), fruits, grains, eggs and young birds. Competition for nesting sites could have serious consequences for endangered native birds (especially cavity nesters of similar body-mass index) in the risk assessment area, especially when natural nest holes are in short supply.

In its invasive range, the crested myna mainly inhabits urban areas, where few native endangered birds are present (Eguchi and Amano 2004a; Chébez and Rodríguez 2013; Saavedra et al. 2015). However, if the crested myna became established in larger parts of the risk assessment area and spreads to less urbanized environments, it could have impact on threatened native bird species.

As it is a generalist species, it is very difficult to foresee what species will be most impacted by the crested myna, but it is likely that those cavity nesting native species already threatened or nearly threatened may be particularly at risk (Tom Evans, pers. comm. 2020). The crested myna is known to destroy eggs and kill chicks of other birds (Chébez and Rodríguez, 2013) and could therefore have a direct impact on several small to medium-sized passerine species with similar habitat characteristics (eg. man-made environments, low tree density, cavity-nesting). especially obligate cavity nesters such as woodpeckers, owls and nuthatches (e.g. great spotted woodpecker *Dendrocopos major*, Eurasian scops owl *Otus scops*, Eurasian nuthatch *Sitta europaea*), but also facultative cavity nesting birds might be affected by breeding competition (e.g. European roller *Coracias garrulus*, stock dove *Columba oenas*, spotless starling *Sturnus unicolor,* common starling *S. vulgaris* or Eurasian wren (*Troglodytes troglodytes*). These species also have a potential for encountering crested myna considering niche overlap and display similarity in body-mass which is a predictor of the strength of competition in birds (Leyequién et al. 2007). Similar impacts of invasive common myna were reported in cavity-nesting bird communities in Israel, yet these interactions were dependent on the timing of breeding, nesting preferences and the ability to excavate or widen the cavities (Orchan et al. 2013). Here, the common myna excluded the smaller invasive vinous-breasted starling, a direct competitor of the primary nest excavator, the native Syrian woodpecker.

In the risk assessment area, the crested myna has been observed to aggressively interact with several native bird species (see Qu. 4.2). Based on this information, the crested myna may be expected to affect a number of European species similar to the ones listed above by Grarock et al. (2012). Even though these birds are listed as “Least Concern” on the IUCN Red List (Birdlife International 2019a; 2019b), populations of the house sparrow and the common starling are decreasing in Europe and the added pressure of competition and predation from the crested myna could accelerate this decline.

Predation by crested myna on threatened invertebrates could be an issue, for example for small populations of rare species or on islands endemics.

Another potential ecological impact of the crested myna is through dispersal of seeds of both native and alien plants. The potential of mynas to contribute to the dispersal of invasive alien plants and induce habitat changes has been well documented for the closely related common myna (Fleischmann 1997, Lever 1994) or other frugivorous birds like the red-vented bulbul (*Pycnonotus cafer*) (Verzelen et al. 2020), but little information was found on the spread of IAS plants by crested myna outside its native range.

For example, a number of established and emerging invasive alien plants for Mediterranean countries produce fleshy fruits and could therefore potentially be spread by birds such as the crested myna in the risk assessment area (cf. Gosper et al. 2005; Spotswood et al. 2012, 2013). Some of these species typically occur in human-modified areas such as parks, gardens and ruderal terrains. Spread of typical garden ornamentals by crested myna could be an issue considering the habitat preference of the species for man-made habitat

Because the potential for future species extinctions is limited, we scored moderate. Confidence is medium since there is some direct observational evidence to support the assessment, but some information is inferred from common myna.

Qu. 4.4. How important is the decline in conservation value with regard to European and national nature conservation legislation caused by the organism currently in the risk assessment area? including the following elements: ● native species impacted, including red list species, endemic species and species listed in the Birds and Habitats directives ● protected sites impacted, in particular Natura 2000 ● habitats impacted, in particular habitats listed in the Habitats Directive, or red list habitats ● the ecological status of water bodies according to the Water Framework Directive and environmental status of the marine environment according to the Marine Strategy Framework Directive

RESPONSE	minimal **minor** moderate major massive	**CONFIDENCE**	**low** medium high

As stated in Qu. 4.2, Saavedra et al. (2015) noted that some native bird species have been affected by the crested myna, but all these species are listed as Least Concern on the IUCN Red List and are not included in Annex I of the Birds Directive, which lists threatened bird species. However, the Birds Directive aims to protect all of the wild bird species naturally occurring in the EU, and a threat to one or more of those native bird species should therefore not be ignored. Crested myna has the potential to impact already threatened cavity nesting native bird species (see Qu. 4.3) which may affect their conservation status.

Qu. 4.5. How important is the decline in conservation value with regard to European and national nature conservation legislation caused by the organism likely to be in the future in the risk assessment area? ● See guidance to Qu. 4.4.

RESPONSE	minimal minor **moderate** major massive	**CONFIDENCE**	**low** medium high

It is not possible to predict which native species will be impacted by the crested myna in the risk assessment area in the future. According to the SDM (Annex VIII), this species could find suitable environmental conditions in every country and every biogeographical region within the risk assessment area. If the crested myna was to establish in larger parts of the risk assessment area, it could impact native species in and around urbanized areas. No information has been found on the impact of the crested myna in nature conservation areas.

The main threats posed by the crested myna include competition for food and nesting sites, predation and seed dispersal of introduced plants. For more information, also see Qu. 4.1 and 4.3. In conclusion, it is likely that the proportion of suitable habitat in the risk assessment area for the crested myna will increase under future scenario RCP2.6 and RCP4.5, and therefore the crested myna may have the opportunity to cause impacts to a wider range of native species.

Ecosystem Services impacts

Qu. 4.6. How important is the impact of the organism on provisioning, regulating, and cultural services in its non-native range excluding the risk assessment area?

- For a list of services use the CICES classification V5.1 provided in Annex V.
- Impacts on ecosystem services build on the observed impacts on biodiversity (habitat, species, genetic, functional) but focus exclusively on reflecting these changes in relation to their links with socio-economic well-being.
- Quantitative data should be provided whenever available and references duly reported.

RESPONSE	minimal minor **moderate** major massive	**CONFIDENCE**	low medium **high**

The following services are impacted by the crested myna in its non-native range outside of the risk assessment area, according to the CICES classification V 5.1:

1. Provisioning
    a. Biomass
        i. Cultivated terrestrial plants

According to Yap and Sodhi (2004), the crested myna is considered by some to be a crop pest in Malaysia and the Philippines. Crop damage is also reported in other overseas introduced populations (Eguchi and Amano 2004a, Wood 1924). In its introduced range in Vancouver (British Columbia, Canada), the crested myna was initially considered to have a negative impact on fruit production, such as cherries, blackberries, apples and similar crops (Wood 1924; Phillips 1928). Scheffer and Cottam (1935) found approximately one third of the food consumed by crested mynas in Vancouver to be fruit. They also described around 4% of the crested myna stomach contents they analysed to consist of cultivated leafy vegetable material, meaning the species could also impact agriculture. However, no serious "depredations" of crops were reported in this area (British Columbia) in later years (Lever 2005).

ii. Wild plants

About one third of the food consumed by the crested myna in Vancouver (Canada) consisted of fruits, but not all fruits were cultivated, so the species could have had a potential impact on wild plants such as berries (Scheffer and Cottam 1935).

It is likely that the species has an impact on cultural services too (e.g. in relation to "Physical and experiential interactions with natural environment" and "Intellectual and representative interactions with natural environment") but no documented evidence was found to discuss this in detail.

Qu. 4.7. How important is the impact of the organism on provisioning, regulating, and cultural services currently in the different biogeographic regions or marine sub-regions where the species has established in the risk assessment area (include any past impact in your response)?

- See guidance to Qu. 4.6.

RESPONSE	**minimal** minor moderate major massive	CONFIDENCE	**low** medium high

There are no reported impacts on provisioning, regulating and cultural services within the risk assessment area caused by the crested myna.

Qu. 4.8. How important is the impact of the organism on provisioning, regulating, and cultural services likely to be in the different biogeographic regions or marine sub-regions where the species can establish in the risk assessment area in the future?

- See guidance to Qu. 4.6.

RESPONSE	minimal minor **moderate** major massive	CONFIDENCE	low **medium** high

See also Qu. 4.6. The following services could be impacted by the crested myna in the risk assessment area, according to the CICES classification V 5.1:

2. Provisioning
    a. Biomass
        i. Cultivated terrestrial plants

Crop damage by the crested myna is considered as a possible future threat within the risk assessment area as it is already considered to be a crop pest in its alien range (Yap and Sodhi 2004, Eguchi and Amano 2004a, Wood 1924, Scheffer and Cottam 1935). A study by Scheffer and Cottam (1935) found approximately one third of the food consumed by crested mynas in Vancouver to be fruit. They also described around 4% of the crested myna stomach contents they analysed to consist of cultivated leafy vegetable material, meaning the species could also impact vegetable agriculture. As a side note, this shows the negative drawbacks of introducing alien species as a biological control agent, as documented for this species in the Philippines and Malaysia (see Qu.1.1).

ii. Wild plants

The crested myna could impact wild plants that are consumed in the risk assessment area, such as berries, thus decreasing food resources for other species.

Economic impacts

Qu. 4.9. How great is the overall economic cost caused by the organism within its current area of distribution (excluding the risk assessment area), including both costs of / loss due to damage and the cost of current management.

- Where economic costs of / loss due to the organism have been quantified for a species anywhere in the world these should be reported here. The assessment of the potential costs of / loss due to damage shall describe those costs quantitatively and/or qualitatively depending on what information is available. Cost of / loss due to damage within different economic sectors can be a direct or indirect consequence of the earlier-noted impacts on ecosystem services. In such case, please provide an indication of the interlinkage. As far as possible, it would be useful to separate costs of / loss due to the organism from costs of current management.

RESPONSE	minimal **minor** moderate major massive	**CONFIDENCE**	**low** medium high

The crested myna is considered to be a crop pest outside the risk assessment area (Wood 1924, Phillips 1928, Eguchi and Amano 2004a, Yap and Sodhi 2004).

As with other flocking bird species (e.g. Allan et al., 1995), flocks of crested mynas at airports could increase the risk of bird strikes. Hence the species could be responsible for costs associated with alien bird eradications at airports, and for repairs to damaged aircraft (see Evans et al. in press). As a side note, outside of the risk assessment areas, the common starling (a similar species to the crested myna) poses a growing threat to aviation safety. Across the USA, between 1990 and 2001, there were 852 reported strikes that involved common starlings, and over that time-period the annual strike rate more than doubled. Together with airstrikes involving native blackbird species, these incidents cost approximately US$ 1.6 million (€ 1.4 million), although damage to aircraft was only reported in approximately 6% of strikes (Barras et al. 2003). Should the crested myna establish in the risk assessment area, it has the potential to contribute to the costs associated with air strikes at airports.

However, there is evidence of common myna being implicated in birdstrikes in its native range (Linnell et al. 1996, 1999) and the risk of airstrips keeping large numbers of sparrows and mynas can be mitigated by keeping the grass sufficiently high (grass height > 10-15 cm) (Narwade et al. 2012). Yet other damages are possible. For example, on Mauritius, nesting common mynas in aircraft maintenance buildings (hangars) can drop nesting material and faeces on to aircraft during service. This can be particularly concerning for helicopters (Chris Feare pers. comm. 2020).

Qu. 4.10. How great is the economic cost of / loss due to damage (excluding costs of management) of the organism currently in the risk assessment area (include any past costs in your response)?

- Where economic costs of / loss due to the organism have been quantified for a species anywhere in the EU these should be reported here. Assessment of the potential costs of damage on human health, safety, and the economy, including the cost of non-action. A full economic assessment at EU scale might not be possible, but qualitative data or different case studies from across the EU (or third countries if relevant) may provide useful information to inform decision making. In absence of specific studies or other direct evidence this should be clearly stated by using the standard answer “No information has been found on the issue”. This is necessary to avoid confusion between “no information found” and “no impact found”. Cost of / loss due to damage within different economic sectors can be a direct or indirect consequence of the earlier-noted impacts on ecosystem services. In such case, please provide an indication of the interlinkage.

RESPONSE	N/A	CONFIDENCE	N/A

No information has been found.

Qu. 4.11. How great is the economic cost of / loss due to damage (excluding costs of management) of the organism likely to be in the future in the risk assessment area?

- See guidance to Qu. 4.10.

RESPONSE	minimal **minor** moderate major massive	CONFIDENCE	**low** medium high

No information has been found. No information is available regarding existing economic costs, and therefore it is not possible to assess future economic. However, since the overall occurrence of the species is likely to increase, then the economic costs may also increase.

Qu. 4.12. How great are the economic costs / losses associated with managing this organism currently in the risk assessment area (include any past costs in your response)?

- In absence of specific studies or other direct evidence this should be clearly stated by using the standard answer “No information has been found on the issue”. This is necessary to avoid confusion between “no information found” and “no impact found”.

RESPONSE	**minimal** minor moderate major massive	CONFIDENCE	**low** medium high

No information has been found on the issue. For the removal of breeding crested mynas in Belgium no costs were reported (Bosmans 2009).

Qu. 4.13. How great are the economic costs / losses associated with managing this organism likely to be in the future in the risk assessment area?

- See guidance to Qu. 4.12.

RESPONSE	minimal minor moderate **major** massive	CONFIDENCE	**low** medium high

According to Saavedra et al. (2015), eradications of small common myna populations (< 50 individuals) are achievable and relatively straightforward. Therefore, if tackled early, costs associated with the eradication of crested myna populations may be low. Based on data available for the common myna (for a short review, see Scalera et al. 2018), should a population of the species become established and widespread in the risk assessment area, its management may cost 10,000-100,000 Euro or higher at each established location. Booy et al. (2020) in their eradication feasibility assessment for Europe, estimated the cost for eradication of crested myna from Europe (assuming the current scenario with 4-10 populations over a total combined area of >100 km2) as high, with medium confidence. This represents a cost in the order of 1-10 million euros, which would represent a major indirect economic impact here.

Social and human health impacts

Qu. 4.14. How important is social, human health or other impact (not directly included in any earlier categories) caused by the organism for the risk assessment area and for third countries, if relevant (e.g. with similar eco-climatic conditions). The description of the known impact and the assessment of potential future impact on human health, safety and the economy, shall, if relevant, include information on ● illnesses, allergies or other affections to humans that may derive directly or indirectly from a species; ● damages provoked directly or indirectly by a species with consequences for the safety of people, property or infrastructure; ● direct or indirect disruption of, or other consequences for, an economic or social activity due to the presence of a species. Social and human health impacts can be a direct or indirect consequence of the earlier-noted impacts on ecosystem services. In such case, please provide an indication of the interlinkage.

RESPONSE	minimal **minor** moderate major massive	**CONFIDENCE**	low **medium** high

A recent study by Dong et al. (in prep.) identified two *Cryptosporidium* species and *Giardia duodenalis* in fecal samples of crested mynas in parks and pet shops. Out of 132 samples, three contained *Cryptosporidium baileyi*, one *Cryptosporidium meleagridi*s and 13 *Giardia duodenalis*. *Cryptosporidium* spp. are parasites that inhabit the microvillous border of a variety of epithelial surfaces, mostly the intestinal tract of human beings and other vertebrates (Lindsay et al. 1989). They are obligate intracellular parasites, and so they must live and reproduce within an animal cell (Duszynski et al. 2004). *Cryptosporidium* can cause respiratory and gastrointestinal illness, called cryptosporidiosis, that primarily causes diarrhea and a persistent cough (Sponseller et al. 2014). It is an acute, short-term infection that can be life-threatening in immunocompromised individuals, e.g. in people infected with HIV (Wang et al. 2018). *Cryptosporidium meleagridis*, which is found in the crested myna (Dong et al. in prep.), can infect humans, whereas *Cryptosporidium baileyi* has only been found once (that we know of) in the stool of an immunocompromised human, and primarily infects birds (Ditrich et al. 1991). *Giardia duodenalis* colonizes and reproduces in the small intestine, causing diarrhea (Simner and Kraft 2017). Cysts can be found on surfaces, soil, food or water that has been contaminated with faeces from infected animals, and can survive conventional water treatment methods (Huang and White 2006). These three parasites have been found in crested mynas and may pose a health risk if escaped/released birds come into contact with humans or other animals. Currently, there seems to be limited evidence of cases of human health problems or agricultural damage associated with the crested myna, unlike for the common myna, which is known to spread parasites and diseases that may pose a human health risk (Scalera et al. 2018). Probably, this is a consequence of lack of studies on the issue and there is a fair chance crested mynas can equally act as a reservoir of parasites and diseases just like other myna species (e.g. psittacosis, ornithosis, salmonellosis, arboviruses, mites, lice and bird flu H5N1) (see e.g. Mori et al. 2018). We could not find any reports on social or human health impacts of the crested myna in the risk assessment area. According to Chris Feare (pers. comm. 2020) it's also unlikely that numbers of crested mynas will ever build up sufficiently to present a problem in the risk area. But a warning that removal of the species from Portugal's Lisbon area should be a priority

As with other starlings and mynas, large flocks of birds can be expected to be a nuisance to people. In Vancouver (Canada), crested mynas were unpopular for their large winter flocks (Scheffer and Cottam 1935), their noise and droppings and their habit of building messy nests on buildings, taking grain and fruit and competing with native birds. The crested myna has been described as noisy, disrupting public life where it occurs in large numbers, such as in Buenos Aires (Argentina) (Chébez and Rodriguez 2013). In some places, 150-200 individuals gather around twilight to roost, accompanied by singing and whistling. In addition to the noise in the evening, they become active and to communicate from 4:00 a.m., waking up residents in the area. Restall (1968), who kept a diary of how he took care of a pair of crested mynas, notes that they chatter away regularly and cheerfully, exactly like a cage full of budgerigars (parakeets) with a pair of cockatiels, and that they are capable of calling quite loudly. So, if the crested myna was to establish within the risk assessment area, the species could be a nuisance for nearby residents. Communal roost sites of mynas in proximity to residential areas are typically noisy, cause accumulation of droppings on lawns, buildings, pavements and trees, and have unpleasant odours and this is for example well documented for the common myna (Peacock et al. 2007, GISD 2017, Peacock et al. 2007, Scalera et al. 2018). But documented evidence on this regard is lacking for crested mynas, although is reasonable to assume that it could have similar impacts.

We scored this impact as minor because of the local scale of the potential problems caused. Furthermore, any impacts on human activities would be limited in time and confined to the few months associated with the aggregation period for the species. We scored this impact with a medium confidence, as whilst there is some direct observational evidence, some is extrapolated from another myna species (the common myna).

Qu. 4.15. How important is social, human health or other impact (not directly included in any earlier categories) caused by the organism in the future for the risk assessment area. ● In absence of specific studies or other direct evidence this should be clearly stated by using the standard answer "No information has been found on the issue". This is necessary to avoid confusion between "no information found" and "no impact found".

RESPONSE	minimal minor **moderate** major massive	**CONFIDENCE**	**low** medium high

Future impacts (as described in Qu 4.14) can be expected to increase with increasing range and numbers of individuals of the species.

Other impacts

Qu. 4.16. How important is the organism in facilitating other damaging organisms (e.g. diseases) as food source, a host, a symbiont or a vector etc.?

RESPONSE	**minimal** minor moderate major massive	**CONFIDENCE**	**low** medium high

The crested myna could spread the seeds of several invasive plant species e.g. *Lantana camara*, as was the case with the common myna in Hawaii (Pimentel et al. 2000). There are however no known impacts of the crested myna on this regard.

Qu. 4.17. How important might other impacts not already covered by previous questions be resulting from introduction of the organism?

RESPONSE	**minimal** minor moderate major massive	**CONFIDENCE**	**low** medium high

We found no information on the impacts of the crested myna other than those described above.

Qu. 4.18. How important are the expected impacts of the organism despite any natural control by other organisms, such as predators, parasites or pathogens that may already be present in the risk assessment area?

RESPONSE	minimal minor **moderate** major massive	**CONFIDENCE**	**low** medium high

The impact of the species is unlikely to be affected by the presence of predators, parasites or pathogens (establishment of the crested myna outside its native range, despite naturally occurring predators, parasites or pathogens, has occurred in several countries in the past outside and inside the risk assessment area, see Qu. 2.4).

Qu. 4.19. Estimate the overall impact in the risk assessment area under current climate conditions. In addition, details of overall impact in relevant biogeographical regions should be provided. Thorough assessment of the overall impact on biodiversity and ecosystem services, with impacts on economy as well as social and human health as aggravating factors, in current conditions.

RESPONSE	minimal minor **moderate** major massive	**CONFIDENCE**	**Low** medium high

All biogeographical regions within the risk assessment area are predicted to be suitable for the establishment of the crested myna (Annex VIII). No major differences between them are expected, although there might be differences due to differing densities of human populations (mynas more usual in urban areas) and due to the social propensity to keep birds in captivity (especially prevalent in Mediterranean region) (Chris Feare, pers. comm. 2020). Therefore, in the light of the various type of impacts documented, and the fact that in current conditions the suitable area for the species is very large (hence further increasing the risk of impacts to many other species/communities) the magnitude of impact could be moderate, but with a low confidence (as further evidence is needed to confirm the assessed impacts). Even though currently a body of evidence on population level impacts on native species is lacking, ecological impacts are multifaceted and have been documented on common yet declining species. Also, the potential impacts of this flocking species though agricultural damage, nuisance and birdstrike hazard are aggravating factors.

The main impact reported for the crested myna is predation of native species resulting from competition for food and nesting sites (Lindell 1996; Eguchi and Amano 2004a; Craig and Feare 2009; Saavedra et al. 2015). The bird destroys eggs and kills chicks of other birds breeding in holes and crevices (Chébez and Rodríguez 2013). For this reason, it was considered a threat to native bird species in British Columbia (Canada) (Wood 1924).

Furthermore, the crested myna predates on arthropods, including Diptera, Lepidoptera, parasitic wasps, Arachnids, terrestrial isopods (Oniscidae), and also on earthworms (Lumbricidae) and wild plants (fruits, grains and berries) (Scheffer and Cottam 1935). This could potentially negatively affect prey species with small populations, particularly if the crested myna colonizes ecosystems that support threatened species.

Third, the crested myna could disperse the seeds of invasive plant species, as is the case with its relative, the common myna, that is known to contribute to the spread of *Lantana camara* in Hawaii (Pimentel et al. 2000) and in St Helena *Lantana camara*, *Schinus terebinthifolia* (Feare and Saavedra 2009). Also *Juniperus bermudiana, Chrysanthemoides monilifera, Pittosporum viridiflorum*, and pollination of highly invasive New Zealand Flax (*Phormium tenax*) (Ashmole and Ashmole 2000). This could increase the range of invasive plant species and thus indirectly affect species, sites and habitats colonised by the introduced plants.

Fourth, the crested myna is considered a crop pest in its invasive range (Wood 1924, Phillips 1928, Eguchi and Amano 2004a, Yap and Sodhi 2004), and therefore affect agricultural activities, although the scale of this impact and the associated economic losses are difficult to assess.

Fifth, the crested myna could carry parasites that affect the health of humans or other animals (Dong et al., in prep.).

Sixth, the crested myna may disrupt public life where it occurs in large numbers, primarily because of its loud roosting behaviour (Chébez and Rodriguez 2013).

Qu. 4.20. Estimate the overall impact in the risk assessment area in foreseeable climate change conditions. In addition, details of overall impact in relevant biogeographical regions should be provided. Thorough assessment of the overall impact on biodiversity and ecosystem services, with impacts on economy as well as social and human health as aggravating factors, under future conditions.

RESPONSE	minimal minor **moderate** major massive	**CONFIDENCE**	**low** medium high

Under current conditions the species could already occur in large parts of the risk assessment area, hence the proportion of suitable area under future scenario RCP2.6 and RCP4.5 is not expected to change significantly. Therefore, there is no evidence that the impacts of the crested myna listed in Qu. 4.19 may change.

RISK SUMMARIES			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Introduction and Entry*	very unlikely unlikely moderately likely likely **very likely**	low medium **high**	There is evidence that the species has been introduced to the risk assessment area as a pet, and to be exhibited in zoos. There is also evidence that the crested myna has entered into the environment within the risk assessment area through releases/escapes of cage birds. The species is known to have been introduced to, and subsequently entered, the risk assessment area in Austria, Belgium, Germany, Portugal and Spain. The likelihood of introduction and entry into the risk assessment area is not expected to change under future scenarios RCP2.6 and RCP4.5.
Summarise Establishment*	very unlikely unlikely moderately likely likely **very likely**	low medium **high**	The crested myna is already established in the risk assessment area (in Portugal). The SDM indicates that it could potentially establish in all biogeographical regions and all countries within the risk assessment area, both under current climatic conditions and under future scenarios RCP2.6 and RCP4.5.
Summarise Spread*	very slowly slowly **moderately** rapidly very rapidly	low **medium** high	Detailed account of spread rates is lacking, but as documented in several locations around the world (and particularly based on the documented invasions in Vancouver and Portugal), the spread of the crested myna was assessed as moderate, and could subsequently be moderate across the entire risk assessment area. Spread will mostly occur through natural dispersal and to a lesser extent as stowaway i.e. on trucks, trains or ships (the latter vector being considered more effective in contributing to the spread of the species than the other two ones). Since the proportion of suitable environmental conditions will become greater in the risk

			assessment area under future scenario RCP2.6 and RCP4.5, the risk of spread of the crested myna may increase.
Summarise Impact*	minimal minor **moderate** major massive	**low** medium high	The crested myna behaves aggressively in interactions towards several native bird species. It could compete with native species, for food and breeding sites, could disperse seeds of harmful invasive plants, and have an effect on native species (birds, invertebrates) through predation. In particular, native cavity breeding birds could be impacted through breeding competition or predation of fledglings. Furthermore, the species could become a crop pest, pose a health risk because of its parasites and disrupt public life because of its roosting behaviour. The potential cost of management is considered high. Since the proportion of suitable environmental conditions will increase in the risk assessment area under future scenario RCP2.6 and RCP4.5, the impact of the crested myna may increase accordingly.
Conclusion of the risk assessment (overall risk)	low **moderate** high	low **medium** high	The crested myna is already established in the risk assessment area, indicating that suitable habitat and climate for establishment are present. The species is very likely to be introduced elsewhere in the risk assessment area as an escaped or introduced pet. Escapes from zoos are expected to be less likely. Considering the potential of crested myna for predation on and competitive displacement of native species (despite the absence of documented cases of native species extinctions), as well as the moderate spread capacity of the species, we scored moderate risk overall.

*in current climate conditions and in foreseeable future climate conditions

REFERENCES

Aagaard K, Lockwood J (2014) Exotic birds show lags in population growth. Divers Distrib 20: 547-554

Ahmad bin Darus, Stuebing R (1986) Vertebrate exotics in Sabah. Sabah Sac J 8: 296-306

American Ornithologists' Union (1998) Checklist of North American Birds. 7th edition. American Ornithologists' Union, Washington, DC.

Ashmole P, Ashmole M (2000) St Helena and Ascension Island: a natural history. Samuel Arnold, Oswestry.

Banks RC (1970) Birds imported into the United States in 1968. Special Scientific Report - Wildlife No. 136. Bureau of Sport Fisheries and Wildlife, Washington D.C.

Banks RC, Cicero C, Dunn JL, Kratter AW, Rasmussen PC, Remsen JV, Rising JD, Stotz DF (2005) Forty-Sixth Supplement to the American Ornithologists' Union Checklist of North American Birds. The Auk 122: 1026-1031

Banks RC, Clapp RB (1972) Birds imported into the United States in 1969. Special Scientific Report - Wildlife No. 148. Bureau of Sport Fisheries and Wildlife, Washington D.C.

Barras SC, Wright SE, Seamans TW (2003) Blackbird and starling strikes to civil aircraft in the United States, 1990-2001. USDA National Wildlife Research Center - Staff Publications 200: 91-96

Bartlett BR, Clausen CP (1978) Introduced parasites and predators of arthropod pests and weeds: a world review. Washington, D.C.: Agricultural Research Service, U.S. Dept. of Agriculture.

Bassó A, Leiva LA, Bierig PL (2012) Primeros registros de reproducción y nuevas observaciones del estornino crestado (*Acridotheres cristatellus*) en la Provincia de Santa Fé, Argentina. Nuestras Aves 57: 40-44

Bauer HG, Woog F (2008) Nichtheimische Vogelarten (Neozoen) in Deutschland. Teil 1: Auftreten, Bestände und Status. Vogelwarte 46: 157-194

Beck HE, Zimmermann NE, McVicar TR, Vergopolan N, Berg A, Wood EF (2018) Present and future Köppen-Geiger climate classification maps at 1-km resolution. Scientific data 5:180214

Bent AC (1950) Life histories of North American Wagtails, Shrikes, Vireos and their allies. Dover publications. New York.

BirdForum Opus contributors (2020) Crested Myna. In: BirdForum, the forum for wild birds and birding. Retrieved 8 June 2020 from https://www.birdforum.net/opus/Crested_Myna

Birdlife International (2015) European Red List of Birds. Luxemburg, Official Publications of the European Communities.

BirdLife International (2016) *Acridotheres cristatellus*. The IUCN Red List of Threatened Species 2016: e.T22710946A94269013. http://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T22710946A94269013.en

BirdLife International (2019a) *Passer domesticus* (amended version of 2018 assessment). The IUCN Red List of Threatened Species 2019: e.T103818789A155522130. https://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T103818789A155522130.en

BirdLife International (2019b) *Sturnus vulgaris*. The IUCN Red List of Threatened Species 2019: e.T22710886A137493608. https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T22710886A137493608.en

Booy O, Robertson PA, Moore N, Ward J, Roy HE, Adriaens T, Shaw D, Van Valkenburg J, Wyn G, Bertolino S, Blight O, Branquart E, Brundu G, Caffrey J, Capizzi D, Casaer J, De Clerck O, Coughlan NE, Davis E, Dick JTA, Essl F, Fried G, Genovesi P, González-Moreno P, Huysentruyt F, Jenkins SR, Kerckhof F, Lucy FE, Nentwig W, Newman J, Rabitsch W, Roy S, Starfinger U, Stebbing PD, Stuyck J, Sutton-Croft M, Tricarico E, Vanderhoeven S, Verreycken H, Mill AC (2020) Using structured eradication feasibility assessment to prioritise the management of new and emerging invasive alien species in Europe. Global Change Biol., doi: 10.1111/gcb.1528

Bosmans J (2009) Eerste broedgevallen van Treurmaina *Acridotheres tristis* voor België. Natuur.oriolus 75: 122-123

Brazil M (2009) Birds of East Asia: eastern China, Taiwan, Korea, Japan, eastern Russia. Christopher Helm, London.

Campbell W, Dawe NK, McTaggart-Cowan I, Cooper JM, Kaiser GW, McNall MC, Smith GJ (2007) Birds of British Columbia, Volume 3: Passerines-Flycatchers through Vireos: UBC Press.

Cardador, L., Tella, J.L., Anadón, J.D., Abellán Rodenas, P. y Carrete, M. (2019). The European trade ban on wild birds reduced invasion risks. Conservation Letters, 12 (3), e12631.

Cassey P, Blackburn TM, Sol D, Duncan RP, Lockwood JL (2004) Global patterns of introduction effort and establishment success in birds. P Roy Soc Lond B BIO 271: S405-S408

Chébez JC, Rodríguez G (2013) La fauna gringa: especies introducidas en la Argentina. Buenos Aires. Fundación de Historia Natural Félix de Azara. 224 pp.

Cheke A (2008) Seafaring behaviour in House Crows *Corvus splendens* - a precursor to ship-assisted dispersal. Phelsuma 16:65-68

Chiurla EH (1997) Nidificación del Estornino Crestado (*Acridotheres cristatellus*) en el sudeste de la provincia de Buenos Aires. Nuestras Aves 39: 6

Clapp RB (1975) Birds imported into the United States in 1972. Special Scientific Report - Wildlife no. 193. U.S. Fish and Wildlife Service, Washington, DC.

Clapp RB, Banks RC (1973a) Birds imported into the United States in 1970. Special Scientific Report - Wildlife no. 164. U.S. Fish and Wildlife Service, Washington, DC.

Clapp RB, Banks RC (1973b) Birds imported into the United States in 1971. Special Scientific Report - Wildlife no. 170. U.S. Fish and Wildlife Service, Washington, DC.

Clout MN, Hay JR (1989) The importance of birds as browsers, pollinators and seed dispersers in new zealand forests. New Zeal J Ecol 12: 27-33

Colautti RI, MacIsaac HJ (2004) A neutral terminology to define 'invasive' species. Divers Distrib 10: 135-141

CONABIO (2017) Análisis de riesgo rápido de *Acridotheres cristatellus*. Sistema de información sobre especies invasoras en México. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. México DF.

Conser C (2013) Invasive Species Pathway Risk Analysis for California. University of California, Davis, 1–97. http://www.iscc.ca.gov/docs/reports/CISAC-Pathway-Report-July-2013-web.pdf

Craig AJFK, Feare CJ (2009) Family Sturnidae (starlings), p. 653-758. In: del Hoyo J, Elliot A, Christie DA (eds.) Handbook of the birds of the world. Vol. 14. Bush-shrikes to Old World sparrows. Barcelona: Lynx Edicions.

Craig AJFK, Feare CJ (2020) Crested Myna (*Acridotheres cristatellus*). In: del Hoyo J, Elliott A, Sargatal J, Christie DA, de Juana E (eds.) Handbook of the Birds of the World Alive. Lynx Edicions, Barcelona. (retrieved from https://www.hbw.com/node/60868 on 16 February 2020).

De Juana E, Garcia E (2015) The Birds of the Iberian Peninsula. Bloomsbury Publishing PLC.

Del Hoyo JAE, Christie D (2009) Handbook of the Birds of the World. Volume 14: Bush-shrikes to Old World Sparrows. Barcelona: Lynx Edicions.

Di Giácomo AG, Di Giácomo AS, Barbaskas M (1993) Nuevos registros de *Sturnus vulgaris* y *Acridotheres cristatellus* en Buenos Aires. Nuestras Aves 29: 32-33.

Ditrich O, Palkovič L, Štěrba J, Prokopič J, Loudová J, Giboda M (1991) The first finding of *Cryptosporidium baileyi* in man. Parasitol. Res. 77: 44-47

Dong H, Cheng R, Li X, Li J, Chen Y, Ban C, Zhang X, Liu F, Zhang L (in prep.) Identification of *Cryptosporidium* species, *Enterocytozoon bieneusi* genotypes, and *Giardia duodenalis* assemblages in birds in Henan, China. DOI: 10.21203/rs.2.19784/v1

Duszynski DW, Upton SJ, Couch L (2004) The Coccidia of the World. https://web.archive.org/web/20101230215149/http:/biology.unm.edu/biology/coccidia/home.html

eBird Basic Dataset (2023) Version: EBD_relDec-2022. Cornell Lab of Ornithology, Ithaca, New York. Dec 2022.

Eguchi K, Amano HE (2004a) Invasive birds in Japan. Global Environmental Research 8: 29-39

Eguchi K, Amano HE (2004b). Spread of exotic birds in Japan. Ornithol Sci 3: 3-11

Evans T, Blackburn TM, Jeschke JM, Probert A, Bacher S (in press) Application of the Socio-economic Impact Classification for Alien Taxa (SEICAT) to a global assessment of alien bird impacts. NeoBiota, in press.

Evans T, Kumschick S, Blackburn TM (2016) Application of the Environmental Impact Classification for Alien Taxa (EICAT) to a global assessment of alien bird impacts. Divers Distrib 22: 919-931

Feare C, Craig A (1999) Starlings and Mynas. Princeton University Press, Princeton, NJ.

Feare CJ, Saavedra S (2009) Development of a strategy for control of Common Mynas (*Acridotheres tristis)* on St Helena. A report to the Royal Society for the Protection of Birds September 2009. Project code: 9IS-G-SAIS.

Fleischmann K (1997) Invasion of alien woody plants on the islands of Mahé and Silhouette, Seychelles. J Veg Sci 8: 5-12

Florida Fish and Wildlife Conservation Commission (2003) Florida's breeding bird atlas: A collaborative study of Florida's birdlife. http://www.myfwc.com/bba/ (Date accessed 14/03/2020).

Flower SS (1938) Further notes on the duration of life in animals. IV. Birds. P Zool Soc Lond A 107: 195-235

Gabrielson IN, Jewett SG (1940) Birds of Oregon. Oregon State College, Corvallis, Oregon.

Gimena Aguerre P, Petracci F, Zamorano M (2008) Confirmación de la reproducción del Estornino Crestado (*Acridotheres cristatellus*) en la ciudad de La Plata, Buenos Aires, Argentina. Revista Nuestras Aves 53: 19

GISD (2017) Species profile: *Acridotheres tristis*. Global Invasive Species Database. Downloaded from http://www.iucngisd.org/gisd/speciesname/Acridotheres+tristis on 20-04-2017.

Gonzalez GC (2006) Impact of Introduced Birds in the Philippines. J Environ Sci Manag 9: 66-79

Grarock K, Tidemann CR, Wood J, Lindenmayer DB (2012) Is It Benign or Is It a Pariah? Empirical Evidence for the Impact of the Common Myna (*Acridotheres tristis*) on Australian Birds. PLoS ONE 7: e40622

Guiaşu RC (2016) Non-native Species and Their Role in the Environment. The need for a broader perspective. Boston: Brill. 316 pp.

Hawkins CL, Bacher S, Essl F, Hulme PE, Jeschke JM, Kühn I, Kumschick S, Nentwig W, Pergl J, Pyšek P, et al. (2015) Framework and guidelines for implementing the proposed IUCN Environmental Impact Classification for Alien Taxa (EICAT). Divers Distrib 21: 1360-1363

Holzapfel C, Levin N, Hatzofe O, Kark S (2006) Colonisation of the Middle East by the invasive Common Myna *Acridotheres tristis* L., with special reference to Israel. Sandgrouse 28: 44-51

Huang DB, White AC (2006) An updated review on *Cryptosporidium* and *Giardia*. Gastroenterol Clin N 35: 291-314

Iqbal M, Noske RA, Hermawan B, Istanto D, Arfi M (2014) The first wild Common Mynas *Acridotheres tristis* in Java: colonists or aviary escapees? Kukila 18: 22-26

Jeyarajasingam A, Pearson A (2012) A Field Guide to the Birds of Peninsular Malaysia and Singapore (Second Edition). Oxford: Oxford University Press.

Johnson SR, Campbell RW (1995) Crested Myna (*Acridotheres cristatellus*), version 2.0. In: Poole AF, Gill FB (eds) The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bna.157

Kresse VA, Kepka O (1988) Haubenmaina, *Acridotheres cristatellus* (L.), ansässig in Graz (Aves, Sturnidae). Mitteilungen der Abteilung für Zoologie am Landesmuseum Joanneum Graz 41: 49-50

Levatich T, Ligocki S (2020) EOD - eBird Observation Dataset. Cornell Lab of Ornithology. Occurrence dataset https://doi.org/10.15468/aomfnb accessed via GBIF.org on 2020-08-31. https://www.gbif.org/occurrence/2216746958

Lever C (1994) Naturalized Animals: The Ecology of Successfully Introduced Species. T. and A.D. Poyser, London, xiii + 354 pp.

Lever C. (2005) Naturalised Birds of the World. T and AD Poyser London UK.

Leyequién E, de Boer WF, Cleef A (2007) Influence of body size on coexistence of bird species. Ecological Research 22: 735–741

Lindell C (1996) Patterns of nest usurpation: when should species converge on nest niches? Condor 98: 464-473

Lindsay DS, Blagburn BL, Sundermann CA (1989) Morphometric Comparison of the Oocysts of *Cryptosporidium meleagridis* and *Cryptosporidium baileyi* from Birds. P Helm Soc Wash 56: 91-92

Linnell MA, Conover MR, Ohashi TJ (1996) Analysis of bird strikes at a tropical airport. J Wildlife Manage 60: 935-945

Linnell MA, Conover MR, Ohashi TJ (1999) Biases in bird strike statistics based on pilot reports. J Wildlife Manage 63: 997-1003

Mann CF (1987) Notable bird observations from Brunei, Borneo. Forktall 3: 51–56

Marshall DB, Hunter MG, Contreras AL (eds) (2003) Birds of Oregon: A General Reference. Oregon State University Press, Corvallis.

Massam M, Kirkpatrick W, Page A (2010) Assessment and prioritisation of risk for forty introduced animal species. Invasive Animals Cooperative Research Centre, Canberra.

Matias R (2002) Aves exóticas que nidificam em Portugal Continental. Instituto da Conservação da Natureza, Lisboa.

McCarthy EM (2006) Handbook of Avian Hybrids of the World. New York, NY. Oxford University Press. 583 pp.

Monticelli D (2008) Finding introduced birds near Lisbon, Portugal. Birding World 21: 1-4

Mori E, Meini S, Strubbe D, Ancillotto L, Sposimo P, Menchetti M (2018) Do alien free-ranging birds affect human health? A global summary of known zoonoses. In: Mazza G, Tricarcio E (eds) Invasive Species and Human Health, 1st ed. CABI, Wallingford.

Narusue M (1981) Exotic birds seen in a metropolitan area of Tokyo. Yurikamome 309: 6-7 (in Japanese)

Narwade SS, Prabhu MV, Shaikh PA, Rahmani AR (2012) Third Tri-monthly report of the Avifaunal survey carried out in 10 km radius area of Navi Mumbai International Airport (NMIA). Submitted by BNHS, India. 42 pp.

Navas JR (2002) Las aves exóticas introducidas y naturalizadas en la Argentina. Revista del Museo Argentino de Ciencias Naturales 4: 191-202

Nehring S, Rabitsch W (2015) Artenliste der Neozoa (Wirbeltiere) in Deutschland. In: Nehring, S., Rabitsch, W., Kowarik, I. and Essl, F. (Eds.) Naturschutzfachliche Invasivitätsbewertungen für in Deutschland wild lebende gebietsfremde Wirbeltiere. BfN-Skripten 409: 151-222

Oliveira R, Godinho R, Randi E, Ferrand N, Alves PC (2008) Molecular analysis of hybridisation between wild and domestic cats *(Felis silvestris*) in Portugal: implications for conservation. Conserv Genet 9: 1-11

Orchan Y, Chiron F, Shwartz A, Kark S (2013) The complex interaction network among multiple invasive bird species in a cavity-nesting community. Biol Invasions 15: 429-445

OwYong A (2015) Singapore Avifauna, July 15, 2015 https://singaporebirdgroup.wordpress.com/2015/07/15/four-introduced-species-gone-maybe-extinct-locally/

Pacheco NN (2018) Annotated Checklist of the Birds of Cuba: 2018-2019 edition. Ediciones Nuevos Mundos.

Pacheco NN, Mouriño ER (2017) Annotated Checklist of the Birds of Cuba. Ediciones Nuevos Mundos.

Peacock DS, van Rensburg BJ, Robertson MP (2007) The distribution and spread of the invasive alien Common Myna, *Acridotheres tristis* L. (Aves: Sturnidae), in southern Africa. S Afr J Sci 103: 465-473

Phillips JC (1928) Wild birds introduced or transplanted in North America. US Department of Agriculture Technical Bulletin No. 61. Publications from USDA-ARS / UNL Faculty. 819.

Phillips R (1898) Breeding insectivores birds. Avicultural Magazine 44: 137

Pimentel D, Lach L, Zuniga R, Morrison D (2000) Environmental and economic costs of nonindigenous species in the United States. BioScience 50: 53-65

Prestwich AA (1969) News and views. Avicultural Magazine 75: 277

Puglisi L, Bosi E, Corsi I, Del Sere M, Pezzo F, Sposimo P (2009) Usignolo del Giappone, Bengalino and Co: alieni in Toscana. Alula, XVI (1-2): 426-431

Restall RL (1968) *The Chinese crested myna*. The Avicultural magazine 74: 161-168.

Robino Gómez A (2011) Registros de estornino crestado (*Acridotheres cristatellus*) en la ciudad de Córdoba. EcoRegistros Revista No 14.

Robson C (2000) A field guide to the Birds of South-East Asia. London: New Holland.

Rodrigo TF (2017) Estornino crestado (*Acridotheres cristatellus*) en la ciudad de Bahía Blanca: una especie invasora de la Argentina? BioScriba 8: 9-11

Rodriguez Castaneda Y, Wiley JW, Garrido OH (2017) Additional records of Lazuli Bunting (*Passerina amoena*) and first records of several wild-caught exotic birds for Cuba. The Journal of Caribbean Ornithology 30: 134-142

Saavedra S, Maraver A, Anadón J, Tella JL (2015) A survey of recent introduction events, spread and mitigation efforts of mynas (*Acridotheres* sp.) in Spain and Portugal. Anim Biodiv Conserv 38: 121-127

Scalera R, Rabitsch W, Genovesi P, Adriaens T, Robertson P, Moore N, Booy O, Chapman D, Kettunen M (2018) Risk Assessment for *Acridotheres tristis* (Linnaeus, 1766). In: Roy HE, Rabitsch W, Scalera R (eds.) Risk assessment developed under the *Study on Invasive Alien Species – Development of risk assessments to tackle priority species and enhance prevention* Contract No 07.0202/2016/740982/ETU/ENV.D.2. Luxemburg: Publications Office of the European Union, 83 pp.

Scheffer TH, Cottam C (1935) The Crested Myna, Or Chinese Starling, In The Pacific Northwest. Tech. Bull. U.S. Dep. Agric. 467: 1-26

Self BA (2003) Vancouver crested mynas gone. Winging It 15: 7

Sheldon FH, Moyle RG, Kennard J (2001) Ornithology of Sabah: history, gazetteer, annotated checklist, and bibliography. Ornithological Monographs 52: 1-285

Simberloff D, Gibbons L (2004) Now you see them, now you don't - population crashes of established introduced species. Biol Invasions 6: 161-172

Simner PJ, Kraft CS (2017) *Medical Parasitology Taxonomy Update: January 2012 to December 2015*. J Clin Microbiol 55: 43-47

Smythies BE (2000) *The Birds of Borneo*. 4th ed. (revised by G. W. H. Davison). Natural History Publications, Kota Kinabalu, Sabah.

Sol D, Timmermans S, Lefebvre L (2002) Behavioural flexibility and invasion success in birds. Anim Behav 63: 495-502

Soorae PS (2015) Alien species recorded in the United Arab Emirates: an initial list of terrestrial and freshwater species. Journal of Threatened Taxa 7: 7910-7921

Sponseller J K, Griffiths JK, Tzipori S (2014) The evolution of respiratory Cryptosporidiosis: evidence for transmission by inhalation. Clin Microbiol Rev 27: 575-586

Van den Top G (2004) The Social Dynamics of Deforestation in the Philippines: Actions, Options and Motivations. NIAS Press 352 pp.

Vergeer JW, van Zuylen J (1994) Broedvogels van Zeeland. Avifauna van Nederland dl. 2. KNNV Uitgeverij/Sovon, Utrecht.

Vermeersch G, Anselin A, Devos K (2006) Bijzondere broedvogels in Vlaanderen in de periode 1994-2005. Populatietrends en recente status van zeldzame, kolonievormende en exotische broedvogels in Vlaanderen. Mededeling INBO.M.2006.2. Instituut voor Natuur- en Bosonderzoek, Brussel.

Verzelen Y, Adriaens T, Scalera R, Beckmann B, Thibault M, Robertson P, Kettunen M, Bacher S, Rabitsch W (2020) Risk Assessment and annex on measures for red-vented bulbul *Pycnonotus cafer* (Linnaeus, 1766). In: Roy HE, Rabitsch W, Scalera R (eds.) Development of risk assessments to tackle priority species and enhance prevention : final report, executive summary and annexes: Contract No 07.0202/2018/788519/ETU/ENV.D2. Luxembourg: Publications Office of the European Union, 109 pp.

Wai CS (2006) Religious Release of Birds in Hong Kong. Unpublished thesis. University of Hong Kong, Hong Kong.

Wang Z-D, Liu Q, Liu H-H, Li S, Zhang L, Zhao Y-K, Zhu X-Q (2018) Prevalence of *Cryptosporidium microsporidia* and *Isospora* infection in HIV-infected people: a global systematic review and meta-analysis. Parasites and Vectors 11: 28

Wells DR (2010) The birds of the Thai-Malay peninsula. Bloomsbury Publishing.

Wood CA (1924) The Starling Family at Home and Abroad. The Condor 26: 123-136

Woods M, McDonald RA, Harris S (2003) Predation of wildlife by domestic cats *Felis catus* in Great Britain. Mammal Rev 33: 174-188

Yap CAM, Sodhi NS (2004) Southeast Asian invasive birds: ecology, impact and management. Ornithol Sci 3: 57-67

Zelaya D, Forcelli D, Goldfeder S, Ramadori D, Silva Croome M, Bellagamba P (2001) El Estornino Crestado (*Acridotheres cristatellus*) en el sudeste de la provincia de Buenos Aires, Argentina. Nuestras Aves 42: 26-27

Zomer RJ, Trabucco A, Bossio DA, Verchot LV (2008) Climate change mitigation: A spatial analysis of global land suitability for clean development mechanism afforestation and reforestation. Agriculture, Ecosystems and Environment 126: 67-80

Distribution Summary

Please answer as follows:
Yes if recorded, established or invasive
– if not recorded, established or invasive
? Unknown; data deficient

The columns refer to the answers to Questions A5 to A12 under Section A.
For data on marine species at the Member State level, delete Member States that have no marine borders. In all other cases, provide answers for all columns.

Member States

	Recorded	Established (currently)	Possible establishment (under current climate)	Possible establishment (under foreseeable climate)	Invasive (currently)
Austria	Yes		Yes	Yes	
Belgium	Yes		Yes	Yes	
Bulgaria			Yes	Yes	
Croatia			Yes	Yes	
Cyprus			Yes	Yes	
Czech Republic			Yes	Yes	
Denmark			Yes	Yes	
Estonia			Yes	Yes	
Finland					
France			Yes	Yes	
Germany	Yes		Yes	Yes	
Greece			Yes	Yes	
Hungary			Yes	Yes	
Ireland			Yes	Yes	
Italy			Yes	Yes	
Latvia			Yes	Yes	
Lithuania			Yes	Yes	
Luxembourg			Yes	Yes	
Malta			Yes	Yes	
Netherlands	Yes		Yes	Yes	
Poland			Yes	Yes	
Portugal	Yes	Yes	Yes	Yes	
Romania			Yes	Yes	
Slovakia			Yes	Yes	
Slovenia			Yes	Yes	
Spain	Yes		Yes	Yes	
Sweden					

Biogeographical regions of the risk assessment area

	Recorded	Established (currently)	Possible establishment (under current climate)	Possible establishment (under foreseeable climate)	Invasive (currently)
Alpine					
Atlantic	Yes		Yes	Yes	
Black Sea			Yes	Yes	
Boreal					
Continental	Yes		Yes	Yes	
Mediterranean	Yes	Yes	Yes	Yes	
Pannonian			Yes	Yes	
Steppic			Yes	Yes	

ANNEX I Scoring of Likelihoods of Events

(taken from UK Non-native Organism Risk Assessment Scheme User Manual, Version 3.3, 28.02.2005)

Score	**Description**	**Frequency**
Very unlikely	This sort of event is theoretically possible, but is never known to have occurred and is not expected to occur	1 in 10,000 years
Unlikely	This sort of event has occurred somewhere at least once in the last millenium	1 in 1,000 years
Possible	This sort of event has occurred somewhere at least once in the last century	1 in 100 years
Likely	This sort of event has happened on several occasions elsewhere, or on at least once in the last decade	1 in 10 years
Very likely	This sort of event happens continually and would be expected to occur	Once a year

ANNEX II Scoring of Magnitude of Impacts

(modified from UK Non-native Organism Risk Assessment Scheme User Manual, Version 3.3, 28.02.2005)

Score	**Biodiversity and ecosystem impact**	**Ecosystem Services impact**	**Economic impact (Monetary loss and response costs per year)**	**Social and human health impact, and other impacts**
	Question 5.1-5	*Question 5.6-8*	*Question 5.9-13*	*Question 5.14-18*
Minimal	Local, short-term population loss, no significant ecosystem effect	No services affected[5]	Up to 10,000 Euro	No social disruption. Local, mild, short-term reversible effects to individuals.
Minor	Some ecosystem impact, reversible changes, localised	Local and temporary, reversible effects to one or few services	10,000-100,000 Euro	Significant concern expressed at local level. Mild short-term reversible effects to identifiable groups, localised.
Moderate	Measureable long-term damage to populations and ecosystem, but reversible; little spread, no extinction	Measureable, temporary, local and reversible effects on one or several services	100,000-1,000,000 Euro	Temporary changes to normal activities at local level. Minor irreversible effects and/or larger numbers covered by reversible effects, localised.
Major	Long-term irreversible ecosystem change, spreading beyond local area	Local and irreversible or widespread and reversible effects on one / several services	1,000,000-10,000,000 Euro	Some permanent change of activity locally, concern expressed over wider area. Significant irreversible effects locally or reversible effects over large area.
Massive	Widespread, long-term population loss or extinction, affecting several species with serious ecosystem effects	Widespread and irreversible effects on one / several services	Above 10,000,000 Euro	Long-term social change, significant loss of employment, migration from affected area. Widespread, severe, long-term, irreversible health effects.

[5] Not to be confused with “no impact”.

ANNEX III Scoring of Confidence Levels

(modified from Bacher et al. 2017)

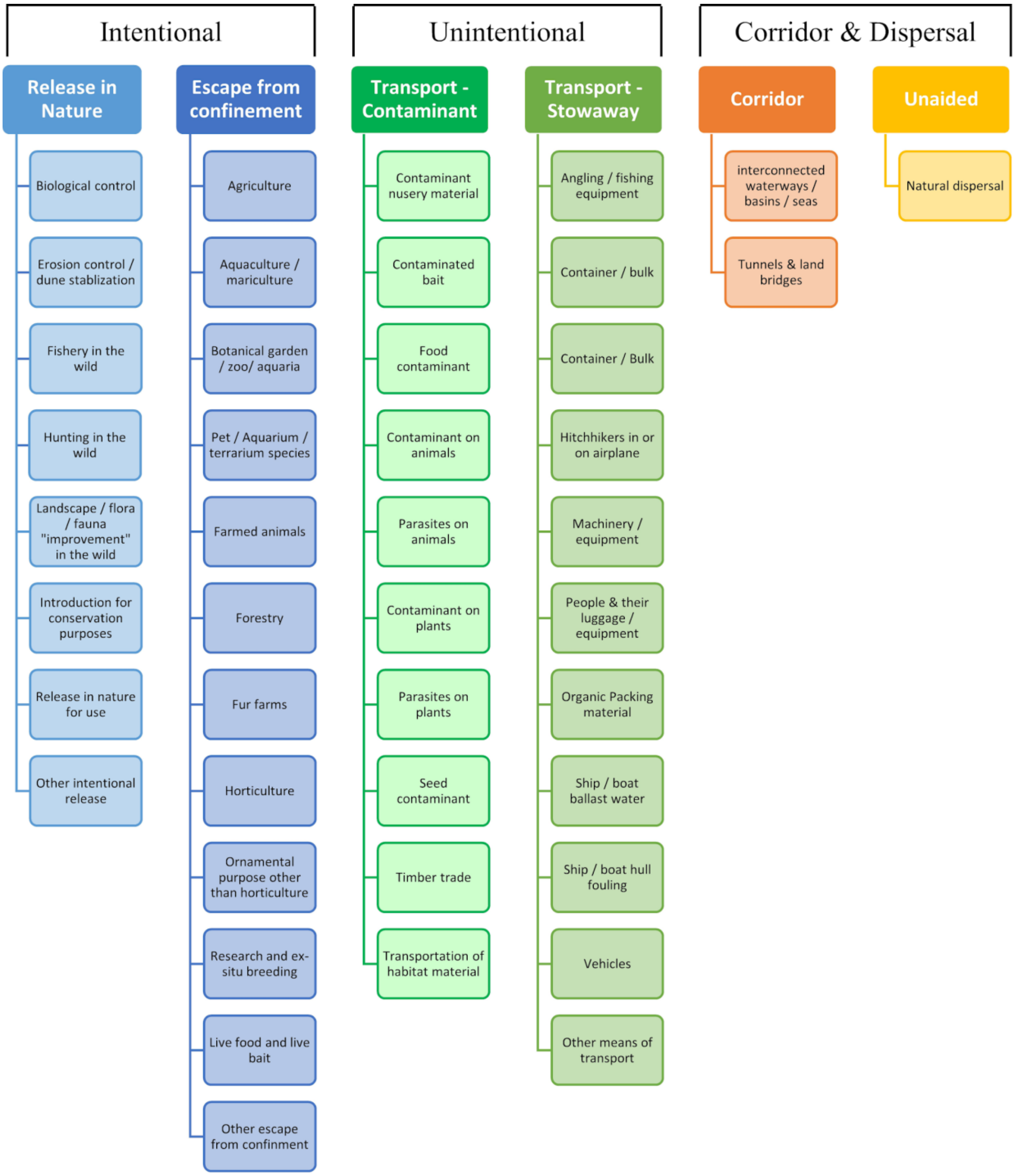
Each answer provided in the risk assessment must include an assessment of the level of confidence attached to that answer, reflecting the possibility that information needed for the answer is not available or is insufficient or available but conflicting.

The responses in the risk assessment should clearly support the choice of the confidence level.

Confidence level	**Description**
Low	There is no direct observational evidence to support the assessment, e.g. only inferred data have been used as supporting evidence *and/or* Impacts are recorded at a spatial scale which is unlikely to be relevant to the assessment area *and/or* Evidence is poor and difficult to interpret, e.g. because it is strongly ambiguous *and/or* The information sources are considered to be of low quality or contain information that is unreliable.
Medium	There is some direct observational evidence to support the assessment, but some information is inferred *and/or* Impacts are recorded at a small spatial scale, but rescaling of the data to relevant scales of the assessment area is considered reliable, or to embrace little uncertainty *and/or* The interpretation of the data is to some extent ambiguous or contradictory.
High	There is direct relevant observational evidence to support the assessment (including causality) *and* Impacts are recorded at a comparable scale *and/or* There are reliable/good quality data sources on impacts of the taxa *and* The interpretation of data/information is straightforward *and/or* Data/information are not controversial or contradictory.

ANNEX IV CBD pathway categorisation scheme

Overview of CBD pathway categorisation scheme showing how the 44 pathways relate to the six main pathway categories. All of the pathways can be broadly classified into 1) those that involve intentional transport (blue), 2) those in which the taxa are unintentionally transported (green) and 3) those where taxa moved between regions without direct transportation by humans and/or via artificial corridors (orange and yellow). **Note that the pathways in the category "Escape from confinement" can be considered intentional for the introduction into the risk assessment area and unintentional for the entry into the environment.**



ANNEX V Ecosystem services classification (CICES V5.1, simplified) and examples

For the purposes of this risk assessment, please feel free to use what seems as the most appropriate category / level / combination of impact (Section – Division – Group), reflecting information available.

Section	Division	Group	Examples (i.e. relevant CICES "classes")
Provisioning	**Biomass**	**Cultivated *terrestrial* plants**	Cultivated terrestrial plants (including fungi, algae) grown for nutritional purposes; Fibres and other materials from cultivated plants, fungi, algae and bacteria for direct use or processing (excluding genetic materials); Cultivated plants (including fungi, algae) grown as a source of energy *Example: negative impacts of non-native organisms to crops, orchards, timber etc.*
		Cultivated *aquatic* plants	Plants cultivated by in- situ aquaculture grown for nutritional purposes; Fibres and other materials from in-situ aquaculture for direct use or processing (excluding genetic materials); Plants cultivated by in- situ aquaculture grown as an energy source. *Example: negative impacts of non-native organisms to aquatic plants cultivated for nutrition, gardening etc. purposes.*
		Reared animals	Animals reared for nutritional purposes; Fibres and other materials from reared animals for direct use or processing (excluding genetic materials); Animals reared to provide energy (including mechanical) *Example: negative impacts of non-native organisms to livestock*
		Reared *aquatic* animals	Animals reared by in-situ aquaculture for nutritional purposes; Fibres and other materials from animals grown by in-situ aquaculture for direct use or processing (excluding genetic materials); Animals reared by in-situ aquaculture as an energy source *Example: negative impacts of non-native organisms to fish farming*
		Wild plants (terrestrial and aquatic)	Wild plants (terrestrial and aquatic, including fungi, algae) used for nutrition; Fibres and other materials from wild plants for direct use or processing (excluding genetic materials); Wild plants (terrestrial and aquatic, including fungi, algae) used as a source of energy *Example: reduction in the availability of wild plants (e.g. wild berries, ornamentals) due to non-native organisms (competition, spread of disease etc.)*
		Wild animals (terrestrial and aquatic)	Wild animals (terrestrial and aquatic) used for nutritional purposes; Fibres and other materials from wild animals for direct use or processing (excluding genetic materials); Wild animals (terrestrial and aquatic) used as a source of energy

			Example: reduction in the availability of wild animals (e.g. fish stocks, game) due to non-native organisms (competition, predations, spread of disease etc.)
	Genetic material from all biota	**Genetic material** from plants, algae or fungi	Seeds, spores and other plant materials collected for maintaining or establishing a population; Higher and lower plants (whole organisms) used to breed new strains or varieties; Individual genes extracted from higher and lower plants for the design and construction of new biological entities *Example: negative impacts of non-native organisms due to interbreeding*
		Genetic material from animals	Animal material collected for the purposes of maintaining or establishing a population; Wild animals (whole organisms) used to breed new strains or varieties; Individual genes extracted from organisms for the design and construction of new biological entities *Example: negative impacts of non-native organisms due to interbreeding*
	Water[6]	**Surface water** used for nutrition, materials or energy	Surface water for drinking; Surface water used as a material (non-drinking purposes); Freshwater surface water, coastal and marine water used as an energy source *Example: loss of access to surface water due to spread of non-native organisms*
		Ground water for used for nutrition, materials or energy	Ground (and subsurface) water for drinking; Ground water (and subsurface) used as a material (non-drinking purposes); Ground water (and subsurface) used as an energy source *Example: reduced availability of ground water due to spread of non-native organisms and associated increase of ground water consumption by vegetation.*
Regulation and Maintenance	**Transformation** of biochemical or physical inputs to ecosystems	**Mediation of wastes or toxic substances** of anthropogenic origin by living processes	Bio-remediation by micro-organisms, algae, plants, and animals; Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals *Example: changes caused by non-native organisms to ecosystem functioning and ability to filtrate etc. waste or toxics*
		Mediation of nuisances of anthropogenic origin	Smell reduction; noise attenuation; visual screening (e.g. by means of green infrastructure) *Example: changes caused by non-native organisms to ecosystem structure, leading to reduced ability to mediate nuisances.*
	Regulation of physical, chemical, biological conditions	**Baseline flows and extreme event** regulation	Control of erosion rates; Buffering and attenuation of mass movement; Hydrological cycle and water flow regulation (Including flood control, and coastal protection); Wind protection; Fire protection *Example: changes caused by non-native organisms to ecosystem functioning or structure leading to, for example,*

[6] Note: in the CICES classification provisioning of water is considered as an abiotic service whereas the rest of ecosystem services listed here are considered biotic.

			destabilisation of soil, increased risk or intensity of wild fires etc.
		Lifecycle maintenance, habitat and gene pool protection	Pollination (or 'gamete' dispersal in a marine context); Seed dispersal; Maintaining nursery populations and habitats (Including gene pool protection) *Example: changes caused by non-native organisms to the abundance and/or distribution of wild pollinators; changes to the availability / quality of nursery habitats for fisheries*
		Pest and disease control	Pest control; Disease control *Example: changes caused by non-native organisms to the abundance and/or distribution of pests*
		Soil quality regulation	Weathering processes and their effect on soil quality; Decomposition and fixing processes and their effect on soil quality *Example: changes caused by non-native organisms to vegetation structure and/or soil fauna leading to reduced soil quality*
		Water conditions	Regulation of the chemical condition of freshwaters by living processes; Regulation of the chemical condition of salt waters by living processes *Example: changes caused by non-native organisms to buffer strips along water courses that remove nutrients in runoff and/or fish communities that regulate the resilience and resistance of water bodies to eutrophication*
		Atmospheric composition and conditions	Regulation of chemical composition of atmosphere and oceans; Regulation of temperature and humidity, including ventilation and transpiration *Example: changes caused by non-native organisms to ecosystems' ability to sequester carbon and/or evaporative cooling (e.g. by urban trees)*
Cultural	**Direct, in-situ and outdoor interactions** with living systems that depend on presence in the environmental setting	**Physical and experiential** interactions with natural environment	Characteristics of living systems that that enable activities promoting health, recuperation or enjoyment through active or immersive interactions; Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions *Example: changes caused by non-native organisms to the qualities of ecosystems (structure, species composition etc.) that make it attractive for recreation, wildlife watching etc.*
		Intellectual and representative interactions with natural environment	Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge; Characteristics of living systems that enable education and training; Characteristics of living systems that are resonant in terms of culture or heritage; Characteristics of living systems that enable aesthetic experiences

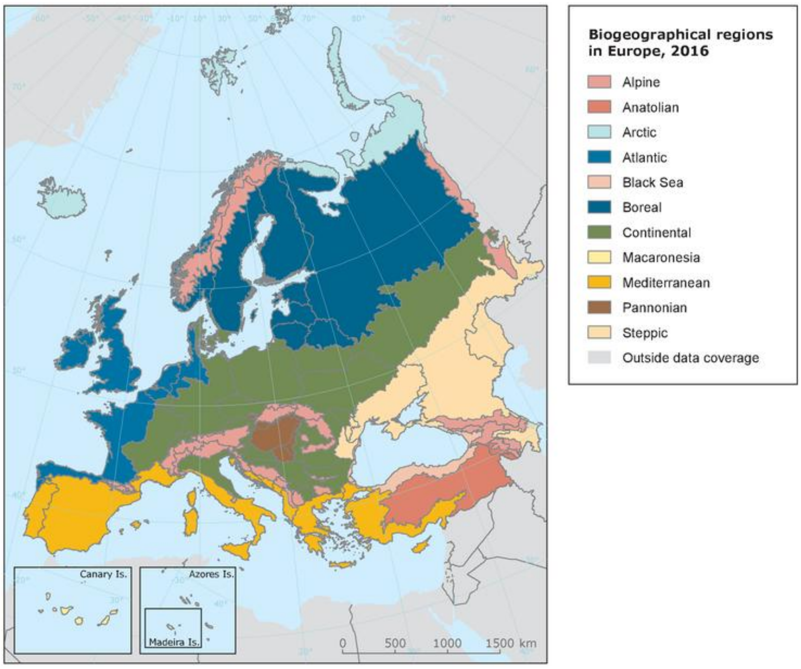
			Example: changes caused by non-native organisms to the qualities of ecosystems (structure, species composition etc.) that have cultural importance
	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	**Spiritual, symbolic** and other interactions with natural environment	Elements of living systems that have symbolic meaning; Elements of living systems that have sacred or religious meaning; Elements of living systems used for entertainment or representation *Example: changes caused by non-native organisms to the qualities of ecosystems (structure, species composition etc.) that have sacred or religious meaning*
		Other biotic characteristics that have a **non-use value**	Characteristics or features of living systems that have an existence value; Characteristics or features of living systems that have an option or bequest value *Example: changes caused by non-native organisms to ecosystems designated as wilderness areas, habitats of endangered species etc.*

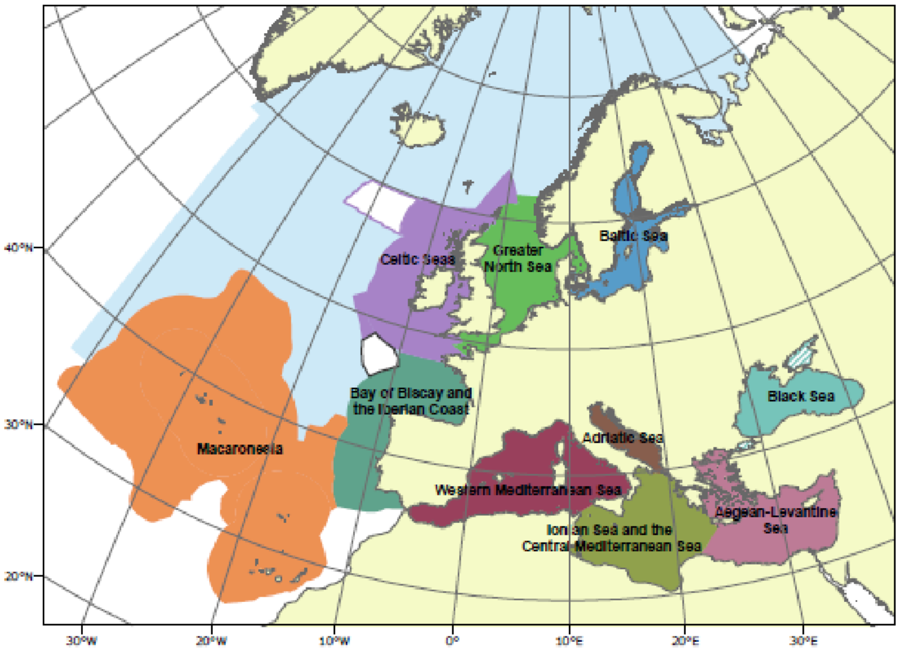
ANNEX VI EU Biogeographic Regions and MSFD Subregions

See https://www.eea.europa.eu/data-and-maps/figures/biogeographical-regions-in-europe-2 , http://ec.europa.eu/environment/nature/natura2000/biogeog_regions/

and

https://www.eea.europa.eu/data-and-maps/data/msfd-regions-and-subregions-1/technical-document/pdf





ANNEX VII Delegated Regulation (EU) 2018/968 of 30 April 2018

see https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32018R0968

ANNEX VIII Species Distribution Model

Projection of environmental suitability for *Acridotheres cristellatus* establishment in Europe

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08 October 2020

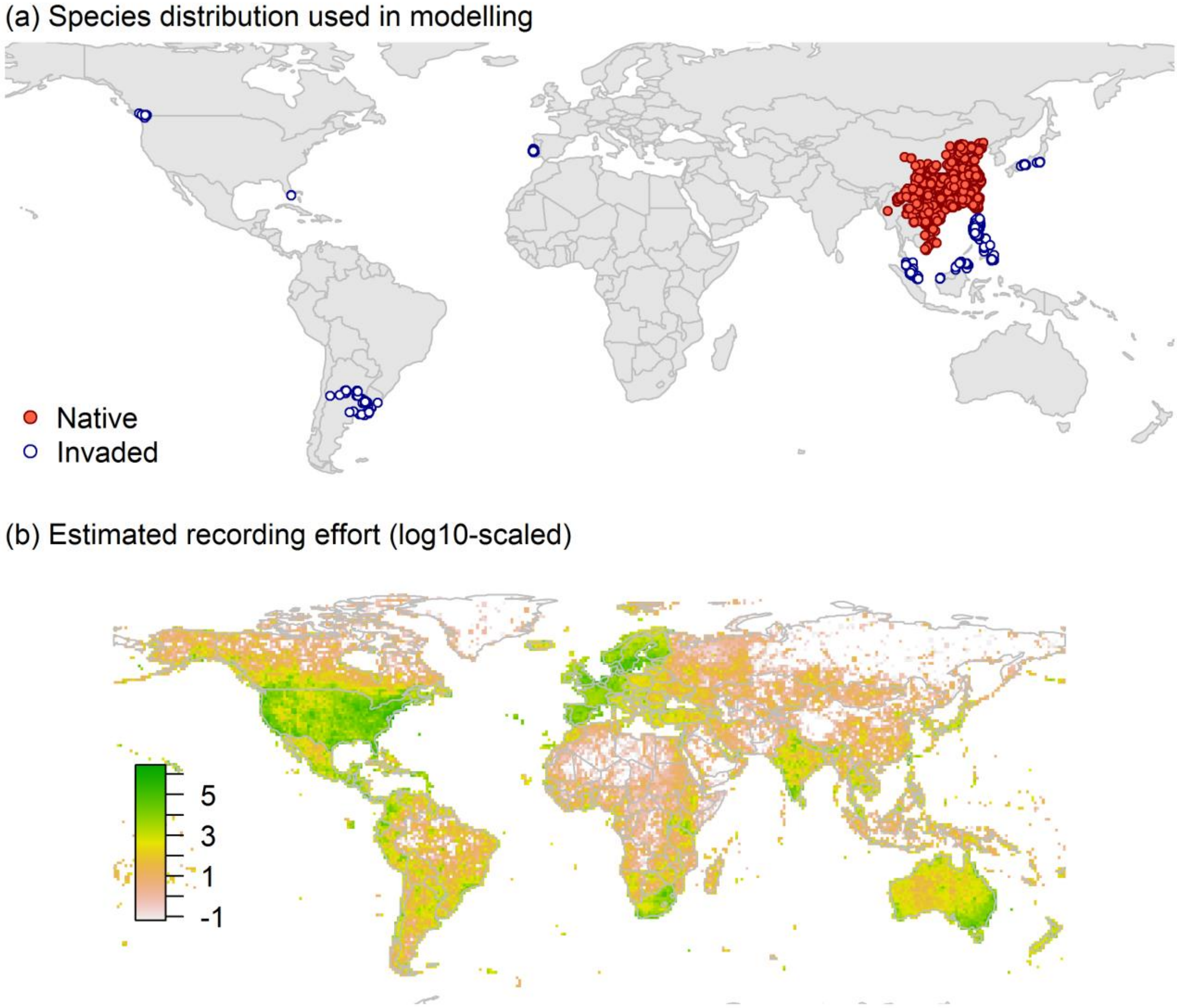
Aim

To project the suitability for potential establishment of *Acridotheres cristellatus* in Europe, under current and predicted future climatic conditions.

Data for modelling

Species occurrence data were obtained from the Global Biodiversity Information Facility (GBIF) (45565 records), the Biodiversity Information Serving Our Nation database (BISON) (1381 records), iNaturalist (832 records), the Integrated Digitized Biocollections (iDigBio) (42 records), and additional records from the risk assessment team. We scrutinised occurrence records from regions where the species is not known to be established and removed any dubious records or where the georeferencing was too imprecise (e.g. records referenced to a country or island centroid) or outside of the coverage of the predictor layers (e.g. small island or coastal occurrences). The remaining records were gridded at a 0.25 x 0.25 degree resolution for modelling, yielding 928 grid cells with occurrences (Figure 1a). As a proxy for recording effort, the density of Aves records held by GBIF was also compiled on the same grid (Figure 1b).

Figure 1. (a) Occurrence records obtained for *Acridotheres cristellatus* and used in the modelling, showing native and invaded distributions. (b) The recording density of Aves on GBIF, which was used as a proxy for recording effort.



Climate data were selected from the 'Bioclim' variables contained within the WorldClim database (Hijmans et al., 2005), originally at 5 arcminute resolution (0.083 x 0.083 degrees of longitude/latitude) and aggregated to a 0.25 x 0.25 degree grid for use in the model.

Based on the biology of *Acridotheres cristellatus*, the following climate variables were used in the modelling:

- Minimum temperature of the coldest month (Bio6)
- Mean temperature of the warmest quarter (Bio10)
- Precipitation seasonality (Bio15)
- Climatic moisture index (CMI): ratio of mean annual precipitation to potential evapotranspiration, log+1 transformed. For its calculation, monthly potential evapotranspirations were estimated from the WorldClim monthly temperature data and solar radiation using the

simple method of Zomer et al. (2008) which is based on the Hargreaves evapotranspiration equation (Hargreaves, 1994).

To estimate the effect of climate change on the potential distribution, equivalent modelled future climate conditions for the 2070s under the Representative Concentration Pathways (RCP) 2.6 and 4.5 were also obtained. These represent low and medium emissions scenarios, respectively. The above variables were obtained as averages of outputs of eight Global Climate Models (BCC-CSM1-1, CCSM4, GISS-E2-R, HadGEM2-AO, IPSL-CM5A-LR, MIROC-ESM, MRI-CGCM3, NorESM1-M), downscaled and calibrated against the WorldClim baseline (see http://www.worldclim.org/cmip5_5m).

The following habitat layers were also used:

- Tree cover (Tree): This was estimated from the MODerate-resolution Imaging Spectroradiometer (MODIS) satellite continuous tree cover raster product, produced by the Global Land Cover Facility (http://glcf.umd.edu/data/vcf/). The raw product contains the percentage cover by trees in each 0.002083 x 0.002083 degree grid cell. We aggregated this to the mean cover in our 0.25 x 0.25 degree grid cells.
- Human influence index (HII): As many non-native invasive species associate with anthropogenically disturbed habitats. We used the Global Human Influence Index Dataset of the Last of the Wild Project (Wildlife Conservation Society - WCS & Center for International Earth Science Information Network - CIESIN - Columbia University, 2005), which is developed from nine global data layers covering human population pressure (population density), human land use and infrastructure (built-up areas, nighttime lights, land use/land cover) and human access (coastlines, roads, railroads, navigable rivers). The index ranges between 0 and 1 and was ln+1 transformed for the modelling to improve normality.

Species distribution model

A presence-background (presence-only) ensemble modelling strategy was employed using the BIOMOD2 R package version 3.4.6 (Thuiller et al., 2020, Thuiller et al., 2009). These models contrast the environment at the species' occurrence locations against a random sample of the global background environmental conditions (often termed 'pseudo-absences') in order to characterise and project suitability for occurrence. This approach has been developed for distributions that are in equilibrium with the environment. Because invasive species' distributions are not at equilibrium and subject to dispersal constraints at a global scale, we took care to minimise the inclusion of locations suitable for the species but where it has not been able to disperse to (Chapman et al. 2019). Therefore the background sampling region included:

- The area accessible by native *Acridotheres cristellatus* populations, in which the species is likely to have had sufficient time to disperse to all locations. Based on presumed maximum dispersal distances, the accessible region was defined as a 400km buffer around the native range occurrences; AND
- A 30km buffer around the non-native occurrences, encompassing regions likely to have had high propagule pressure for introduction by humans and/or dispersal of the species; AND
- Regions where we have an *a priori* expectation of high unsuitability for the species so that absence is assumed irrespective of dispersal constraints (see Figure 2). The following rules were applied to define a region expected to be highly unsuitable for *Acridotheres cristellatus* at the spatial scale of the model:
    - Minimum temperature of the coldest month (Bio6) < -16°C
    - Mean temperature of the warmest quarter (Bio10) < 11°C

Altogether, only 0.9% of occurrence grid cells were located in the unsuitable background region.

Within the unsuitable background region, 10 samples of 5000 randomly sampled grid cells were obtained. In the accessible background (comprising the accessible areas around native and non-native occurrences as detailed above), the same number of pseudo-absence samples were drawn as there were presence records (928), weighting the sampling by a proxy for recording effort (Figure 2).

Figure 2. The background from which pseudo-absence samples were taken in the modelling of *Acridotheres cristellatus*. Samples were taken from a 400km buffer around the native range and a 30km buffer around non-native occurrences (together forming the accessible background), and from areas expected to be highly unsuitable for the species (the unsuitable background region). Samples from the accessible background were weighted by a proxy for recording effort (Figure 1(b)).

Each dataset (i.e. combination of the presences and the individual background samples) was randomly split into 80% for model training and 20% for model evaluation. With each training dataset, five statistical algorithms were fitted with the default BIOMOD2 settings and rescaled using logistic regression, except where specified below:

- Generalised linear model (GLM)
- Generalised boosting model (GBM)
- Generalised additive model (GAM) with a maximum of four degrees of freedom per smoothing spline
- Random forest (RF)
- Maxent

Since the total background sample was larger than the number of occurrences, prevalence fitting weights were applied to give equal overall importance to the occurrences and the background. Normalised variable importance was assessed and variable response functions were produced using BIOMOD2's default procedure.

Model predictive performance was assessed by the following three measures:

- AUC, the area under the receiver operating characteristic curve (Fielding & Bell 1997). Predictions of presence-absence models can be compared with a subset of records set aside for model evaluation (here 20%) by constructing a confusion matrix with the number of true positive, false positive, false negative and true negative cases. For models generating non-dichotomous scores (as here) a threshold can be applied to transform the scores into a dichotomous set of presence-absence predictions. Two measures that can be derived from the confusion matrix are sensitivity (the proportion of observed presences that are predicted as such, quantifying omission errors), and specificity (the proportion of observed absences that are predicted as such, quantifying commission errors). A receiver operating characteristic (ROC) curve can be constructed by using all possible thresholds to classify the scores into confusion matrices, obtaining sensitivity and specificity for each matrix, and plotting sensitivity against the corresponding proportion of false positives (equal to 1 - specificity). The use of all possible thresholds avoids the need for a selection of a single threshold, which is often arbitrary, and allows appreciation of the trade-off between sensitivity and specificity. The area under the ROC curve (AUC) is often used as a single threshold-independent measure for model performance (Manel, Williams & Ormerod 2001). AUC is the probability that a randomly selected presence has a higher model-predicted suitability than a randomly selected absence (Allouche et al. 2006).
- Cohen's Kappa (Cohen 1960). This measure corrects the overall accuracy of model predictions (ratio of the sum of true presences plus true absences to the total number of records) by the accuracy expected to occur by chance. The kappa statistic ranges from -1 to +1, where +1 indicates perfect agreement and values of zero or less indicate a performance no better than random. Advantages of kappa are its simplicity, the fact that both commission and omission errors are accounted for in one parameter, and its relative tolerance to zero values in the confusion matrix (Manel, Williams & Ormerod 2001). However, Kappa has been criticised for being sensitive to prevalence (the proportion of sites in which the species was recorded as present) and may therefore be inappropriate for comparisons of model accuracy between species or regions (McPherson, Jetz & Rogers 2004, Allouche et al. 2006).
- TSS, the true skill statistic (Allouche et al. 2006). TSS is defined as sensitivity + specificity - 1, and corrects for Kappa's dependency on prevalence. TSS compares the number of correct forecasts, minus those attributable to random guessing, to that of a hypothetical set of perfect forecasts. Like kappa, TSS takes into account both omission and commission errors, and success as a result of random guessing, and ranges from -1 to +1, where +1 indicates perfect agreement and values of zero or less indicate a performance no better than random (Allouche et al. 2006).

An ensemble model was created by first rejecting poorly performing algorithms with relatively extreme low AUC values and then averaging the predictions of the remaining algorithms, weighted by their AUC. To identify poorly performing algorithms, AUC values were converted into modified z-scores based on their difference to the median and the median absolute deviation across all algorithms (Iglewicz & Hoaglin, 1993). Algorithms with $z < -2$ were rejected. In this way, ensemble projections were made for each dataset and then averaged to give an overall suitability, as well as its standard deviation. The projections were then classified into suitable and unsuitable regions using the 'minROCdist' method, which minimizes the distance between the ROC plot and the upper left corner of the plot (point (0,1)).

We also produced limiting factor maps for Europe following Elith et al. (2010). For this, projections were made separately with each individual variable fixed at a near-optimal value. These were chosen as the median values at the occurrence grid cells. Then, the most strongly limiting factors were identified as the one resulting in the highest increase in suitability in each grid cell.

Results

The ensemble model suggested that suitability for *Acridotheres cristellatus* was most strongly determined by Minimum temperature of the coldest month (Bio6), accounting for 41.5% of variation explained, followed by Human influence index (HII) (27%), Mean temperature of the warmest quarter (Bio10) (25.9%), Climatic moisture index (CMI) (3.6%), Global tree cover (Tree) (1.1%) and Precipitation seasonality (Bio15) (0.8%) (Table 1, Figure 3).

Table 1. Summary of the cross-validation predictive performance (AUC, Kappa, TSS) and variable importance of the fitted model algorithms and the ensemble (AUC-weighted average of the best performing algorithms). Results are the average from models fitted to 10 different background samples of the data.

					Variable importance (%)					
Algorithm	**AUC**	**Kappa**	**TSS**	**Used in the ensemble**	**Minimum temperature of the coldest month (Bio6)**	**Human influence index (HII)**	**Mean temperature of the warmest quarter (Bio10)**	**Climatic moisture index (CMI)**	**Precipitation seasonality (Bio15)**	**Global tree cover (Tree)**
GLM	0.949	0.629	0.843	yes	39	34	23	4	0	0
GAM	0.952	0.651	0.844	yes	42	30	24	4	0	0
GBM	0.957	0.661	0.862	yes	46	23	28	4	0	0
RF	0.938	0.638	0.854	no	34	19	28	9	6	4
Maxent	0.951	0.635	0.848	yes	39	21	30	3	3	4
Ensemble	**0.955**	**0.653**	**0.856**		**42**	**27**	**26**	**4**	**1**	**1**

Figure 3. Partial response plots from the fitted models. Thin coloured lines show responses from the algorithms in the ensemble, while the thick black line is their ensemble. In each plot, other model variables are held at their median value in the training data. Some of the divergence among algorithms is because of their different treatment of interactions among variables.

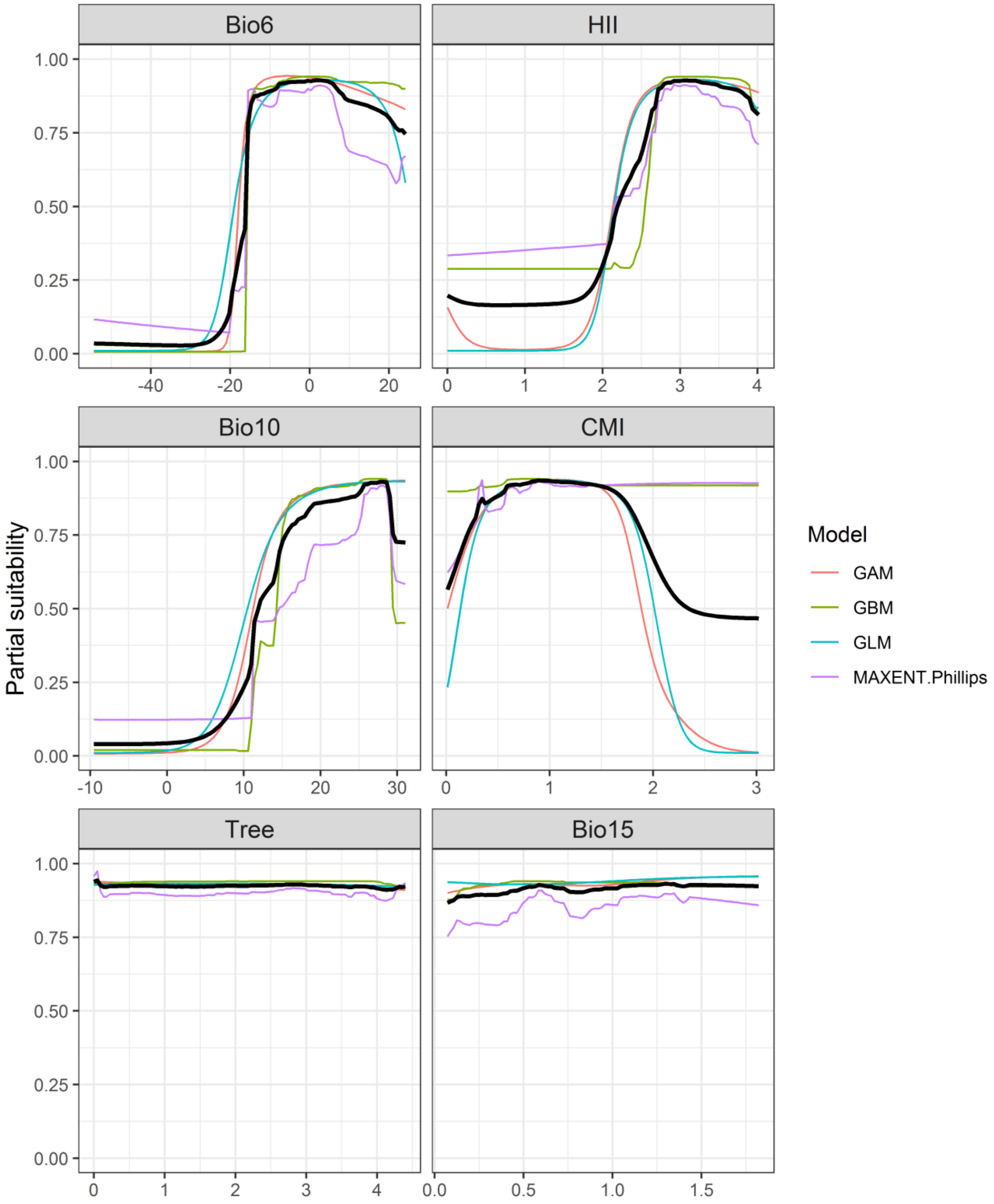


Figure 4. (a) Projected global suitability for *Acridotheres cristellatus* establishment in the current climate. For visualisation, the projection has been aggregated to a 0.5 x 0.5 degree resolution, by taking the maximum suitability of constituent higher resolution grid cells. Values > 0.44 may be suitable for the species. (b) Uncertainty in the ensemble projections, expressed as the among-algorithm standard deviation in predicted suitability, averaged across the 10 datasets.

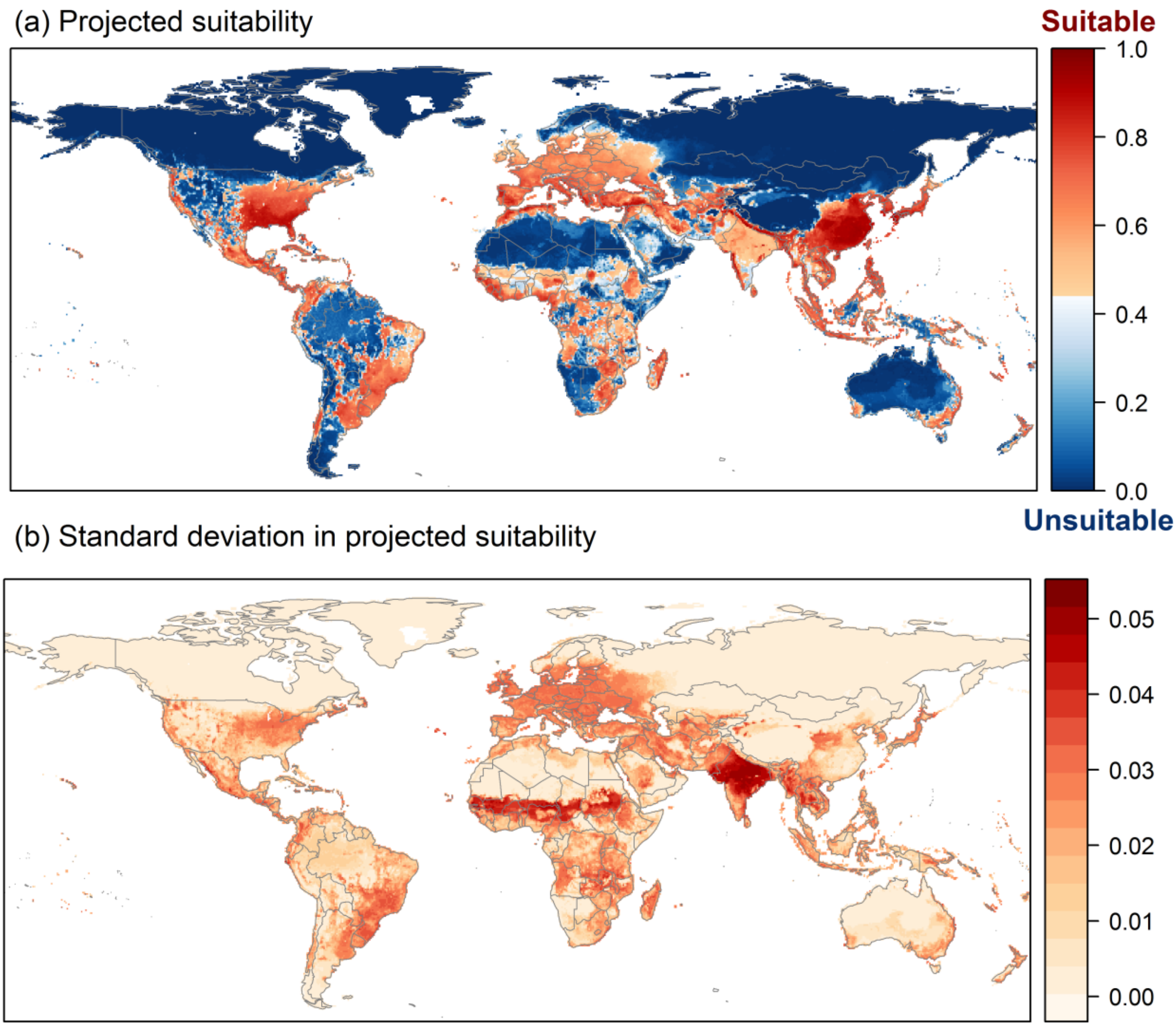


Figure 5. (a) Projected current suitability for *Acridotheres cristellatus* establishment in Europe and the Mediterranean region. (b) Uncertainty in the ensemble projections, expressed as the among-algorithm standard deviation in predicted suitability, averaged across the 10 datasets.

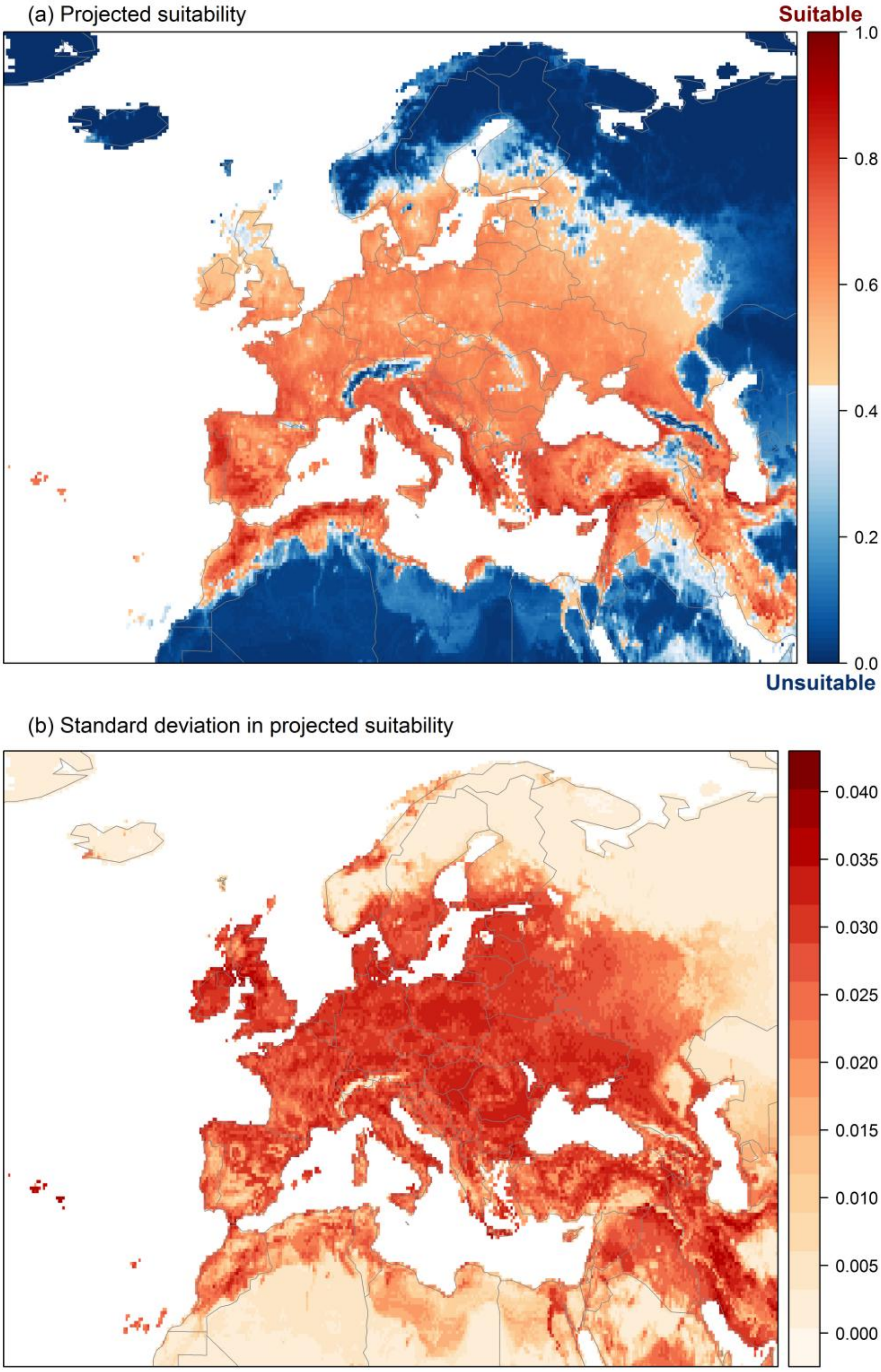


Figure 6. The most strongly limiting factors for *Acridotheres cristellatus* establishment estimated by the model in Europe and the Mediterranean region in current climatic conditions.

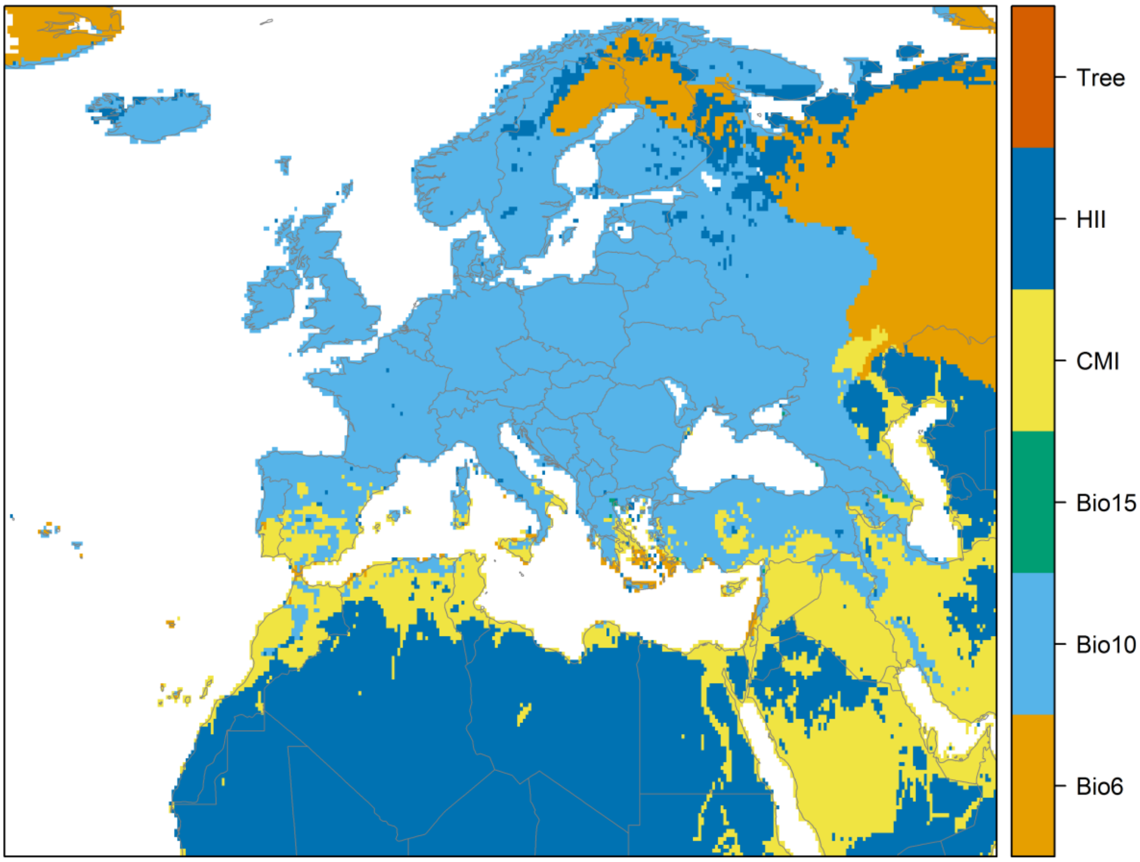


Figure 7. (a) Projected suitability for *Acridotheres cristellatus* establishment in Europe and the Mediterranean region in the 2070s under climate change scenario RCP2.6, equivalent to Figure 5. (b) Uncertainty in the ensemble projections, expressed as the among-algorithm standard deviation in predicted suitability, averaged across the 10 datasets.

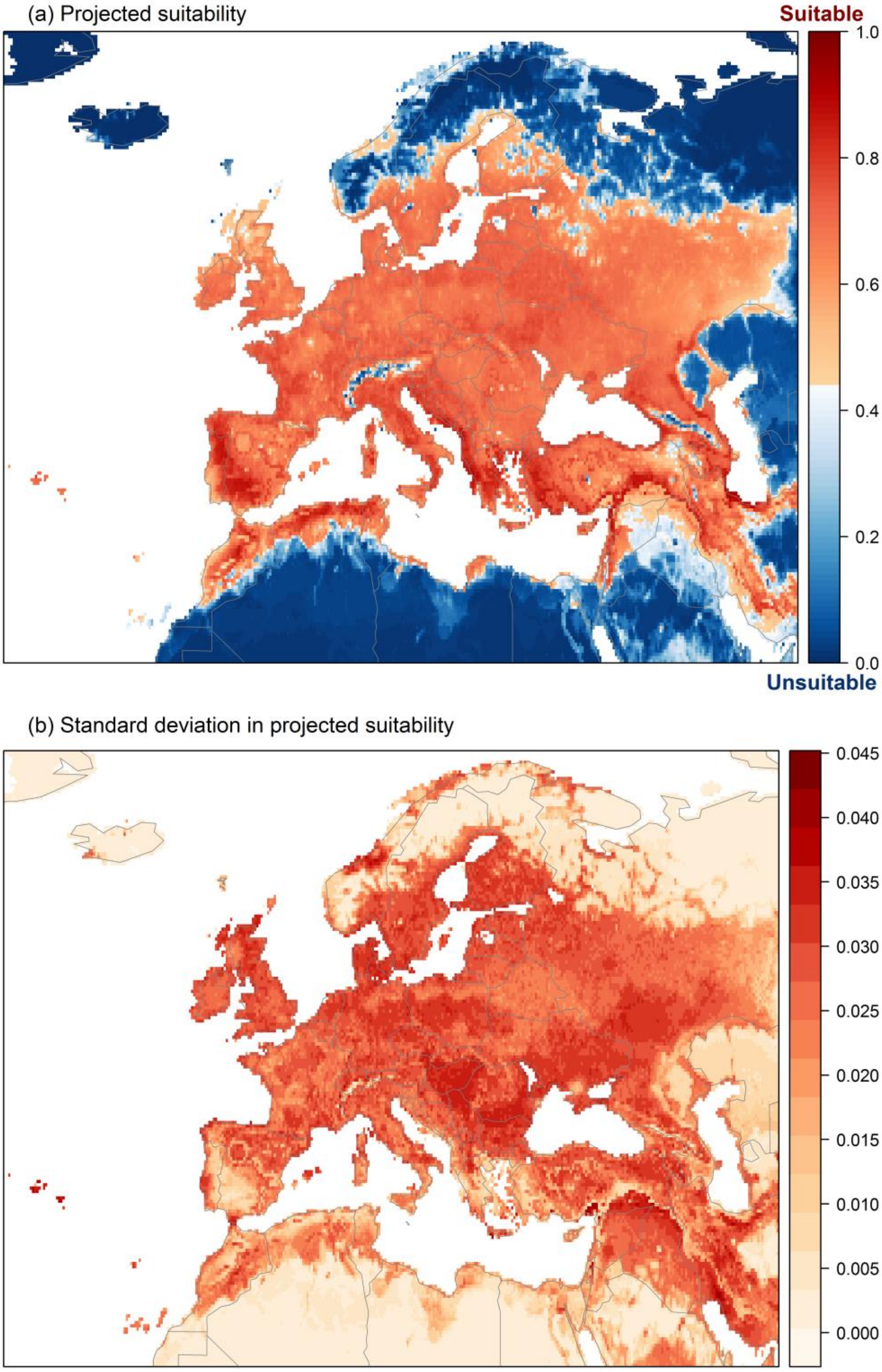


Figure 8. (a) Projected suitability for *Acridotheres cristellatus* establishment in Europe and the Mediterranean region in the 2070s under climate change scenario RCP4.5, equivalent to Figure 5. (b) Uncertainty in the ensemble projections, expressed as the among-algorithm standard deviation in predicted suitability, averaged across the 10 datasets.

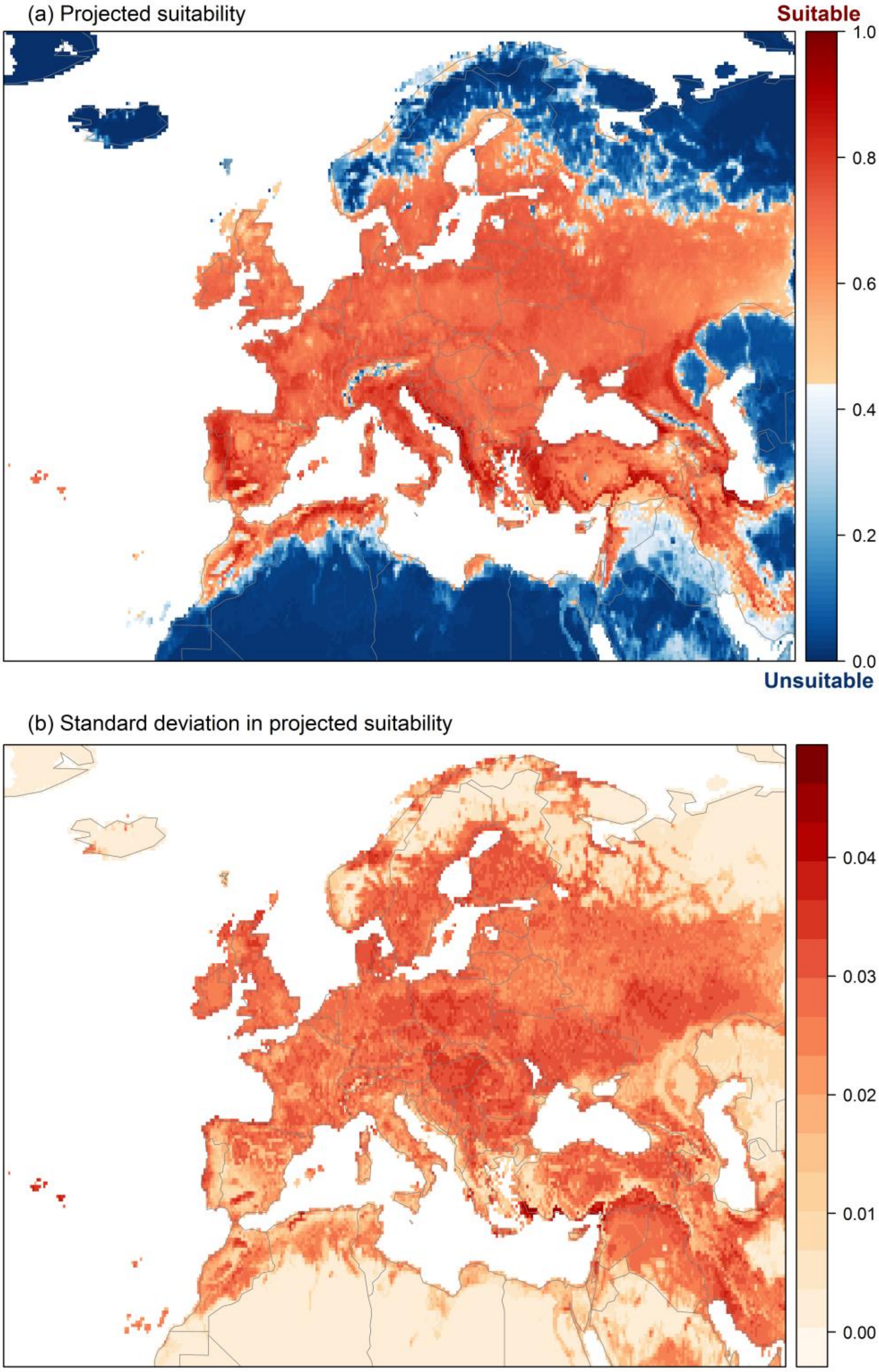


Figure 9. Variation in projected suitability for *Acridotheres cristellatus* establishment among Biogeographical Regions of Europe (https://www.eea.europa.eu/data-and-maps/data/biogeographical-regions-europe-3). The bar plots show the proportion of grid cells in each region classified as suitable in the current climate and projected climate for the 2070s under two RCP emissions scenarios. The location of each region is also shown. The Arctic and Macaronesian biogeographical regions are not part of the study area, but are included for completeness.

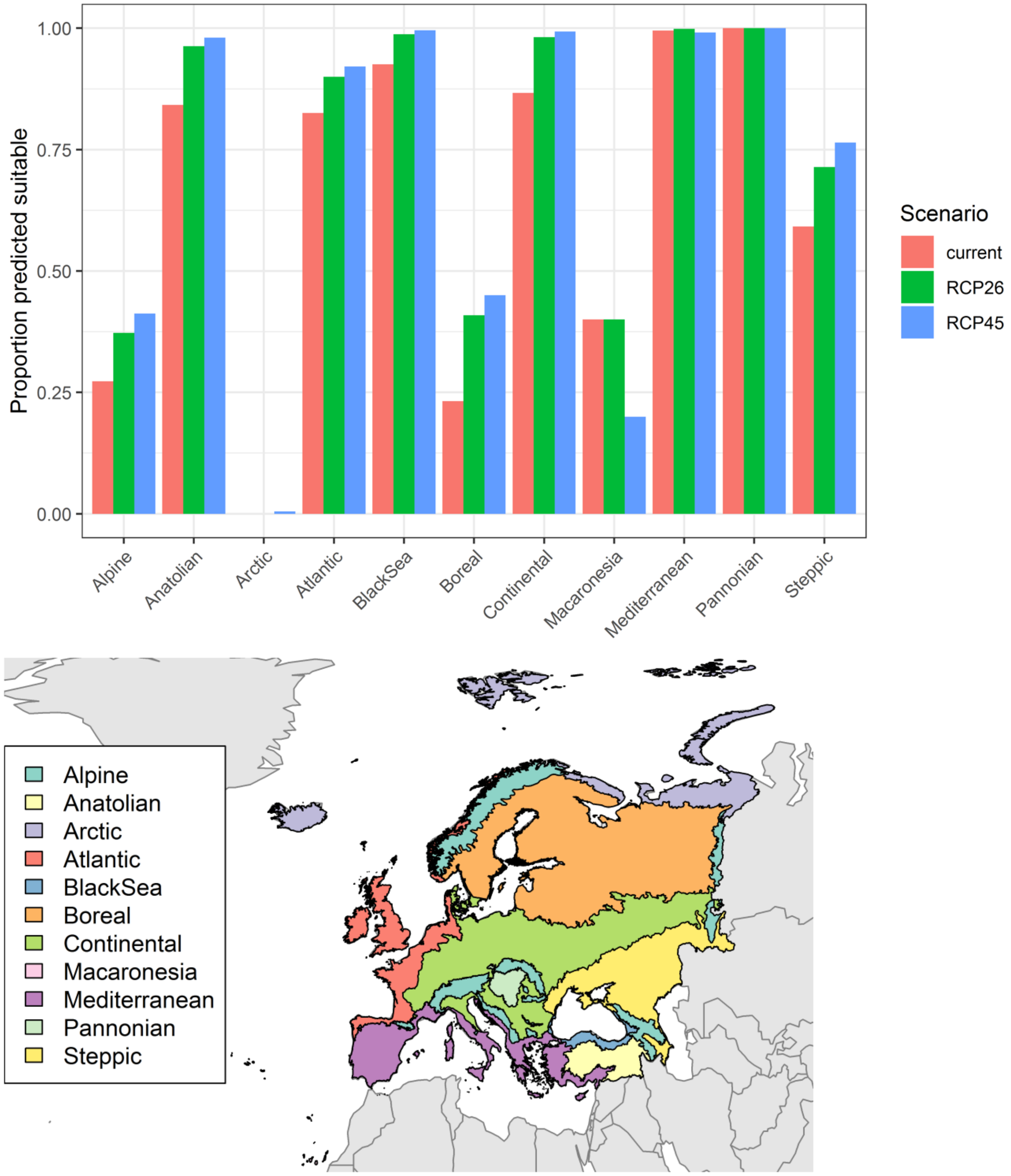


Table 2. Variation in projected suitability for *Acridotheres cristellatus* establishment among Biogeographical regions of Europe (numerical values of Figure 9 above). The numbers are the proportion of grid cells in each region classified as suitable in the current climate and projected climate for the 2070s under two RCP emissions scenarios. The Arctic and Macaronesian biogeographical regions are not part of the study area, but are included for completeness.

Biogeographical region	Current climate	RCP26	RCP45
Alpine	0.27	0.37	0.41
Anatolian	0.84	0.96	0.98
Arctic	0.00	0.00	0.00
Atlantic	0.83	0.90	0.92
BlackSea	0.93	0.99	1.00
Boreal	0.23	0.41	0.45
Continental	0.87	0.98	0.99
Macaronesia	0.40	0.40	0.20
Mediterranean	1.00	1.00	0.99
Pannonian	1.00	1.00	1.00
Steppic	0.59	0.71	0.76

Figure 10. Variation in projected suitability for *Acridotheres cristellatus* establishment among European Union countries and the UK. The bar plots show the proportion of grid cells in each country classified as suitable in the current climate and projected climate for the 2070s under two RCP emissions scenarios. Malta has been excluded because the Human Influence Index dataset lacks coverage for Malta.

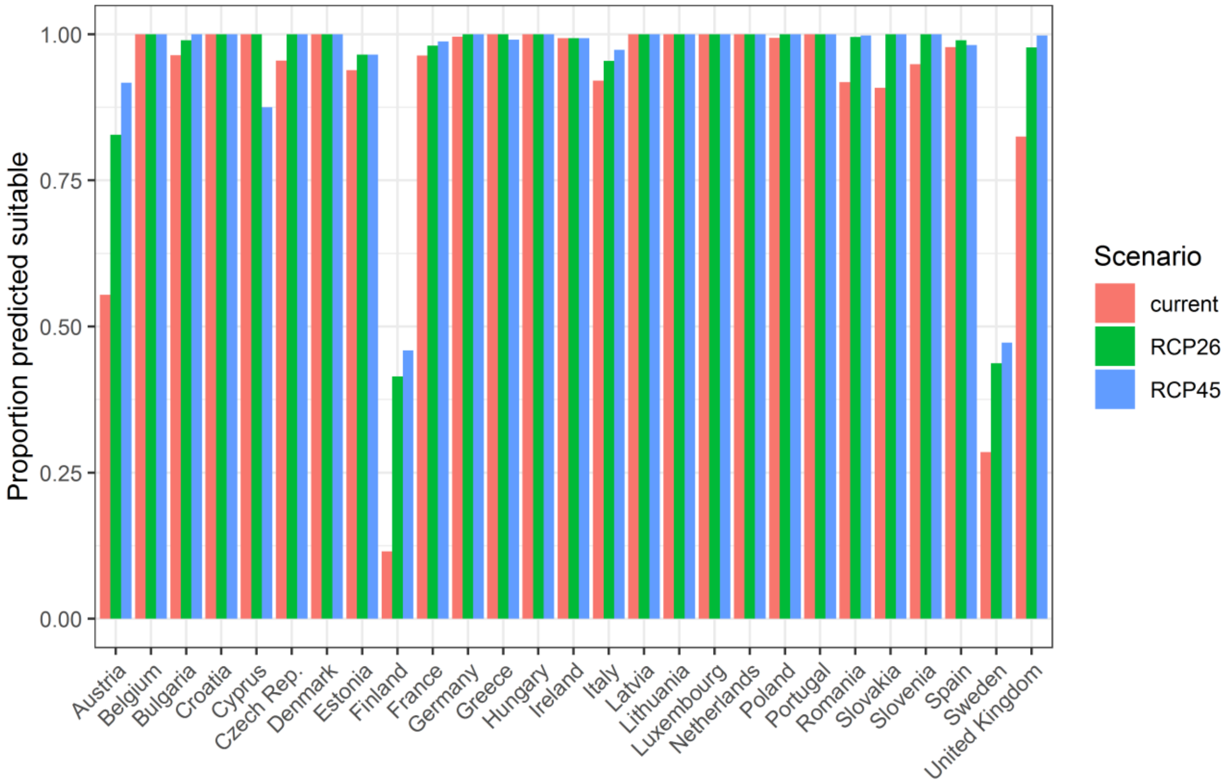


Table 3. Variation in projected suitability for *Acridotheres cristellatus* establishment among European Union countries and the UK (numerical values of Figure 10 above). The numbers are the proportion of grid cells in each country classified as suitable in the current climate and projected climate for the 2070s under two RCP emissions scenarios. Malta has been excluded because the Human Influence Index dataset lacks coverage for Malta.

Country	**Current climate**	**RCP26**	**RCP45**
Austria	0.55	0.83	0.92
Belgium	1.00	1.00	1.00
Bulgaria	0.96	0.99	1.00
Croatia	1.00	1.00	1.00
Cyprus	1.00	1.00	0.88
Czech Rep.	0.96	1.00	1.00
Denmark	1.00	1.00	1.00
Estonia	0.94	0.96	0.96
Finland	0.12	0.41	0.46
France	0.96	0.98	0.99
Germany	1.00	1.00	1.00
Greece	1.00	1.00	0.99
Hungary	1.00	1.00	1.00
Ireland	0.99	0.99	0.99
Italy	0.92	0.95	0.97
Latvia	1.00	1.00	1.00
Lithuania	1.00	1.00	1.00
Luxembourg	1.00	1.00	1.00
Netherlands	1.00	1.00	1.00
Poland	0.99	1.00	1.00
Portugal	1.00	1.00	1.00
Romania	0.92	1.00	1.00
Slovakia	0.91	1.00	1.00
Slovenia	0.95	1.00	1.00
Spain	0.98	0.99	0.98
Sweden	0.29	0.44	0.47
United Kingdom	0.82	0.98	1.00

Caveats to the modelling

To remove spatial recording biases, the selection of the background sample from the accessible background was weighted by the density of Aves records on the Global Biodiversity Information Facility (GBIF). While this is preferable to not accounting for recording bias at all, it may not provide the perfect measure of recording bias.

There was substantial variation among modelling algorithms in the partial response plots (Figure 3). In part this will reflect their different treatment of interactions among variables. Since partial plots are made with other variables held at their median, there may be values of a particular variable at which this does not provide a realistic combination of variables to predict from.

Other variables potentially affecting the distribution of the species, such as types of land cover other than trees were not included in the model.

References

Allouche O, Tsoar A, Kadmon R (2006) Assessing the accuracy of species distribution models: prevalence, kappa and the true skill statistic (TSS). J APPL ECOL 43: 1223-1232.

Chapman D, Pescott OL, Roy HE, Tanner R (2019) Improving species distribution models for invasive non-native species with biologically informed pseudo-absence selection. J BIOGEOGR 46: 1029-1040. https://doi.org/10.1111/jbi.13555

Cohen J (1960) A coefficient of agreement of nominal scales. Educational and Psychological Measurement 20: 37-46

Elith J, Kearney M, Phillips S (2010) The art of modelling range-shifting species. METHODS ECOL EVOL 1: 330-342

Fielding AH, Bell JF (1997) A review of methods for the assessment of prediction errors in conservation presence/absence models. ENVIRON CONSERV 24: 38-49

Hargreaves GH (1994) Defining and Using Reference Evapotranspiration. Journal of Irrigation and Drainage Engineering 120.

Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A (2005) Very high resolution interpolated climate surfaces for global land areas. INT J CLIMATOL 25: 1965-1978

Iglewicz B, Hoaglin DC (1993) How to detect and handle outliers, Asq Press.

Manel S, Williams HC, Ormerod SJ (2001) Evaluating presence-absence models in ecology: the need to account for prevalence. J APPL ECOL 38: 921-931

McPherson JM, Jetz W, Rogers DJ (2004) The effects of species' range sizes on the accuracy of distribution models: ecological phenomenon or statistical artefact? J APPL ECOL 41: 811-823

Thuiller W, Lafourcade B, Engler R, Araújo MB (2009) BIOMOD-a platform for ensemble forecasting of species distributions. Ecography 32: 369-373

Thuiller W, Georges D, Engler R and Breiner F (2020). biomod2: Ensemble Platform for Species Distribution Modeling. R package version 3.4.6. https://CRAN.R-project.org/package=biomod2

Zomer RJ, Trabucco A, Bossio DA, Verchot LV (2008) Climate change mitigation: A spatial analysis of global land suitability for clean development mechanism afforestation and reforestation. Agriculture, Ecosystems and Environment 126: 67-80